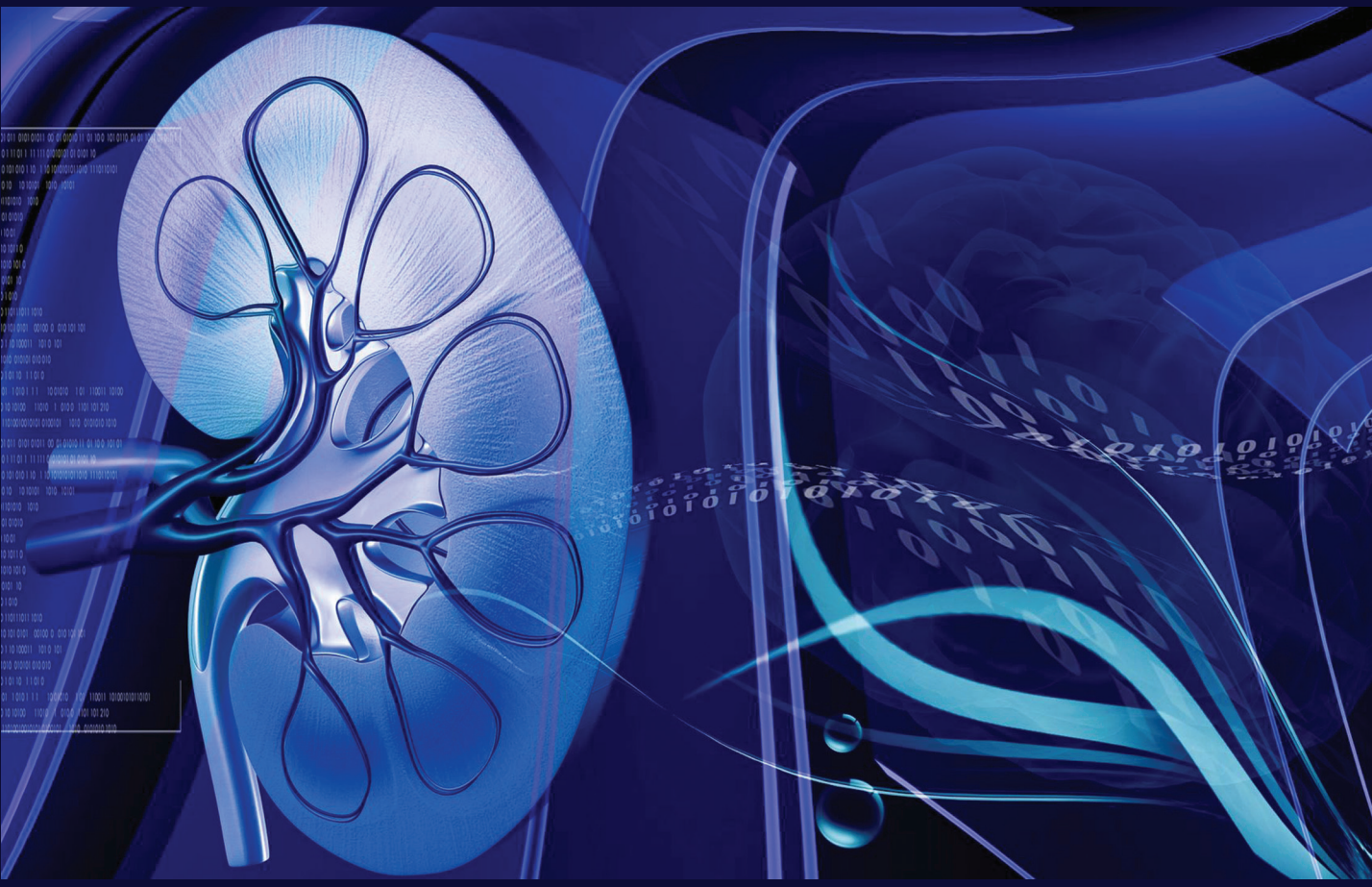
RENAL NURSING

FOURTH EDITION

Edited by Nicola Thomas



WILEY Blackwell

Renal Nursing

Renal Nursing

Fourth Edition

Edited by

Nicola Thomas RGN, BSc (Hons), MA, PhD
Independent Renal Nursing Consultant
and
Senior Lecturer,
London South Bank University,
London, UK.

WILEY Blackwell

This edition first published 2014, © 2014 by John Wiley & Sons, Ltd.
First edition 1997, Second edition 2002,Third edition 2008 © Elsevier Limited

Registered office: John Wiley & Sons, Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial offices: 9600 Garsington Road, Oxford, OX4 2DQ, UK
111 River Street, Hoboken, NJ 07030-5774, USA

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at www.wiley.com/wiley-blackwell

Library of Congress Cataloging-in-Publication Data
Renal nursing / edited by Nicola Thomas. – Fourth edition.
p. ; cm.
Includes bibliographical references and index.
ISBN 978-1-118-41064-6 (pbk.)
I. Thomas, Nicola, editor.
[DNLM: 1. Kidney Diseases–nursing. WY 164]
RC918.R4
616.6'140231–dc23
2013019908

A catalogue record for this book is available from the British Library.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Cover image: 123RF © KrishnaKumar Sivaraman.

Cover design by Meaden Creative.

Set in 9.5/11.5pt Sabon by Aptara Inc., New Delhi, India

1 2014

Contents

Contributors

Diane Blyton RN (Child), BN (Hons), MSc
Paediatric Renal Nurse Educator, Nottingham Children's Hospital, Nottingham, UK

Paul Challinor RN, BSc, DN
Nurse Director, B. Braun Avitum, UK

Charlotte Chalmers BSc (Hons), PhD
Lecturer in Biological Sciences, Edinburgh Napier University, Edinburgh, UK

Ratna Das

Annette Davies RGN, BSc (Hons), PGCAP, MSc
Tutor in Acute Care, University of Surrey, Guildford, UK

Victoria Dunsmore RGN
Clinical Nurse Specialist in Transplantation, Barts Health NHS Trust, London, UK

Barbara Engel BSc Biochem, RD, PhD
Senior Tutor, Nutrition & Dietetics, Surrey University, Guildford, UK

Brian Gracey MA (Hons)
London, UK

Linda Gracey RGN
London, UK

Shelley Jepson RGN, RSCN, BSc (Hons), MSc
Lead Nurse, Children's Renal and Urology Unit, Nottingham Children's Hospital, Nottingham, UK

Fiona Loud BA (Hons)
Kidney Alliance and Lister Area Kidney Patients Association, West Herts Hospital, St Albans, UK

Althea Mahon RGN, BSc, MSc
Consultant Nurse, Denali Medical Services, Perth, Western Australia

Claire Main RN (Adult), BSc (Hons)
Clinical Education Manager for Renal Division, Baxter Healthcare, Newbury, UK

Shahid Muhammad BSc (Hons), BMS, MRes, LIBMS
Biomedical Scientist Practitioner, Renal Patient Support Group Chief in Research and Paediatric Nephrology Researcher, Bristol, UK

Fiona Murphy RGN, RNT, BSc (Hons) Renal Nurs, BSc (Hons) Health Stud, PGDip Adv Nurs Scie, PGDip CHSciEduc, MA, MSc, PhD (c)
Assistant Professor, School of Nursing and Midwifery, Trinity College Dublin, Dublin, Ireland

Fliss Murtagh PhD, MRCGP
Clinical Senior Lecturer and Consultant in Palliative Care, King's College London, Cicely Saunders Institute, London, UK

Nicola Thomas RGN, BSc (Hons), MA, PhD
Independent Renal Nursing Consultant and Senior Lecturer, London South Bank University, London, UK

Foreword

People with kidney disease have a wide range of needs. These needs include encouragement to achieve the behavioural change goals they have set themselves, support on dialysis, education about their condition, traditional basic care needs delivered with kindness and an understanding of the complexity of renal disease, often occurring with a range of other co-morbidities. The skills and competencies required to address these needs are the foundation of high quality renal nursing care. Looking after people with kidney disease is a 'hands-on' job requiring an understanding of psychology – your own, the patients, the carers and the families; knowledge of the biology and pathophysiology of the kidney; expertise in the nursing of the acutely unwell and the management of complex long-term conditions, as well as emotional resilience.

People with kidney disease need to be involved in their care and decisions about their care if outcomes are to be optimised. Renal nurses are the leaders of the kidney care multiprofessional team. Not only do renal nurses bring their understanding of kidney disease and the experience of managing others in a similar situation – they must also be the advocates for holistic care and involve patients and carers in shared decision making. They must be sensitive to the individual who has a disease that is common or rare, but whose experience is unique and who needs support and encouragement appropriate to his/her age, cultural background and degree of health literacy.

Kidney disease is common, harmful and often treatable. Although much progress has been made in identifying chronic kidney disease earlier and delaying the need for dialysis and transplantation, the number of people affected by kidney disease grows each year. In China alone there are 120 million people with kidney disease and it is expected that 1 million Chinese will be receiving dialysis by 2020. Globally 15 million people each year develop acute kidney injury resulting in over 1.5 million deaths. Many survivors of acute kidney injury do not recover completely and go on to develop progressive chronic kidney disease. In the United States, costs of end-stage kidney disease are over 6% of the total costs of healthcare. To change this trajectory we need to support our healthcare systems to address the increasing burden of hypertension, diabetes and obesity. That means helping individual people make healthier choices at whatever stage of kidney disease they are at. In healthcare, quality is added by the direct interactions between healthcare professionals and our patients. Renal nurses have a crucial role in adding quality to care.

This fourth edition of *Renal Nursing* provides you with all the information you need to understand kidney care. Use this textbook in conjunction with gaining practical hands-on experience in renal units and wards and you will have the knowledge to make a big difference to many people.

Professor Donal O'Donoghue
National Clinical Director for Kidney Care (2007–2013)
Consultant Renal Physician,
Salford Royal NHS Foundation Trust, United Kingdom

Preface

I have very much enjoyed editing the fourth edition of this successful book for nurses and allied healthcare professionals working in nephrology, dialysis and transplantation. Since 2008 there have been tremendous changes in renal care in the United Kingdom, particularly in the area of acute kidney injury. All chapters have been updated accordingly, with up-to-date references and resources included. With an increasing emphasis on making 'no decision about me, without me' a reality, I am particularly pleased to include a new chapter on patient and carer involvement in renal care, which has been written by patients and partners of those who have kidney disease. One co-author of this chapter, Ms Ratna Das, very sadly died soon after writing her contribution. It was a privilege to know Ratna as she was constantly striving to improve care for people who were in the same situation, despite often struggling with infection and hospitalisation herself.

This book is mostly for those who are new to the renal specialty. Nurses who are studying on preregistration courses and practitioners who are commencing a post-registration course in renal nursing will find it particularly helpful. It also serves as a good foundation for nurses who wish to refresh their knowledge in a part of the renal field in which they are currently not practising, or for other members of the multiprofessional team who are commencing a career in nephrology. This new edition is again written in a style that promotes renal care for what it is: a dynamic, varied and rewarding specialty.

Each chapter has been written by an expert in his or her field. Recognition must go to those authors who wrote chapters for the previous edition, but were unable to contribute to this edition. They are Juliet Auer, Natasha McIntyre, Judith Hurst, Frances Coldstream and Raymond Trevitt.

Renal nurses in the twenty-first century face a constant challenge to keep abreast of developments in care and management. They have to keep up-to-date with new technologies, respond to the rapid evolution in standards of care and use resources effectively. They have to manage an ever increasing workload as a consequence of more accurate screening of those with chronic kidney disease. What do not change are the constant physical and psychosocial challenges that patients and their families have to face. This must always be in our minds. In my 30 years of practice as a renal nurse the repeated request from patients is that we should emphasise what *can* be done rather than what cannot. The word 'restriction' should not be part of a renal nurse's vocabulary: why not fluid or dietary *allowance*? As in the third edition, I have endeavoured to use a language in this book that puts patients at the centre of care. I hope that this latest edition will continue to encourage renal nurses to care for their patients with compassion, sensitivity and understanding.

Dr Nicola Thomas
London

CHAPTER 1

The History of Dialysis and Transplantation

Nicola Thomas
London South Bank University, UK

Learning Outcomes

- To understand the evolution of haemodialysis (HD), peritoneal dialysis (PD) and transplantation.
- To appreciate the challenges that healthcare professionals have had to overcome in the development of the nephrology specialty.
- To evaluate the changing focus of renal care in the twenty-first century.
- To identify the opportunities for nephrology nursing in the future.

Introduction

The introduction of dialysis as a life-saving treatment for kidney failure was not the result of any large-scale research programme; rather, it emerged from the activities of a few pioneering individuals who were able to use ideas, materials and methods from a range of developing technologies.

Haemodialysis, as a routine treatment for renal failure, was initiated in the 1960s, followed by continuous ambulatory peritoneal dialysis (CAPD) in the late 1970s. The recognition of the need for immunosuppression in transplantation in the 1960s enabled it to become the preferred treatment for many patients.

Haemodialysis (HD)

The beginning

It was the Romans who first used a form of dialysis therapy by giving hot baths to patients to remove urea. The action of the hot water made the patient sweat profusely and this, together with the toxins diffusing through the skin into the bath water, would temporarily relieve symptoms. However, the Romans did not understand why the treatment worked. The effect was to leave the patient fatigued but, as the only hope, this treatment was still used on occasions into the 1950s.

Renal Nursing, Fourth Edition. Edited by Nicola Thomas. Published 2014 by John Wiley & Sons, Ltd.

The first time that the term 'dialysis' was used was in 1854, by Thomas Graham, a Scottish chemist (Graham 1854). He used dialysis to describe the transport of solutes through an ox bladder, and this was the catalyst for other researchers working in a similar field to focus on the membrane.

Membranes were made from a variety of substances, including parchment and collodion (Eggerth 1921). Collodion is a syrupy liquid that dries to form a porous film, and allows the passage of small-molecular-weight substances, whilst being impermeable to substances with a molecular weight greater than 5 kDa. In 1889, B.W. Richardson referred to the use of collodion membranes in the dialysis of blood. So, by this method, living animals were dialysed in experimental conditions (Richardson 1889), but the limiting factor that prevented the treatment being used in humans at this time was the lack of suitable materials.

Pre-1920

It was not until 1913 that the first article on the technique of HD, named the 'artificial kidney', was reported. Experimental dialysis was performed on animals, by using variances in the composition of dialysis fluid (Abel *et al.* 1914). Substances could be added to the solution to avoid their net removal. The main aim of the experiments was the removal of salicylates. The removal of fluid and toxins accumulated due to kidney disease was not, at this time, considered.

In 1914, Hess and McGuigan were experimenting with dialysis in a pharmacology laboratory in Chicago. As a result they were able to transfer sugar from tissue to blood and from the blood across a collodion membrane. The design of the dialyser minimised the length of tubing from the patient, and a high blood flow was achieved by connection to the carotid artery in an effort to minimise the necessity to use an anticoagulant. A single U-shaped collodion tube was inserted into a glass cylinder with a rubber stopper at one end. The blood flow both to and from the dialyser was at one end, with a port for adjusting the pressure inside the tube. These experiments were still only performed on animals. The only anticoagulant available was in the form of an extract obtained from crushed leech heads, called hirudin. This was far from satisfactory, even though leeches were plentiful and readily available from the corner shop for around $25 per 1000.

The 1920s

The first dialysis performed on a human was carried out by the German physician, Georg Haas, in Giessen in the latter half of the 1920s. He performed six treatments in six patients. Handmade collodion membranes were used, and clotting was prevented by using hirudin and, later, a crude form of heparin. Haas used multiple dialysers to increase the surface area of blood exposed to the dialysis fluid. This necessitated as many as six dialysers arranged in parallel and he found that the arterial pressure of the blood was insufficient to propel the blood through the entire extracorporeal circuit. He therefore introduced a pump into the circuit. Haas was aware of the lack of support given to him by the hospital and his colleagues and by the late 1920s he gave up and the work was stopped. Georg Haas died in 1971, aged 85 years, and was honoured as the pioneer of dialysis.

Despite these treatments, carried out from the 1920s to the 1940s, those with uraemia suffering from poor appetite and vomiting could be offered nothing more than bed-rest, and a bland salt-free diet composed mainly of vegetables, carbohydrate and fat to reduce protein metabolism. Dialysis was not considered a realistic option and the conservative therapy was only offered as a palliative measure.

Heinrich Necheles was the founder of the contemporary dialyser. In 1923, he experimented with the sandwiching of membranes, thus giving an increased surface area without the necessity for multiple dialysers. The membrane used was the peritoneum of a sheep. As the membrane was prone to expansion, support sheets were placed between the layers of membrane, thus allowing a large surface area of membrane to come into contact with the dialysis fluid. Other features introduced by Necheles were a heater, the priming of the pathway for the blood, and a filter to prevent clots returning to the patient.

The 1930s

The 1920s and 1930s saw great advances in synthetic polymer chemistry, resulting in the availability of cellulose acetate, which could be used as a membrane for HD. It was in 1937 that the first synthetic membrane was used by the American scientist William Thalhimer. The material, cellophane – a form of cellulose acetate, which was used extensively in the sausage industry – had potential that was not recognised for some years. In the mid-1930s came the purification of heparin (Thalhimer *et al.* 1938), which could be used as an anticoagulant. Together, these two advances gave rise to the next stage of development, which took place in 1943 in occupied Holland.

The 1940s and 1950s

Willem Kolff, a physician working in Groningen in Nazi-occupied Holland, had his attention drawn to the work of a colleague who was concentrating plasma by using cellulose acetate as a membrane and immersing it in a weak solution of sugar. Kolff noticed that toxins in the blood were altered by this method (Kolff 1950). He built a rotating drum dialyser, which provided sufficient surface area for his first attempt at human dialysis (Kolff and Berk 1944). His machine consisted of 30 m of cellophane tube that was wound round a large cylinder. The cylinder was placed in a tank containing a weak solution of salts – the dialysate. The patient's blood was passed through the cellophane tube, the walls acting as a semipermeable membrane. Blood flow was achieved by the addition of a circuit containing a burette, which, when filled with blood, could be raised high enough to allow the blood to flow into the dialyser. The burette was then lowered, allowing the blood to drain back, and raised again to allow the blood to return to the patient. The slats in the construction of the cylinder were of wood due to the shortage at this time of materials such as aluminium – in retrospect, this was fortunate because the toxicity of aluminium is now appreciated. Six hours were required for the treatment, and it is interesting to note that, with this method, the efficiency of dialysis that could be achieved was similar to that which is possible with the dialysers in use today: a clearance of 170 ml/min urea could be achieved. Fluid could only be removed by increasing the osmotic pressure of the dialysate fluid by the addition of sugar, as an increase in pressure on the membrane would result in rupture (Kolff 1965).

The whole procedure was very time consuming and labour intensive, as the process required attention at all times, to raise and lower the burette and observe the membrane for rupture, which happened frequently. Repairs to the membrane were carried out by inserting a glass tube at the point of rupture.

Kolff's first clinical experience was gained with a 29-year-old woman with chronic nephritis. The blood urea was kept stable for 26 days, but after 12 sessions of dialysis, her blood urea began to increase, and she subsequently died.

After the war, in 1945, Kolff's technique was widely used, particularly in Sweden and the United States. The treatment was initially for acute kidney injury, when kidney function could be expected to return to normal following a short period of dialysis treatment. It was widely used in the Korean war in 1952 to treat trauma-induced renal failure. The group, led by Paul Teschan, trained to use the rotating drum dialyser and saved many lives by lowering the high potassium levels of the victims (Teschan 1955).

Some of the earliest research carried out on fluid removal from the blood using negative pressure was conducted by M.R. Malinow and W. Korzon at Michael Reese Hospital in Chicago in 1946 (Malinow and Korzon 1947). The device used was the earliest version of a dialyser with multiple blood paths and negative pressure capacity. It had parallel sections of cellulose acetate tubing and, by adding layers of tubing, the surface area of the device could be increased. The diffusion properties of this device were not considered, as it was intended only for removal of water from the blood. The device required a low priming volume and the circuit included a blood pump.

In the 1940s, interest in dialysis as a treatment for renal failure had spread throughout Europe and across to Canada as the need was becoming widely recognised by the medical profession. After obtaining drawings of the Kolff dialyser, Russell Palmer and a colleague, from Vancouver in Canada, built a replica and dialysed their first patients in September 1947 (Palmer and Rutherford 1949).

Kolff was invited to take his artificial kidney to New York where he trained physicians in the operation of the life-saving device. There was resistance from hospital staff at the Mount Sinai Hospital, who only permitted the treatment to be administered in the surgical suite after normal surgical schedules were completed for the day. The first patient scheduled for treatment was a victim of mercuric chloride poisoning, but treatment was cancelled when a spontaneous diuresis occurred.

The first successful dialysis in Mount Sinai Hospital was in January 1948, in a female admitted to hospital having inserted mercury tablets into her vagina to induce an abortion (Fishman *et al.* 1948). Eight hours after the first dialysis using the Kolff machine, the patient passed urine. The treatment had been a success. Victims of drug overdose were then regularly treated by use of the rotating drum dialyser until 1950.

To expand the use, the rotating drum would have to be modified to become easier to use. Kolff enlisted the help of Dr Carl Walter, who worked at the Peter Brent Brigham Hospital. Together with Edward Olson, an associate engineer from Fenwal, they set about designing and building a new version of the Kolff device. Stainless steel was used for the drum, and refinements included a hose for filling the pan with the 100 L of dialysate fluid, which was heated, and a hood to cover the drum. A tensioning device was used on the cellophane membrane as it had a tendency to stretch during use. The split connection for the patient's tubing was introduced, and this allowed the patient's tubing to remain stationary whilst the drum rotated. This was made leakproof, and a Lucite hood was added to overcome heat loss from the extracorporeal blood (Figure 1.1). These improvements paved the way for wider acceptance of the use of dialysis treatment (Merrill *et al.* 1950).

When the Kolff–Brigham kidney was used, the heparin dose ranged from 6000 to 9000 units, and was infused prior to the start of the treatment. The dialyser was primed with blood, and the blood flow to the dialyser was limited to 200 ml at a time to prevent hypotension. To assist blood flow a pump was inserted in the venous circuit rather than the arterial side, to minimise the probability of pressure buildup in the membrane, which would cause a rupture.

This version of the Kolff–Brigham dialysis machine was used in 1948, and in all, over 40 machines were built and exported all over the world. Orders for spare parts were still being received as late as 1974, from South America and behind the Iron Curtain.

Figure 1.1 Artificial kidney machine (Kolff-Brigham), France, 1955.
Source: With kind permission from Science and Society Picture Library.

The 1950s

The Allis-Chalmers Corporation was one of the first companies to produce dialysis machines commercially. They were prompted into the manufacture when an employee developed renal failure. There was no machine available and so the firm turned its attention to producing a version of the Kolff rotating drum. The resulting machine was commercially available for $5600 and included all the sophistication available at the time. Allis-Chalmers produced 14 of these machines and sold them all over the United States into the early 1950s.

In October 1956, the Kolff system became commercially available, so the unavailability of equipment could no longer be used as an excuse for nontreatment of patients. Centres purchased the complete delivery system for around $1200 and the disposables necessary for the treatment were around $60. The system was still mainly used for reversible acute renal failure drug overdose and poisoning.

The development of the dialyser

Jack Leonards and Leonard Skeggs produced a plate dialyser, which would permit a reduction in the priming volume, and allow negative pressure to be used to remove fluid from the patient's system (Skeggs *et al.* 1949). A modification to this design included a manifold system, which allowed variation of the surface area without altering the blood distribution. Larger dialysers followed, which necessitated the introduction of a blood pump.

In the late 1950s Fredrik Kiil of Norway developed a parallel plate dialyser, with a large surface area (1 m^2), requiring a lower priming volume. A new cellulose membrane, Cuprophan, was used and this allowed the passage of larger molecules than other materials that were available at that time. The Kiil dialyser could be used without a pump. Kiil dialysed the patients using their own arterial pressure. This dialyser was widely used because the disposables were relatively inexpensive when compared with other dialysers available at that time.

A crude version of the capillary-flow dialyser, the parallel dialyser, was developed, using a new blood pump, with a more advanced version of the Alwall kidney (MacNeill 1949). However, it was John Guarino who incorporated the important feature of a closed system, a visible blood pathway.

To reduce the size of the dialyser without reducing the surface area, William Y. Inouye and Joseph Engelberg produced a plastic mesh sleeve to protect the membrane. This reduced the risk of the dialysis fluid coming into contact with the blood. This was a closed system, so the effluent could be measured to determine the fluid loss of the patient. It is the true predecessor of the positive-and negative-pressure dialysers used today.

The first commercially available dialyser was manufactured by Baxter and based on the Kolff kidney. It provided a urea clearance of approximately 140 ml/min, equivalent to today's models, and was based on the coil design. The priming volume was 1200–1800 ml and this was drained into a container at the end of treatment, refrigerated and used for priming for the next treatment. It was commercially available in 1956 at $59.00.

The forerunner of today's capillary-flow dialyser was produced by Richard Stewart in 1960. The criteria for design of this hollow-fibre dialyser were low priming volume and minimal resistance to flow. The improved design contained 11 000 fibres which provided a surface area of 1 m^2.

Future designs for the dialyser focused on refining the solute and water removal capabilities, as well as reducing the size and priming requirements of the device, thus allowing an even higher level of precise individual care.

The emergence of home haemodialysis

It was Scribner's shunt which provided vascular access, at the start, leading to the first dialysis unit to be established for patients at the University of Washington Hospital. Belding Scribner also developed a central dialysate delivery system for multiple use and set this up in the chronic care centre, which had 12 beds. These beds were quickly taken and his plan for expansion was rejected. The only alternative was to send the patients home, and so the patient and family were trained to perform the dialysis and care for the shunts. Home dialysis was strongly promoted by Scribner.

Stanley Shaldon reported in 1961 that a patient dialysing at the Royal Free Hospital in London was able to self-care by setting up his own machine, initiating and terminating dialysis (Figure 1.2); so home HD in the UK was made possible. The shunt was formed in the leg for vascular access, to allow the patient to have both hands free for the procedures. Hence Shaldon was able to report the results of his first patient to be placed on overnight home HD in November 1964. With careful patient selection, the venture was a success. Scribner started to train patients for home at this time, and his first patient was a teenager assisted by her mother. Home dialysis was selected for this patient, so that she would not miss her high-school education. The average time on dialysis was 14 h twice weekly. To allow freedom for the patient, overnight dialysis was widely practised. At first, emphasis was on selection of the suitable patient and family, even to the extent of a stable family relationship, before the patient could be considered for home training (Baillod *et al.* 1965).

From these beginnings, large home HD programmes developed in the United States and the United Kingdom, thus allowing expansion of the dialysis population without increasing hospital facilities. Many patients could now be considered for home treatment, often with surprisingly good results, as the dialysis could be moulded to the requirements of the individual, rather than the patients conforming

Figure 1.2 Patient and nurse with dialysis machine and Kiil dialyser, 1968.
Source: With kind permission from Science and Society Picture Library.

to a set pattern. However, with the development in the late 1970s and early 1980s of CAPD as the first choice for home treatment, the use of home HD steadily dwindled. It is now however seeing renewed interest. The National Institute for Clinical Excellence (NICE) has published guidance on home versus hospital haemodialysis (National Institute for Clinical Excellence 2002) and recommends all suitable patients should be offered the choice between home haemodialysis or haemodialysis in a hospital/satellite unit.

Vascular access for haemodialysis

It was Sir Christopher Wren, of architectural fame, who in 1657 successfully introduced drugs into the vascular system of a dog. In 1663, Sir Robert Boyle injected successfully into humans. Prison inmates were the subjects and the cannula used was fashioned from a quill. For HD to become a widely accepted form of treatment for renal failure, a way to provide long-term access to the patient's vascular system had to be found and until this problem was solved, long-term treatment could not be considered. In order for good access to be established, a tube or cannula had to be inserted into an artery or vein, thus giving rise to good blood flow from the patient. The repeated access for each treatment quickly led to exhaustion of blood vessels for cannulation. The need for a system whereby a sufficiently large blood flow could be established for dialysis, without destroying a length of blood vessel every time dialysis was required, was imperative.

In the 1950s, Teschan, in the 11th Evacuation Hospital in Korea, was responsible for developing a method of heparin lock for continuous access to blood vessels. The cannulae were made from Tygon tubing and stopcocks, and the blood was prevented from

clotting by irrigation with heparinised saline. It was not a loop design, as the arterial and venous segments were not joined together.

In 1960, in the United States, George Quinton, an engineer, and Belding Scribner, a physician, made use of two new synthetic polymers – Teflon and Silastic – and, using the tubing to form the connection between a vein and an artery, were able to reroute the blood outside the body (usually in the leg). This was known as the arteriovenous (AV) shunt. The tubing was disconnected at a union joint in the centre, and each tube then connected to the lines of the dialysis machine. At the end of treatment, the two ends were then reconnected, establishing a blood flow from the artery to the vein outside the body. In this way, repeat dialysis was made possible without further trauma to the vascular system.

This external shunt, whilst successful, had drawbacks. It was a potential source of infection, often thrombosed, and had a restrictive effect on the activity of the patient. This form of access is still occasionally used for acute treatment, although the patient's potential requirements for chronic treatment must be considered when the choice of vessels is made, so that vessels to be used in the formation of an AV fistula are not scarred. In 1966, Michael Brescia and James Cimino developed the subcutaneous radial artery-to-cephalic vein AV fistula (Cimino and Brescia 1962), with Cimino's colleague, Kenneth Appel, performing the surgery.

The AV fistula required less anticoagulation, had reduced infection risk and gave access to the blood stream without danger of shunt disconnection. Subsequently, a number of synthetic materials have been introduced to create internal AV fistulae (grafts). These are useful when the patient's veins are not suitable to form a conventional AV fistula, such as in severe obesity, with loss of superficial veins due to repeated cannulation or in the elderly or those with diabetes.

Venous access by cannulation of the jugular or femoral veins has now replaced the shunt for emergency dialysis.

The present

Monitoring and total control of the patient's therapy became more important as dialysis became widespread, and so equipment development has continued. Sophisticated machines incorporated temperature monitoring, positive-pressure gauges and flow meters. Negative-pressure monitoring followed, as did a wide range of dialysers with varying surface areas, ultrafiltration capabilities and clearance values. Automatic mixing and delivery of the dialysate and water supply to the machine greatly increased the margin of safety for the procedure, and made the dialysis therapy much easier to manage. The patient system that has evolved provides a machine that monitors all parameters of dialysis through the use of microprocessors, allowing the practitioner to programme a patient's requirements (factors such as blood flow, duration of dialysis and fluid removal) so that the resulting treatment is a prescription for the individual's needs. Average dialysis time has been reduced to 4 h, three times weekly or less if a high-flux (high-performance) dialyser is used.

The early 1970s saw the overall number of patients on RRT increase due to the increased awareness brought about by the availability of treatment. Free-standing units for the sole use of kidney dialysis came into being, leading to dialysis becoming a full-time business. Committees for patient selection were disbanded, and the problems concerned with inadequate financial resources came to the fore. Standards for treatment quality have now been set. Attempts continue to reduce treatment duration, to enhance the patient's quality of life. Good nutrition has also emerged as playing a vital role in reducing dialysis morbidity and mortality. Dialysis facilities

are demanded within easy reach of patients' homes, and this expectation has led to the emergence of small satellite units, managed and monitored by larger units, as a popular alternative to home HD treatment. In 2010 the number of patients receiving home HD increased by 23%, from 636 patients to 780 patients since 2009 (UK Renal Registry 2011).

Peritoneal Dialysis (PD)

Peritoneal dialysis as a form of therapy for kidney disease has been brought about as a result of the innovative efforts and the tenacity of many pioneers over the past two centuries. It was probably the early Egyptian morticians who first recognised the peritoneum and peritoneal cavity as they embalmed the remains of their influential compatriots for eternity. The peritoneal cavity was described in 3000 BC in the Ebers papyrus as a cavity in which the viscera were somehow suspended. In Ancient Greek times, Galen, a physician, made detailed observations of the abdomen whilst treating the injuries of gladiators.

The earliest reference to what may be interpreted as PD was in the 1740s when Christopher Warrick reported to the Royal Society in London that a 50-year-old woman suffering from ascites was treated by infusing Bristol water and claret wine into the abdomen through a leather pipe (Warrick 1744). The patient reacted violently to the procedure, and it was stopped after three treatments. The patient is reported to have recovered, and was able to walk 7 miles (approximately 13 km) a day without difficulty. A modification of this was subsequently tried by Stephen Hale of Teddington in England: two trocars were used – one on each side of the abdomen – allowing the fluid to flow in and out of the peritoneal cavity during an operation to remove ascites (Hale 1744).

Subsequent experiments on the peritoneum (Wegner 1877) determined the rate of absorption of various solutions, the capacity for fluid removal (Starling and Tubby 1894) and evidence that protein could pass through the peritoneum. It was also noted that the fluid in the peritoneal cavity contained the same amount of urea that is found in the blood, indicating that urea could be removed by PD (Rosenberg 1916). This was followed by Tracy Putnam suggesting that the peritoneum might be used to correct physiological problems, when he observed that under certain circumstances fluids in the peritoneal cavity can equilibrate with the plasma and that the rate of diffusion was dependent on the size of the molecules. Research also suggested at this time that the clearance of solutes was proportional to their molecular size and solution pH, and that a high flow rate maximised the transfer of solutes, which also depended on peritoneal surface area and blood flow (Putman 1923).

George Ganter was looking for a method of dialysis that did not require the use of an anticoagulant (Ganter 1923). He prepared a dialysate solution containing normal values of electrolytes and added dextrose for fluid removal. Bottles were boiled for sterilisation and filled with the solution, which was then infused into the patient's abdomen through a hollow needle.

The first treatment was carried out on a woman who was suffering acute kidney injury following childbirth. Between 1 and 3 L of fluid were infused at a time, and the dwell time was 30 min to 3 h. The blood chemistry was reduced to within acceptable limits. The patient was sent home, but unfortunately she died, as it was not realised that it was necessary to continue the treatment in order to keep the patient alive.

Ganter recognised the importance of good access to the peritoneum, as it was noted that it was easier to instil the fluid than it was to attain a good return volume. He was also aware of the complication of infection, and indeed it was the most frequent

complication that he encountered. Ganter identified four principles, which are still regarded as important today:

- There must be adequate access to the peritoneum.
- Sterile solutions are needed to reduce infection.
- Glucose content of the dialysate must be altered to remove greater volumes of fluid.
- Dwell times and fluid volume infused must be varied to determine the efficiency of the dialysis.

There are reports of 101 patients treated with PD in the 1920s (Abbott and Shea 1946; Odel *et al.* 1950). Of these, 63 had reversible causes, 32 irreversible and in two the diagnosis was unknown. There was recovery in 32 of 63 cases of reversible renal failure. Deaths were due to uraemia, pulmonary oedema and peritonitis.

Stephen Rosenak, working in Europe, developed a metal catheter for peritoneal access, but was discouraged by the results because of the high incidence of peritonitis. In Holland, P.S.M. Kop, who was an associate of Kolff during the mid-1940s, created a system of PD by using materials for the components that could easily be sterilised: porcelain containers for the fluid, latex rubber for the tubing, and a glass catheter to infuse the fluid into the patient's abdomen. Kop treated 21 patients and met with success in ten.

Morton Maxwell, in Los Angeles, in the latter part of the 1950s, had been involved with HD, and it was his opinion that HD was too complicated for regular use. Aware of the problems with infection, he designed a system for PD with as few connections as possible. Together with a local manufacturer, he formulated a peritoneal solution, and customised a container and plastic tubing set and a single polyethylene catheter. The procedure was to instil 2 L of fluid into the peritoneum, leave it to dwell for 30 min, and return the fluid into the original bottles. This would be repeated until the blood chemistry was normal. This technique was carried out successfully on many patients and the highly regarded results were published in 1959. This became known as the Maxwell technique (Maxwell *et al.* 1959). This simple form of dialysis recognised that it was no longer necessary to have expensive equipment with highly specialised staff in a large hospital to initiate dialysis. All that was required was an understanding of the procedure and available supplies.

The catheter

Up to the 1970s, PD was used primarily for patients who were not good candidates for HD, or who were seeking a gentler form of treatment. Continuous flow using two catheters (Legrain and Merrill 1953) was still sometimes used, but the single-catheter technique was favoured because of lower infections rates.

The polyethylene catheter was chosen by Paul Doolan (Doolan *et al.* 1959) at the Naval Hospital in San Francisco when he developed a procedure for the treatment to use under battlefield conditions in the Korean war. Because of the flexibility of the catheter, it was considered for long-term treatment. A young physician called Richard Ruben decided to try this procedure, known as the Doolan technique (Ruben *et al.* unpublished work), on a female patient who improved dramatically, but deteriorated after a few days without treatment. The patient was therefore dialysed repeatedly at weekends, and allowed home during the week, with the catheter remaining in place. This was the first reported chronic treatment using a permanent indwelling catheter.

Catheters were made from tubing available on the hospital ward and included gall-bladder trocars, rubber catheters, whistle-tip catheters and stainless-steel sump drains.

However, as with the polyethylene plastic tubes, the main trouble was kinking and blockage. Maxwell described a nylon catheter with perforations at the curved distal end and this was the catheter which became commercially available. Advances in the manufacture of the silicone peritoneal catheter by Palmer (Palmer *et al.* 1964) and Gutch (Gutch 1964) included the introduction of perforations at the distal end and later Tenckhoff included the design of a shorter catheter, a straight catheter and a curled catheter. He also added the Dacron cuff, either single or double, to help to seal the openings through the peritoneum (Tenckhoff and Schechter 1968). He was also responsible for the introduction of the trocar that gave easy placement of the catheter. Dimitrios Oreopoulos, a Greek physician, was introduced to PD in Belfast, Northern Ireland, during his training and he noted the difficulties encountered with the catheters there. He had been shown a simple technique for inserting the catheter by Norman Dean from New York City, which allowed the access to be used repeatedly.

Peritoneal dialysis at home

In 1960, Scribner and Boen (Boen 1959) set up a PD programme that would allow patients to be treated at home. An automated unit was developed which could operate unattended overnight. The system used 40 L containers that were filled and sterilised at the University of Washington. The bottles were then delivered to the patient's home, and returned after use. The machine was able to measure the fluid in and out of the patient by a solenoid device. An indwelling tube was permanently implanted into the patient's abdomen, through which a tube was inserted for each dialysis treatment. The system was open, and therefore was vulnerable to peritonitis. A new method was then used, whereby a new catheter was inserted into the abdomen for each treatment, and removed after the treatment ended. This was still carried out in the home, when a physician would attend the patient at home for insertion of the catheter, leaving once the treatment had begun. The carer was trained to discontinue the treatment and remove the catheter. The wound was covered by a dressing, and the patient would be free of dialysis until the next week. This treatment was carried out by Tenckhoff *et al.* (1965) in a patient for 3 years, requiring 380 catheter punctures.

The large 40 L bottles of dialysate were difficult to handle and delivery to the home and sterilisation were not easy. Tenckhoff, at the University of Washington, installed a water still into the patient's home, thus providing a sterile water supply. The water was mixed with sterile concentrate to provide the correct solution, but this method was not satisfactory as it remained cumbersome and dangerous due to the high pressure in the still. Various refinements were tried using this method, including a reverse osmosis unit, and this was widely used later for HD treatment.

Lasker, in 1961, realised the potential of this type of treatment and concentrated on the idea of a simple version by instilling 2 L of fluid by a gravity-fed system. This proved to be cheaper to maintain but was labour-intensive. Later that year, he was approached by Ira Gottscho, a businessman who had lost a daughter through kidney problems, and together they designed the first peritoneal cycler machine. The refinements included the ability to measure the fluid in and out, and the ability to warm the fluid before the fill cycle. Patients were sent home using the automated cycler treatment as early as 1970, even though there was a bias for HD at that time.

In 1969, Oreopoulos accepted a position at the Toronto Western Hospital and, together with Stanley Fenton, decided to use the Tenckhoff catheter for long-term treatment. Because of a lack of space and facilities at the hospital, it was necessary to send the patients home on intermittent PD. He reviewed the Lasker cycler machine

and ordered a supply, and by 1974 was managing over 70 patients on this treatment at home. Similar programmes were managed in Georgetown University and also in the Austin Diagnostic Clinic in the USA.

The beginning of continuous ambulatory peritoneal dialysis (CAPD)

It was in 1975, following an unsuccessful attempt to haemodialyse a patient at the Austin Diagnostic Clinic, that an engineer, Robert Popovich, and Jack Moncrief became involved in working out the kinetics of 'long-dwell equilibrated dialysis' for this patient. It was determined that five exchanges each of 2 L per day would achieve the appropriate blood chemistry, and that the removal of 1–2 L of fluid from the patient was needed per day. Thus came the evolution of CAPD (Popovich *et al.* 1976).

The treatment was so successful that the Austin group was given a grant to allow it to continue dialysing patients with CAPD. Strangely, the group's first description and account of this clinical experience was rejected by the American Society for Artificial Internal Organs. At this time the treatment was called 'a portable/wearable equilibrium dialysis technique'. The stated advantages compared to HD included:

- good steady-state biochemical control;
- more liberal diet and fluid intake;
- improvement in anaemia.

The main problems were protein loss (Popovich *et al.* 1978) and infection. It was recognised that the source of infection was almost certainly related to the use of the bottles. Oreopoulos found that collapsible polyvinylchloride (PVC) containers for the solution were available in Canada. Once the fluid was instilled, the bag could then be rolled up and concealed under the clothing. The fluid could be returned into the bag during draining by gravity, without a disconnection taking place (Oreopoulos *et al.* 1978). New spike connections were produced for access to the bag of fluid, and a Luer connection for fitting to the catheter, together with tubing devised for HD, greatly reduced the chances of infection. The patients treated on an intermittent basis (by intermittent peritoneal dialysis or IPD) were rapidly converted to CAPD and evaluation of the new treatment was rapid, due to the large numbers being treated. Following approval by the US Food and Drug Administration, many centres were then able to develop CAPD programmes.

The first complete CAPD system was released on to the market in 1979, giving a choice of three strengths of dextrose solution. Included in this system were an administration line, and sterile items packed together to form a preparation kit, to be used at each bag change in an attempt to keep infection at bay. The regime proposed by Robert Popovich and Jack Moncrief entailed four exchanges over a 24-hour period, three dwell times of approximately 4 h in the daytime, and one dwell overnight of 8 h. This regime is the one often used today.

The systems are continually being improved, with connectors moving from spike to Luer to eliminate as far as possible the accidental disconnection of the bag from the line. A titanium connector was found to be the superior form of adaptor for connection of the transfer set to the catheter, and probably led to a reduced infection rate for peritonitis. A disadvantage of this technique is the flow of fresh fluid down the transfer set along the area of disconnection, thus encouraging any bacteria from the disconnection to be instilled into the abdomen. The development of the Y-system (flush before fill) in the mid-1980s in Italy resulted in a further decrease in peritonitis.

Automated peritoneal dialysis

Automated PD in the form of continuous cyclic peritoneal dialysis (CCPD) was further developed by Diaz-Buxo in the early 1980s to enable patients who were unable to perform exchanges in the day to be treated with PD overnight.

Advances in peritoneal dialysis for special needs

Even more recently advances in CAPD treatment include a dialysate that not only provides dialysis but which contains 1.1% amino acid, to be administered to malnourished patients. This is particularly useful for the elderly on CAPD, in whom poor nutrition is a well-recognised complication.

Those with diabetes were initially not considered for dialysis, because of the complications of the disease. Carl Kjellstrand, at the University of Minnesota, suggested that insulin could be administered to those with diabetes by adding it to the PD fluid (Crossley and Kjellstrand 1971). However, when this suggestion was first put forward, it was not adopted because the 30 min dwell did not give time for the drug to be absorbed into the patient. It became viable later, when the long dwell dialysis was initiated, and this gave the advantage of slow absorption, resulting in a steady state of blood sugar in the normal range, thus alleviating the need for painful injections (Flynn and Nanson 1979).

The realisation that patients are individuals, bringing their own problems associated with training, brought many exchange aid devices on to the market to assist the patient in the exchange procedure. These exchange devices were mainly used to assist such disabilities as blindness, arthritis (particularly of the hands) and patients prone to repeated episodes of peritonitis.

The future

In some centres PD is usually the first choice of treatment for established renal disease. In many countries, because of the lack of facilities for in-centre HD, it will remain so. However, the relative prevalence of PD in the United Kingdom has been declining since its peak in the early 1990s, possibly because of the availability of satellite haemodialysis and a high level of PD technique failure. In 2010 only 18.1% of people who required RRT were on peritoneal dialysis (at 90 days after starting dialysis) compared with 68.3% of patients on haemodialysis (UK Renal Registry 2011).

Transplantation

In the beginning

Kidney transplantation as a therapeutic and practical option for renal replacement therapy (RRT) was first reported in published literature at the turn of the twentieth century. The first steps were small and so insignificant that they were overlooked or condemned.

The first known attempts at renal transplantation on humans were made without immunosuppression between 1906 and 1923 using pig, sheep, goat and subhuman primate donors (Elkington 1964). These first efforts were conducted in France and Germany but others followed. None of the kidneys functioned for long, if indeed at all, and the recipients all died within a period of a few hours to nine days later.

Of all the workers at this time, the contribution made by Alixis Carrel (1873–1944) remains the most famous. His early work in Lyons, France and in Chicago

involved the transplantation of an artery from one dog to another. This work later became invaluable in the transplantation of organs. In 1906, Carrel and Guthrie, working in the Hull Laboratory in Chicago, reported the successful transplantation of both kidneys in cats and later a double nephrectomy on dogs, reimplanting only one of the kidneys. He found that the secretion of urine remained normal and the animal remained in good health, despite having only one kidney (Carrel 1983). Carrel was awarded the Nobel Prize in 1912 for his work on vascular and related surgery.

While at this stage there was no clear understanding of the problem, some principles were clearly learned. Vascular suture techniques were reviewed and the possibility of using pelvic implantation sites was investigated and practised. No further renal heterotransplantations (animal to human) were tried until 1963 when experiments using kidneys from chimpanzee (Reemtsma *et al.* 1964) and baboon were tried, with eventual death of the patients. This ended all trials using animal donation.

The first human-to-human kidney transplant was reported in 1936, by the Russian Voronoy, when he implanted a kidney from a cadaver donor of B-positive blood type into a recipient of O-positive blood type, a mismatch that would not be attempted today. The donor had died 6 h before the operation and the recipient died 6 h later without making any urine. The following 20 years saw further efforts in kidney transplantation, all without effective immunosuppression (Groth 1972). The extraperitoneal technique developed by French surgeons Dubost and Servelle became today's standard procedure.

The first successes

The first examples of survival success of a renal transplant can probably be attributed to Hume. Hume placed the transplanted kidney into the thigh of the patient, with function for 5 months. Then at the Peter Bent Brigham Hospital in Boston, USA, in December 1954, the first successful identical-twin transplant was performed by the surgeon Joseph E Murray in collaboration with the nephrologist John P Merrill (Hume *et al.* 1955). The recipient survived for more than 2 decades. The idea of using identical twins had been proposed when it was noted by David C Miller of the Public Health Service Hospital, Boston, that skin grafts between identical twins were not rejected (Brown 1937). The application of this information resulted in rigorous matching, including skin grafting, prior to effective immunosuppression.

Over the period between 1951 and 1976 there were 29 transplants performed between identical twins, and the survival rate for 20 years was 50%. Studies of two successfully transplanted patients, who were given kidneys from their nonidentical twins, were also reported (Merrill *et al.* 1960). The first survived 20 years, dying of heart disease, and the second 26 years, dying of carcinoma of the bladder. Immunosuppression used in these cases was irradiation.

Immunosuppression

It was Sir Peter Medawar who appreciated that rejection is an immunological phenomenon (Medawar 1944), and this led to research into weakening the immune system of the recipients to reduce the rejection. In animals, corticosteriods, total body irradiation and cytotoxic drug therapy were used. Experiments in animals were still far from successful, as were similar techniques when used in humans. It was concluded that the

required degree of immunosuppression would lead to destruction of the immune system and finally result in terminal infections.

A few patients were transplanted between 1960 and 1961 in Paris and Boston, using drug regimens involving 6-mercaptopurine or azathioprine, with or without irradiation. They all died within 18 months. Post-mortem examination of failed kidney grafts showed marked changes in the renal histology, which at first were thought unlikely to be due to immunological rejection, but later it was convincingly shown that this was indeed the underlying process.

In the early days of kidney transplantation, the kidney was removed from either a living related donor or a cadaver donor and immediately transferred to the donor after first flushing the kidney with cold electrolyte solution such as Hartman's solution. In 1967, Belzer and his colleagues developed a technique for continuous perfusion of the kidney using oxygenated cryoprecipitated plasma, which allowed the kidney to be kept up to 72 h before transplantation. This machine perfusion required constant supervision, and it was found that flushing the kidney with an electrolyte solution and storage at 0°C in ice saline allowed the kidney to be preserved for 24 h or more (Marshall *et al.* 1988). This was a major development in transplantation techniques.

During the 1950s it was recognised that many of the survivors of the Hiroshima atomic bomb in 1945 suffered impairment to their immune system. It was concluded that radiation could therefore induce immunosuppression, and clinical total body irradiation was used to prolong the survival of renal transplants in Boston in 1958. This did improve the survival of some transplants; however, the overall outcomes were poor. There was clearly a need for a more effective form of immunosuppression than irradiation.

A breakthrough in immunosuppressive therapy occurred in 1962 in the University of Colorado, when it was discovered that the combination of azathioprine and prednisone allowed the prevention and in some cases reversal of rejection (Starzl *et al.* 1963). Transplantation could at last expand. A conference sponsored by the National Research Council and National Academy of Sciences in 1963 in Washington resulted in the first registry report, which enabled the tracing of all the early non-twin kidney recipients. In 1970, work commenced on the development of ciclosporin by Sandoz in Basle, Switzerland, following recognition of the potential (Borel *et al.* 1976). Clinical trials carried out in Cambridge, United Kingdom (Calne *et al.* 1979) showed that outcomes on renal transplantation were greatly improved, both with graft and with patient survival. Ciclosporin revolutionised immunosuppression treatment for transplant patients, even though it is itself nephrotoxic and its use needs close monitoring.

Tissue typing is a complex procedure and, as yet, is far from perfect. The use of the united networks for organ sharing has increased the efforts of matching donor and recipient, and data available from these sources show a significant gain in survival of well-matched versus mismatched cadaver kidneys. Cross-matching remains as important today as it was at its conception. None of the immunosuppressive measures available today can prevent the immediate destruction of the transplanted organ by humoral antibodies in the hyperacute rejection phase. This was recognised as early as 1965 (Kissmeyer-Neilsen *et al.* 1966), and it may be that this phenomenon holds the key to the future of successful heterotransplantation.

Blood transfusions

It was observed in the late 1960s that patients who had received multiple blood transfusions before organ transplantation did not have a poorer graft survival than those

who had not been transfused. Opelz and Terasaki (1974) observed that patients who had received no transfusions whatsoever were more likely to reject the transplant. It became evident, therefore, that a small number of blood transfusions resulted in an improved organ survival and so the transfusion policies for nontransfused recipients were changed throughout the world. This 'transfusion effect' is of much less importance with the ciclosporin era.

Present

Renal transplantation has been a dramatic success since the 1980s, with patient survival rates not less than 97% after 6 months' transplantation for both living related and cadaver transplants. Although short-term survival for the graft is good – around 90% expectation of survival of the graft at 1 year – cadaveric graft survival at 5 years is around 70%, with a substantial minority losing their renal graft after 15 years.

The future

There is no doubt that renal transplantation is the treatment of choice for many patients requiring RRT giving, in general, a better quality of life than dialysis. However, organs are in short supply. A change in the law may result in more kidneys becoming available for transplantation, by allowing easier access to donors or removing the need for relatives' consent, but until a significant breakthrough is achieved there will continue to be a waiting list for transplantation and it will be necessary to continue to improve the techniques of dialysis. However, the number of people waiting for a kidney transplant has dropped slightly in recent years (down from in 6918 in 2009 to 6300 in 2012) whilst the number of kidney transplants has increased, with 2330 being carried out in 2008/2009 to 2568 being carried out in 2011/2012 (NHS Blood and Transplant 2012). Reasons for this increase are discussed further in Chapter 13.

Summary

Dialysis has come a long way from the small beginnings of the hot baths in Rome. Refinements and improvements continue, most recently with the emergence of erythropoietin in the late 1980s to correct the major complication of anaemia in people with ERF. The challenge of adequate dialysis for all who need treatment remains.

Transplantation is still not available for all those who are eligible, and changes in the law may help with availability of donor organs. The multidisciplinary teams will continue to strive to give patients the best possible quality of treatments until a revolutionary breakthrough in prevention of ERF happens.

In the United Kingdom, the growth rate for RRT appears to be slowing, as the UK Renal Registry (2011) reported that from 2009 to 2010 there was an increase of 1.5% for haemodialysis (HD), a fall of 3.2% for peritoneal dialysis (PD) and an increase of 5.4% with a functioning transplant. The number of patients receiving home HD increased by 23%, from 636 patients to 780 patients since 2009 (Renal Registry 2011). See Figure 1.3.

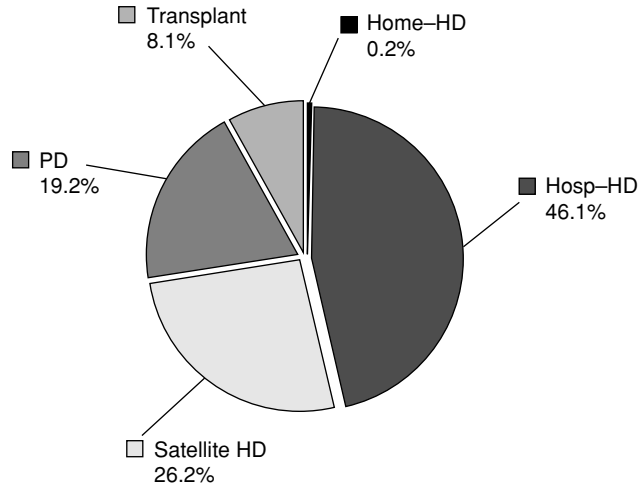


Figure 1.3 Renal replacement therapy modality in the UK at day 90 (2009–2010).

Source: The data reported here have been supplied by the UK Renal Registry of the Renal Association. The interpretation and reporting of these data are the responsibility of the authors and in no way should be seen as an official policy or interpretation of the UK Renal Registry or the Renal Association.

References

Abbott, W.E. and Shea P. (1946) Treatment of temporary renal insufficiency (uraemia) by peritoneal lavage. *American Journal of Medical Science* **211,** 312.

Abel, J.J., Rowntree, L.G. and Turner, B.B. (1914) The removal of diffusable substances from the circulating blood of living animals by dialysis. *Journal of Pharmacology and Experimental Therapeutics* **5,** 275–316.

Baillod, R.A., Comty, C., Ilahi, M. *et al.* (1965*) Proceedings of the European Dialysis and Transplant Association 2*, Excerpta Medica, Amsterdam, p. 99.

Boen, S.T. (1959) *Peritoneal Dialysis,* Van Gorcum, Amsterdam, p. 26.

Borel, J.F., Feurer, C., Gubler, H.U. *et al.* (1976) Biological effects of cyclosporin A. A new antilymphocytic agent. *Agents Actions* **6,** 468–475.

Brown, J.B. (1937) Homografting of the skin. With report of success in identical twins. *Surgery* **1,** 558–563.

Calne, R.Y., Rolles, K., White, D.J.G. *et al.* (1979) Cyclosporin A initially as the only immunosuppressant in 34 recipients of cadaveric organs: 32 kidneys, 2 pancreases, and 2 livers. *Lancet* **1,** 1033–1036.

Carrel, A. (1983) Results of the transplantation of blood vessels, organs and limbs. *JAMA* **250,** 994–953.

Cimino, J.E. and Brescia, M.J. (1962) Simple venepuncture for haemodialysis. *New England Journal of Medicine* **267,** 608–609.

Crossley, K. and Kjellstrand, C.M. (1971) Intraperitoneal insulin for control of blood sugar in diabetic patients during peritoneal dialysis. *British Medical Journal* **1,** 269–290.

Doolan, P.D., Murphy, W.P. Jr., Wiggins, R.A. *et al.* (1959) An evaluation of intermittent peritoneal lavage. *American Journal of Medicine* **26,** 831–844.

Eggerth, A.H. (1921) The preparation and standardization of collodion membranes. *Journal of Biological Chemistry* **48** (1), 203–221.

Elkington, J.R. (1964) Moral problems in the use of borrowed organs artificial and transplanted. *Annals of Internal Medicine* **60,** 309–313.

Fishman, A.P., Kroop, I.G., Leiter, H.E. *et al.* (1948) Management of anuria in acute mercurial intoxication. *NY State Journal of Medicine* **48,** 2393–2396.

Flynn, C.T. and Nanson, J.A. (1979) Intraperitoneal insulin with CAPD – an artificial pancreas. *Transactions of the American Society of Artificial Internal Organs* **25,** 114–117.

Ganter, G. (1923) About the elimination of poisonous substances from the blood by dialysis. *Munchener Medizinische Wochenschrift* **70,** 1478–1480.

Graham, T. (1854) The Bakerian lecture – on osmotic force. *Philosophical Transactions of the Royal Society London* **144,** 177–228.

Groth, C.G. (1972) Landmarks in clinical renal transplantation. *Surgery, Gynecology and Obstetrics* **134,** 323–328.
Gutch, C.F. (1964) Peritoneal dialysis. *Transactions of the American Society of Artificial Internal Organs* **10,** 406–407.
Hale, S. (1744) A method of conveying liquors into the abdomen during the operation of tapping. *Philosophical Transactions of the Royal Society* **43,** 20–21.
Hess, C.L.V. and McGuigan, H. (1914) The condition of the sugar in the blood. *Journal of Pharmacology and Experimental Therapeutics* **6,** 45–55.
Hume, D.M., Merrill, J.P., Miller, B.F. *et al.* (1955) Experience with renal homotransplantation in the human. Report of nine cases. *Journal of Clinical Investigation* **34,** 327–382.
Kidney Alliance (2001) *End-Stage Renal Failure – A Framework for Planning and Service Delivery,* Kidney Alliance, http://www.kidneyalliance.org/docs/k_report.pdf (accessed 10 June 2013).
Kissmeyer-Neilsen, F., Olsen, S., Peterson, V.P. *et al.* (1966) Hyperacute rejection of kidney allografts, associated with pre-existing humoral antibodies against donor cells. *Lancet* **2,** 662–665.
Kolff, W.J. (1950) Artificial kidney – treatment of acute and chronic uraemia. *Cleveland Clinical Quarterly* **17,** 216–228.
Kolff, W.J.(1965) First clinical experience with the artificial kidney. *Annals of Internal Medicine* 62, 608–619.
Kolff, W.J. and Berk, H.T. (1944) The artificial kidney: a dialyser with a great area. *Acta Medica Scandinavica* 117, 121–134.
Legrain, M. and Merrill, J.P. (1953) Short term continuous transperitoneal dialysis. *New England Journal of Medicine* **248,** 125–129.
MacNeill, A.E. (1949) Some possible uses of blood dialysers. Surgeons practice meeting, 23 September 1949, Bretton Woods, NH, *Proceedings of the New England Surgical Society,* p. 3.
Malinow, M.R. and Korzon, W. (1947) Experimental method for obtaining an ultrafiltrate of the blood. *Journal of Laboratory Clinical Medicine* **31,** 461–471.
Marshall, V.C., Jablonski, P. and Scott, D.F. (1988) Renal preservation. In *Kidney Transplantation: Principles and Practice* (ed. P.J. Morris), 3rd edn, W.B. Saunders, Philadelphia, PA, pp. 151–182.
Maxwell, M.H., Rockney, R.E. and Kleeman, C.R. (1959) Peritoneal dialysis, techniques and application. *JAMA* **170,** 917–924.
Medawar, P.B. (1944) The behaviour and fate of skin autografts and skin homografts in rabbits. *Journal of Anatomy* **78,** 176–199.
Merrill, J.P., Murray, J.E., Harrison, J.H. *et al.* (1960) Successful homotransplantation of the kidney between non-identical twins. *New England Journal of Medicine* **262,** 1251–1260.
Merrill, J.P., Thorn, G.W., Walter, C.W. *et al.* (1950) The use of an artificial kidney. 1. Technique. *Journal of Clinical Investigation* **29,** 412–424.
National Institute for Clinical Excellence (2002) *Guidance on Home compared with Hospital Haemodialysis for Patients with End-Stage Renal Failure 2002,* Technology Appraisal No. 48, www.nice.org.uk/page.aspx?o=TA048guidance (accessed 20 May 2013).
NHS Blood and Transplant (2012) *Organ Donation and Transplantation Activity Data 2012: United Kingdom,* http://www.organdonation.nhs.uk/statistics/ (accessed 24 May 2013).
Odel, H.M., Ferris, D.O. and Power, H. (1950) Peritoneal lavage as an effective means of extrarenal excretion. *American Journal of Medicine* **9,** 63–77.
Opelz, G. and Terasaki, P.I. (1974) Poor kidney transplant survival in recipients with frozen-blood transfusions or no transfusions. *Lancet* **2,** 696–698.
Oreopoulos, D.G., Robson, M., Izatt, S. *et al.* (1978) A simple and safe technique for continuous ambulatory peritoneal dialysis. *Transactions of the American Society of Artificial Organs* **24,** 484–489.
Palmer, R.A., Quinton, W.E. and Gray, J.F. (1964) Prolonged peritoneal dialysis for chronic renal failure. *Lancet* **1,** 700–702.
Palmer, R.A. and Rutherford, P.S. (1949) Kidney substitutes in uraemia: the use of Kolff's dialyser in two cases. *Canadian Medical Association Journal* **60,** 261–266.
Popovich, R.P., Moncrief, J.F., Decherd, J.F. *et al.* (1976) The definition of a novel portable/wearable equilibrium peritoneal dialysis technique. *Abstracts of the Transactions of the American Society of Artificial Organs* **5,** 64.
Popovich, R.P., Moncrief, J.W., Nolph, K.D. *et al.* (1978) Continuous ambulatory peritoneal dialysis. *Annals of Internal Medicine* **88,** 449–456.
Putman, T. (1923) The living peritoneum as a dialysing membrane. *American Journal of Physiology* **63,** 548–555.
Reemtsma, K., McCracken, B.H., Schlegel, J.U. *et al.* (1964) Renal heterotransplantation in man. *Annals of Surgery* **160,** 384–410.
Richardson B.W. (1889) Practical studies in animal dialysis. *Asclepiad* **6,** 331–332.
Rosenberg, M. (1916) Nitrogenous retention of substances in the blood and in other body fluids in the core of the kidneys. *Berlin Klinischen Wochenschrift* **53,** 1314–1316.
Skeggs, L.T. Jr, Leonards, J.R. and Heisler, C.R. (1949) Artificial kidney: 11. Construction and operation of an improved continuous dialyser. *Proceedings of the Society for Experimental Biological Medicine* **72** (3), 539–543.
Starling, E.H. and Tubby, A.H. (1894) On the paths of absorption from the peritoneal cavity. *Journal of Physiology* **16,** 140.

Starzl, T.E., Marchioro, T.L. and Waddell, W.R. (1963) The reversal of rejection in human renal homografts with subsequent development of homograft tolerance. *Surgical and Gynecological Obstetrics* **117,** 385–395.

Tenckhoff, H. and Schechter, H. (1968) A bacteriologically safe peritoneal access device. *Transactions of the American Society of Artificial Internal Organs* **14,** 181–186.

Tenckhoff, H., Shilipetar, G. and Boen, S.T. (1965) One year experience with home peritoneal dialysis. *Transactions of the American Society of Artificial Internal Organs* **11,** 11–14.

Teschan, P.E. (1955) Haemodialysis in military casualties. *Transactions of the American Society of Artificial Internal Organs* **2,** 52–54.

Thalhimer, W., Solandt, D.Y. and Best, C.H. (1938) Experimental exchange transfusion using purified heparin. *Lancet* **11,** 554–555.

UK Renal Registry (2011) *The Fourteenth Annual Report of the UK Renal Registry,* Bristol, www.renalreg.com/Reports/2011.html (accessed 20 May 2013).

United Kingdom Transplant (UKT) (2005) *Transplant Activity in the UK 2004–2005,* http://www.organdonation.nhs.uk/statistics/transplant_activity_report/ (accessed 24 May 2013).

Warrick, C. (1744) An improvement in the practice of tapping, whereby that operation instead for the relief of symptoms, became an absolute cure for ascites, exemplified in the case of Jane Roman. *Philosophical Transactions of the Royal Society* **43,** 12–19.

Wegner, G. (1877) Surgical comments on peritoneal cavity with special emphasis on ovariotomy. *Archives of Klinischen Chirurgia* **20,** 53–145.

CHAPTER 2

Applied Anatomy and Physiology and the Renal Disease Process

Charlotte Chalmers
Edinburgh Napier University, UK

Learning Outcomes

- To understand the structure and main functions of the kidney.
- To explain the basic renal processes of filtration, reabsorption and secretion.
- To identify the main conditions causing chronic and established renal failure.
- To analyse the clinical features of these conditions and explain the principles of care management.

Introduction

This chapter provides the reader with a detailed discussion of all aspects of renal physiology and its relationship to important pathophysiological processes in renal disease, and some brief discussion on related nursing observations. The first part of the chapter explores the normal renal anatomy and physiology and the second part deals with disease processes causing established renal failure. This is not intended as a complete reference to all kidney diseases; rather it illustrates how altered renal physiology can affect the whole body and, indeed, how other diseases can affect kidney function.

Structure and Functions of the Kidney

The kidneys are paired organs lying behind the peritoneum, on either side of the vertebral column. The upper pole of the kidney is at the spinal level of T12 and the lower pole at approximately L3. The right kidney is a little lower due to the presence of the liver on that side. Usually, the kidneys are oriented with the concave surface facing the spine. However, due to developmental aberrations, other orientations of the kidney may occasionally exist (e.g. lying in the pelvis) but these do not usually affect function. Each kidney is approximately 11 cm long and weighs about 150 g (Figure 2.1).

Renal Nursing, Fourth Edition. Edited by Nicola Thomas. Published 2014 by John Wiley & Sons, Ltd.

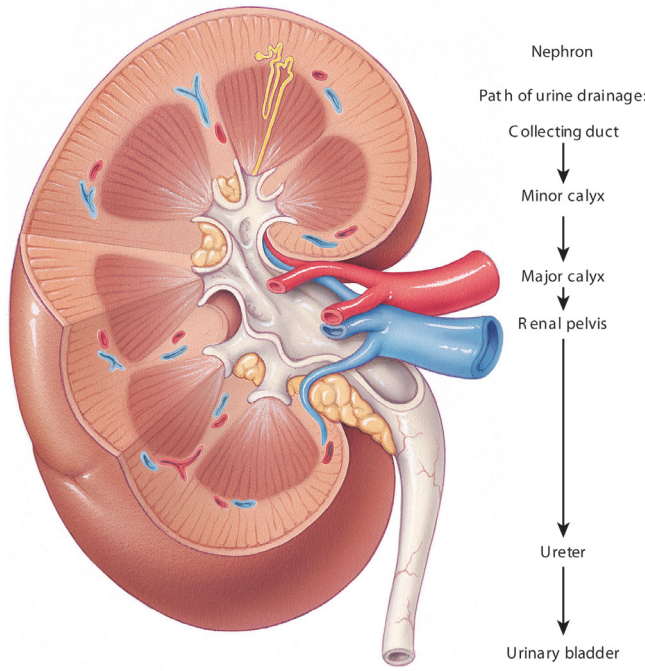


Figure 2.1 Structure of the kidney.

Source: Tortora and Derrickson (2007), *Introduction to the Human Body, The Essentials of Anatomy and Physiology,* 7th edition. This material is reproduced with permission of John Wiley & Sons, Inc.

On the concave surface of the kidney lies the hilus, from which the ureter and the main blood vessels and nerves access the kidney. The cut surface of the kidney reveals two distinct regions: a dark outer region, the cortex and a pale inner region called the medulla. The outer cortex is covered by a fibrous capsule and the whole kidney is surrounded by a pad of fat that offers some protection against injury. Broadly speaking, the cortex contains the filtering and reabsorptive components of the nephrons, whilst the medulla contains the concentrating and diluting components of the nephrons and a system of collection ducts. These ducts funnel the urine into the pelvis at the heart of the medulla, from where it moves down the ureter into the bladder (Figure 2.2).

The nephron

The nephron is the functional unit of the kidney and each kidney contains approximately 1 million nephrons (Figure 2.3). The unique structure of the nephron is critically related to its complex functions and contains five components, each performing a distinct process:

- the Bowman's capsule – forming a blind-ending capsule around a knot of capillaries called the glomerulus (the site of filtration);
- the proximal convoluted tubule (the site of bulk-phase reabsorption and some secretion);
- the loop of Henle (where the concentration and dilution of urine mainly occur);
- the distal convoluted tubule (the site of 'fine-tuning' reabsorption and more secretion);
- the collecting duct (also important for the concentration of urine and for carrying urine into the renal pelvis).

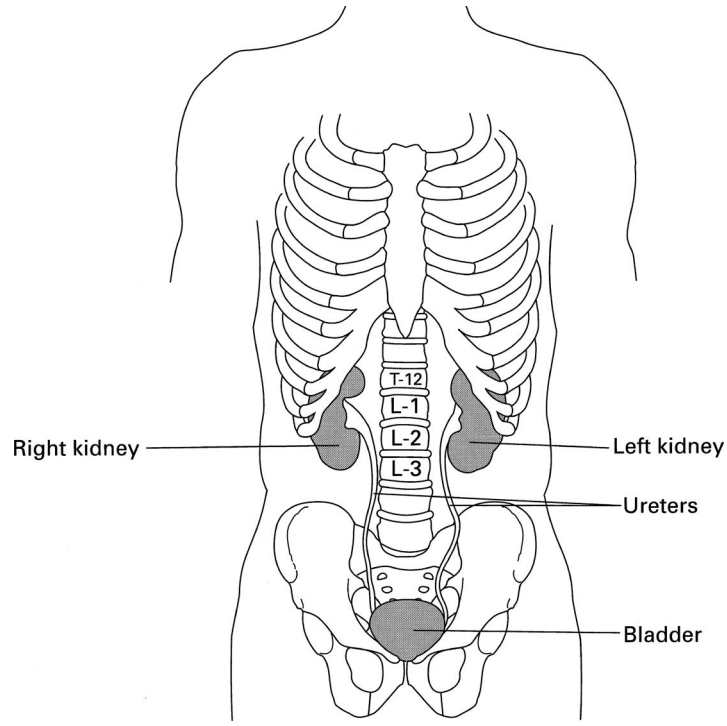


Figure 2.2 Relative position of the kidneys in the body.

These processes do not occur in isolation but are interdependent and intimately related to each other by the shape of the nephron. The importance of this fact will become clear when the renal processes are discussed in more detail.

There are broadly two types of nephron found in the kidney (Figure 2.4). Approximately 85% of nephrons are cortical nephrons, which have short loops of Henle that are contained in the cortex of the kidney. The other 15% of nephrons are called juxtamedullary nephrons and they have long loops of Henle, which extend deep into the medulla of the kidney. It is the long loops of Henle that enable concentration of urine; animals adapted to arid environments have long loops of Henle compared with those that have a lesser requirement to conserve water. It is the loops of Henle, together with the collecting ducts which also pass through the medulla, that give the pyramids of the medulla a striated appearance.

The main functions of the kidney are to rid the body of the end-product of metabolism and to regulate the electrolytes found in the body fluids. A more detailed list of the functions of the kidney can be found in Box 2.1. Before looking at how the kidney achieves its functions, there follows a discussion on the impressive versatility of urine.

The versatility of urine

When the immense variability in the qualities of urine that can be produced in order to control our internal environment is considered, one cannot fail to be impressed by the complexities of the workings of the kidney. Broadly speaking, there are three

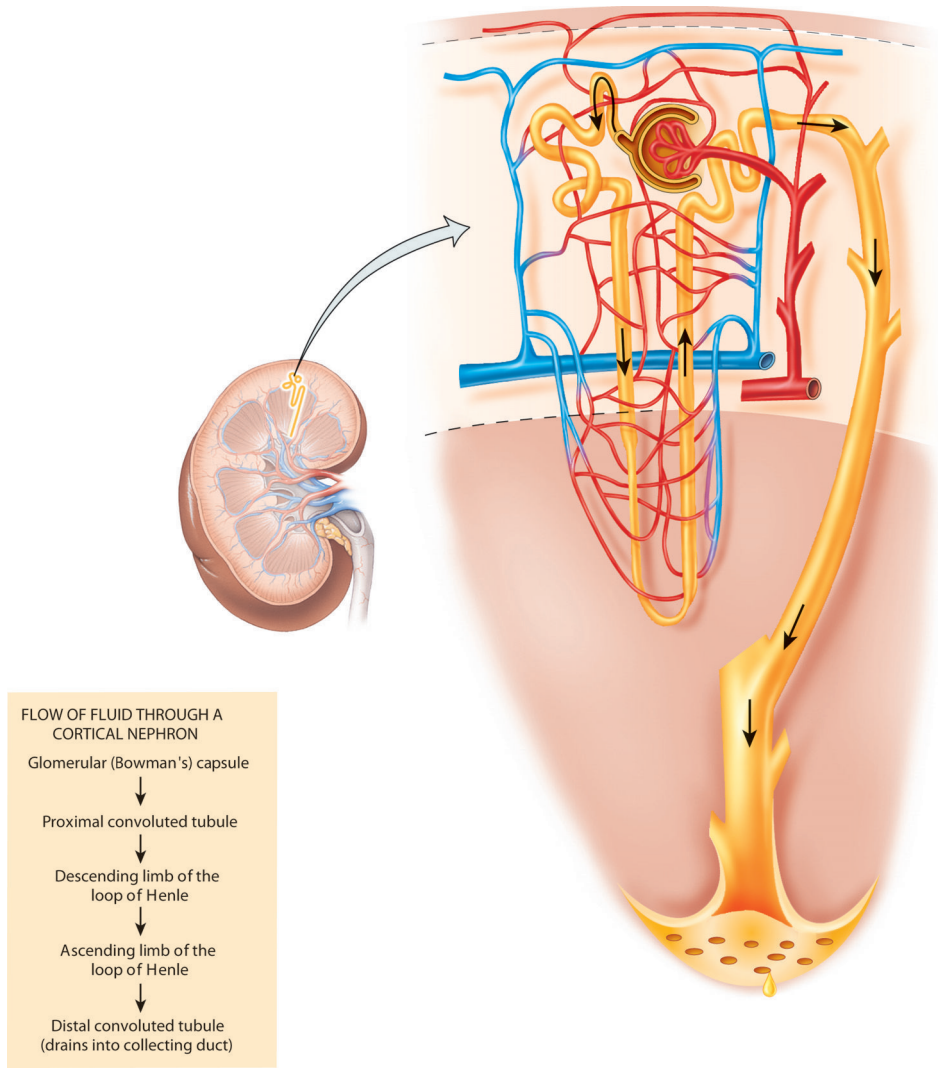


Figure 2.3 The parts of a nephron, collecting duct, and associated blood vessels.

Source: Tortora and Derrickson (2007), *Introduction to the Human Body, The Essentials of Anatomy and Physiology,* 7th edition. This material is reproduced with permission of John Wiley & Sons, Inc.

parameters that can be varied in order to maintain the constancy of our bodily fluids: urinary volume, urinary concentration and urinary content.

Urinary volume

In a healthy person, the volume of urine produced per day can vary from as little as 300 ml, if no water is ingested or there is excessive water loss from the body (as in diarrhoea), up to a maximum of 23 L in cases of excessive fluid ingestion. In health, urine output should not drop below 300 ml/day because this is the absolute minimum water volume required to excrete the daily load of toxic waste products. If the amount of waste products to be removed by the kidney rises, then the minimum urine volume

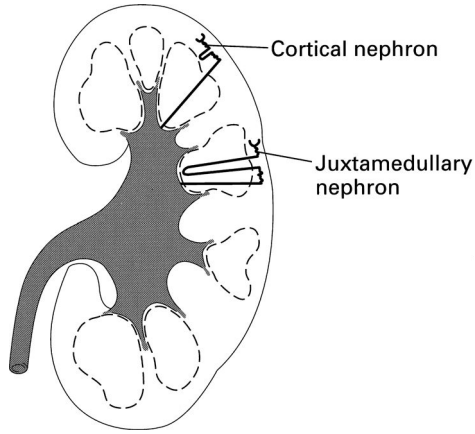


Figure 2.4 The position of the nephrons in the kidney.

BOX 2.1

The functions of the kidney

Excretory

- Excretion of metabolic waste products, e.g. urea and creatinine.

Regulatory

Regulation of:

- body water volume;
- body fluid osmolality;
- electrolyte balance;
- acid–base balance;
- blood pressure.

Metabolic

- Activation of vitamin D.
- Production of renin.
- Production of erythropoietin.

must also rise. However, the average urine output per day is approximately 1500 ml. The kidneys' ability to vary the volume of daily urine output over such a wide range is essential if we are to maintain a constant body fluid volume in the face of adverse factors such as excessive heat, which causes sweating; colonic infections causing diarrhoea; or excessive thirst and water ingestion, as seen in the condition psychogenic polydipsia (Table 2.1).

Urinary concentration

Though the volume of urine can vary over a wide range, the amount of solutes to be excreted by the kidney each day is much less variable. Thus, in order to excrete a fairly fixed volume of solutes each day in a very variable volume of water, the kidney must have the ability to concentrate or dilute the urine. On a hot summer's day when very

Table 2.1 Normal fluid inputs and outputs.

Inputs (ml)		Outputs (ml)		
Water	1500	Urine[a]		1500
Food	500	Insensible loss	lungs	400
			skin[b]	400
Water of metabolism	400	Faeces[c]		100
Total	2400			2400

[a]Urinary volume is the only factor that can be regulated by the body to balance fluid inputs.
[b]This insensible loss of fluid through the skin is by simple evaporation (not sweat). Sweat is called 'sensible loss' and may reach up to 5 l/h, for example, when a person is exercising excessively.
[c]Loss of fluid with the faeces can be as high as several litres per day in the presence of severe colonic infections such as cholera.

little fluid has been drunk, urine is dark in colour and of low volume, whereas if liberal amounts of beer have been consumed at a party, large volumes of watery urine are passed all evening. In fact this diuretic effect of beer is not wholly due to the volume imbibed, but also to the fact that the alcohol present in the beer suppresses the secretion (from the posterior pituitary gland) of antidiuretic hormone (ADH, also known as vasopressin), a hormone that would normally prevent diuresis. The hangover suffered the next day is therefore caused by dehydration.

The ability of the kidneys to excrete all the body's excess solutes in varying amounts of water by concentrating or diluting the urine is essential for maintaining a constant body osmolality (Box 2.2). The mechanism in the kidney that controls the concentration or dilution of urine is often affected early on in renal disease, making it difficult for the individual to control both body fluid volume and osmolality in response to changes in fluid inputs and outputs. This can result in the individual tipping back and forth from states of dehydration to fluid overload.

BOX 2.2

Concepts of osmosis and body osmolality

- Water can move between the different body fluid compartments across semipermeable membranes by the process of osmosis.
- The more concentrated a solution, the more water will be drawn into this solution.
- Any solute that can cause the movement of water across a semipermeable membrane is said to be 'osmotically active'.
- The osmotic activity of substances in solution is dependent on the number of dissolved particles in the solution and not on their size or charge.
- Sodium chloride (NaCl) dissociates in solution into Na^+ and Cl^- ions, so the number of osmotically active particles is almost double the number of NaCl molecules (but not exactly double because the dissociation is not complete; the solution consists of NaCl, Na^+ and Cl^- particles).
- Osmotically active particles in solution are measured by the unit called the osmole or milliosmole (mosmol).
- Osmolality is measured in mosmol/kg water and is a measure of the potential osmotic activity of dissolved solutes in solution.
- Normal body fluid osmolality is 285 mosmol/kg water.
- The concentration (rather than the osmotic activity) of individual electrolytes is measured in mmol (millimoles) or μmol (micromoles) rather than mosmol, e.g. normal fasting blood glucose range = 3.6–5.8 mmol/l

Urinary content

The range of substances that can be constituents of urine is varied and includes:

- ions: sodium, potassium, calcium, magnesium, chloride, bicarbonate, phosphate and ammonium;
- metabolic waste: urea, creatinine and uric acid;
- drug metabolites: most metabolites of pharmacological agents are eventually excreted from the body through the kidneys; many are detoxified in the liver first;
- other products of normal metabolism: metabolites of hormones can be detected in the urine by appropriate assays and may be a diagnostic aid, for example, the appearance of human chorionic gonadotrophin (hCG) in the urine in the early stages of pregnancy forms the basis of the pregnancy test.

Normal urine is clear in appearance, though it may vary in colour from pale to dark amber, depending on its concentration. It has no unpleasant odour, though urine that has been standing a long time may develop a strong ammonia smell. Finally, normal urine has a pH that is slightly acidic – around pH 6 – though urine can have a pH in the range 4.0–8.0 in cases of severe acidosis or alkalosis respectively.

Basic Renal Processes

Glomerular filtration

This is a process of filtration of plasma across the glomerular basement membrane from the glomerulus into the Bowman's capsule (Figure 2.5). The glomerular filtration surface is a unique structure composed of three layers:

- the endothelial lining of the glomerular capillaries;
- the basement membrane;
- the epithelial cells of the Bowman's capsule, or podocytes. Filtration occurs between the slits formed by the finger-like processes of these cells (called pedicels) which surround the glomerular capillaries (Figure 2.5).

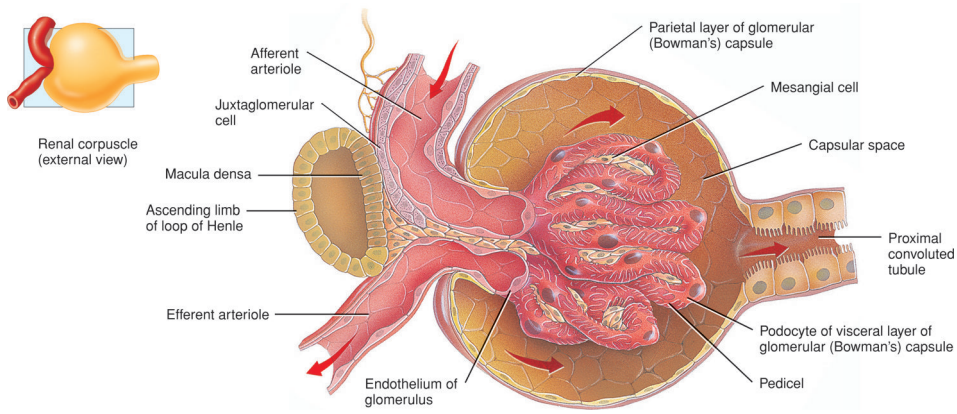


Figure 2.5 Structure of the glomerulus and Bowman's capsule.

Source: Tortora and Nielsen (2009) *Principles of Human Anatomy,* 11th edition. This material is reproduced with permission of John Wiley & Sons, Inc.

These three layers are fused together and act as a barrier to the filtration of large-molecular-weight molecules such as proteins.

Blood enters the glomerulus from a series of branches of the renal artery, ending in the afferent arteriole. Blood then leaves the glomerulus through the efferent arteriole rather than a vein. In the majority of nephrons (those situated in the cortex), the efferent arteriole from the glomerulus divides up into capillaries, which cover the surfaces of the convoluted tubules. The capillaries finally empty into the venous system. In the deeper juxtamedullary nephrons the efferent arteriole from the glomerulus divides to form loops which lie parallel to the loops of Henle and so run down into the medulla. These vessels are called the vasa recta and are concerned with the process of concentration of the urine (Figure 2.6). Blood then leaves the kidney through a series of larger converging veins, ending in the renal vein which returns the blood to the vena cava.

In effect, the nephrons contain two capillary beds, one within the glomerulus and a second which surrounds the convoluted tubules of the nephrons. This unusual

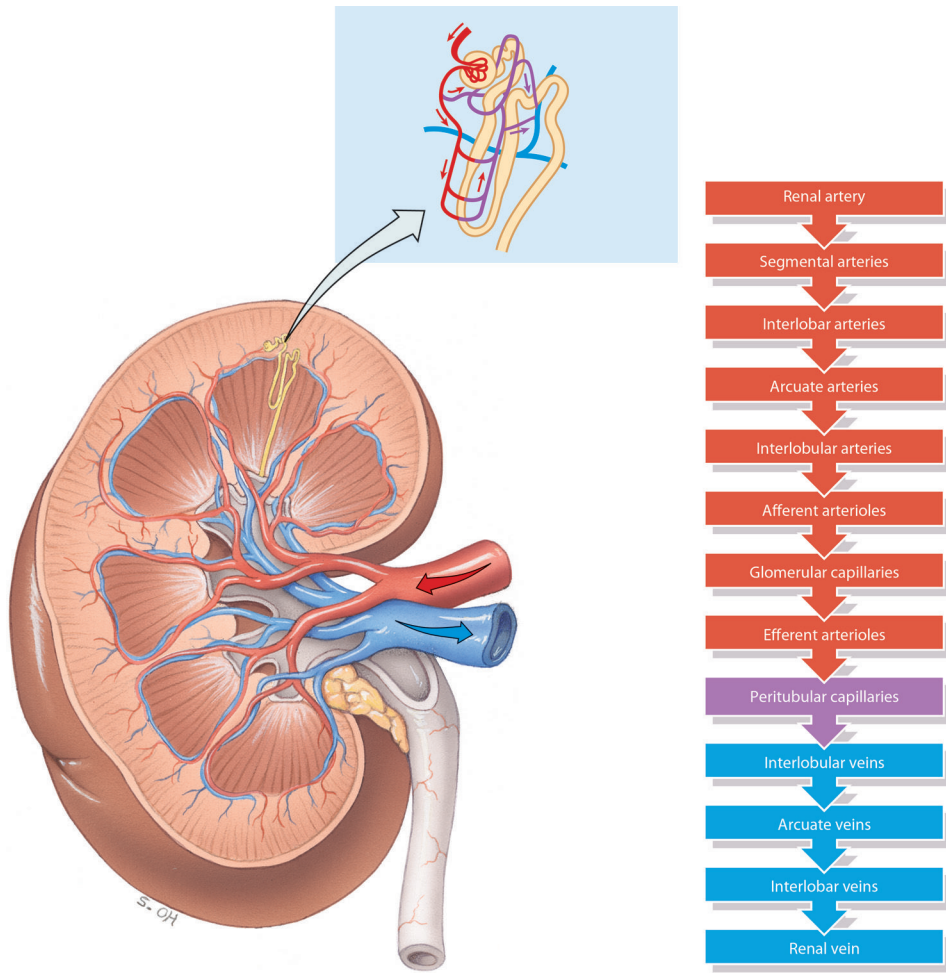


Figure 2.6 Blood supply of the right kidney.

Source: Tortora and Derrickson (2007), *Introduction to the Human Body, The Essentials of Anatomy and Physiology,* 7th edition. This material is reproduced with permission of John Wiley & Sons, Inc.

arrangement of two capillary beds in tandem enables a pressure gradient to exist within the nephron, with high pressure in the glomerulus, favouring filtration, and a relatively low pressure in the peritubular capillaries, favouring reabsorption.

The formation of a filtrate from plasma flowing through the glomerulus occurs due to Starling's forces. These are the same forces that cause the filtration and reabsorption of tissue fluid in other capillary beds in the body, but with some important adaptations. In the glomerulus, filtration depends on three main pressures. One type of pressure promotes filtration, and the other pressures oppose filtration. Fluid is forced across the glomerular basement membrane because of the high hydrostatic pressure of blood flowing through the afferent arteriole. This pressure is greater than the sum of the blood colloid osmotic pressure (BCOP) and the pressure in the Bowman's capsule (capsular hydrostatic pressure) opposing it (Figure 2.7). In an ordinary capillary bed, this filtrate would be almost entirely reabsorbed back into the capillary at the venule end because the hydrostatic pressure would have fallen to below the colloid osmotic pressure of the capillary, which would then pull the fluid back in by osmosis. However, in the glomerulus, because blood leaves via another arteriole (the efferent arteriole) rather than a venule, a high hydrostatic pressure is maintained and the sum of the blood colloid osmotic pressure and capsular hydrostatic pressure is insufficient to move fluid back into the capillary. This situation is obviously desirable so that large amounts of filtrate can be made. All of the filtrate formed in the glomerulus passes into the Bowman's capsule and is often referred to as tubular urine.

Amount and composition of glomerular filtrate

The amount of glomerular filtrate formed per minute is referred to as the glomerular filtration rate (GFR), and in the average healthy person is approximately 125 ml/min. This volume is the sum amount from all 2 million nephrons in the kidneys and thus

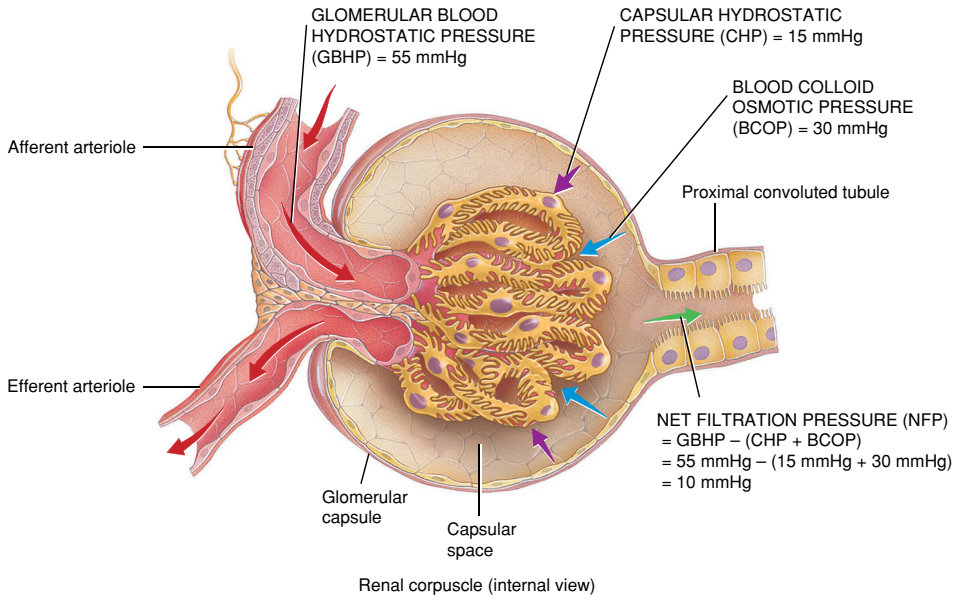


Figure 2.7 The formation of filtrate in the glomerulus.

Source: Jenkins and Tortora (2013).

the amount from each nephron is relatively small. A quick calculation shows that at a GFR of 125 ml/min, the total amount of filtrate formed per day is 180 L – approximately 60 times the circulating plasma volume. Obviously, the majority of this must be reabsorbed to prevent severe dehydration.

The 'average' GFR quoted is generally only average for a young adult. Children have a lower GFR than this because their nephrons are still increasing in size (all nephrons are present at birth). After the age of about 30 years the number of functioning nephrons starts to decrease because of the ageing process, thus the GFR decreases proportionately. However this only becomes significant to health when the GFR falls to around 5 ml/min – a situation that only occurs in a diseased kidney. An estimated GFR (eGFR) can be calculated clinically by measuring serum creatinine and applying a formula. The principles of the eGFR test are described more fully in Chapters 6 and 7.

The composition of the initial glomerular filtrate is that of a plasma ultrafiltration; that is, without proteins. The main determinant of what can pass through the glomerular basement membrane is molecular size, although the molecular shape and charge are also important. The passage of strongly negatively charged molecules such as albumin tends to be retarded because of the presence of fixed negative charges in the basement membrane which repel their movement. Albumin, a small protein, has a molecular weight of 69 000, a weight just below the cut-off point for filtration. It can therefore cross the filter, but does so only in minute quantities since it is also hindered by its negative charge. Similarly, haemoglobin, with a molecular weight of 68 000, is small enough to be filtered, whereas intact erythrocytes are too large to cross into the Bowman's capsule. The appearance of haemoglobin in urine therefore indicates haemolysis, with the release of the protein into the blood. It is because of this free permeability of small molecules that the composition of the initial glomerular filtrate is the same as that of the plasma, and will include the major ions sodium, potassium, chloride, bicarbonate, calcium and phosphate; glucose, amino acids and the toxic waste products of urea and creatinine. Any albumin filtered is reabsorbed through the proximal tubule into the renal lymph system and returned to the blood stream.

Selective reabsorption

Reabsorption is a process that involves the movement of water and dissolved substances from the tubular fluid back into the blood stream. The term 'selective' infers a regulatory function to this process, as indeed not all of the filtered substances are returned to the blood. Any substances not reabsorbed will pass with the urine into the bladder to be excreted from the body. The main sites for reabsorption in the nephron are the proximal and distal convoluted tubules.

Mechanisms of reabsorption

Broadly speaking, there are three mechanisms in the nephron for the reabsorption of water and solutes: osmosis, diffusion and active transport. Osmosis is the movement of water from an area of low concentration to a more concentrated solution across a membrane which allows water molecules through but is selectively permeable to solute molecules (a semipermeable membrane).

Diffusion occurs where a concentrated solution meets one which is less concentrated. The solute will equilibrate throughout the solvent. This may occur across a membrane so long as the membrane is permeable to the solute. Diffusion may also occur through specialised 'protein carriers' in the membrane. This is sometimes known as 'facilitated

diffusion'. In these cases, the number of protein carriers in the membrane is limited, meaning that movement of the solute will be limited. This is true for tubular reabsorption of glucose (which is also linked to sodium transport). Once all the carriers are active, reabsorption of glucose has reached its maximum. If the filtered load of glucose is excessive, not all can be reabsorbed and glucose will appear in the urine, as happens in untreated diabetes mellitus.

Active transport is so named because it is an energy-requiring process. The energy source is adenosine triphosphate (ATP). Active transport can move solutes against a concentration gradient. Cells which carry out a lot of active transport will have a lot of mitochondria present (the 'power-generating' organelles of cells).

In the proximal tubule cells, where most reabsorption is by active transport, the cells are packed with mitochondria. Proximal tubule cells also have a large brush border on their luminal surface (the surface facing into the tubule) to increase their surface area for reabsorption. In contrast, cells lining the descending loop of Henle are comparatively thin, have no brush border and have relatively few mitochondria. This suggests that these cells are not very metabolically active and are adapted for reabsorption by passive diffusion. The epithelial cells of the distal tubule are similar to those of the proximal tubule but with a less well-defined brush border and fewer mitochondria. This suggests that these cells are capable of active transport of substances but in much lesser quantities than in the proximal tubule. This again illustrates how each segment of the nephron is anatomically adapted to carry out its unique functions. The different cell types lining the tubules are illustrated in Figure 2.8.

Reabsorption in the proximal convoluted tubule – the site of bulk-phase reabsorption

Approximately 65% of all reabsorption occurs in the proximal tubule (hence the term 'bulk phase') and is obligatory rather than regulatory. Most substances here are reabsorbed by active transport mechanisms, including sodium, chloride, potassium, glucose, amino acids, phosphate and bicarbonate. Urea is absorbed by passive diffusion and water is reabsorbed by osmosis. Some substances are reabsorbed almost entirely in the proximal tubule, such as glucose and amino acids, which do not appear in the urine, whereas others have only between 60 and 70% reabsorption, such as sodium, water and potassium. Approximately 50% of urea is reabsorbed here but creatinine is not reabsorbed at all. However, for all substances that are reabsorbed, the proximal tubule is the site where the bulk of this reabsorption occurs.

Reabsorption in the distal convoluted tubule – the site of fine-tuning reabsorption

This is the site where more specific regulation of substances occurs according to the needs of the body. In order for the distal tubule to be aware of precisely what the body's reabsorptive needs are, there needs to be some method of communication between the cells of the distal tubule and the rest of the body. This communication system is via a range of hormones that form part of a negative-feedback system for the homeostatic control of ions and water. For example, sodium and water reabsorption are under the control of aldosterone (secreted by the adrenal cortex) and ADH secreted by the posterior pituitary gland. Potassium reabsorption is also controlled by aldosterone, whereas calcium and phosphate are controlled by parathyroid hormone (PTH). The precise mechanisms for controlling the electrolytes outlined above will be dealt with in later sections in this chapter.

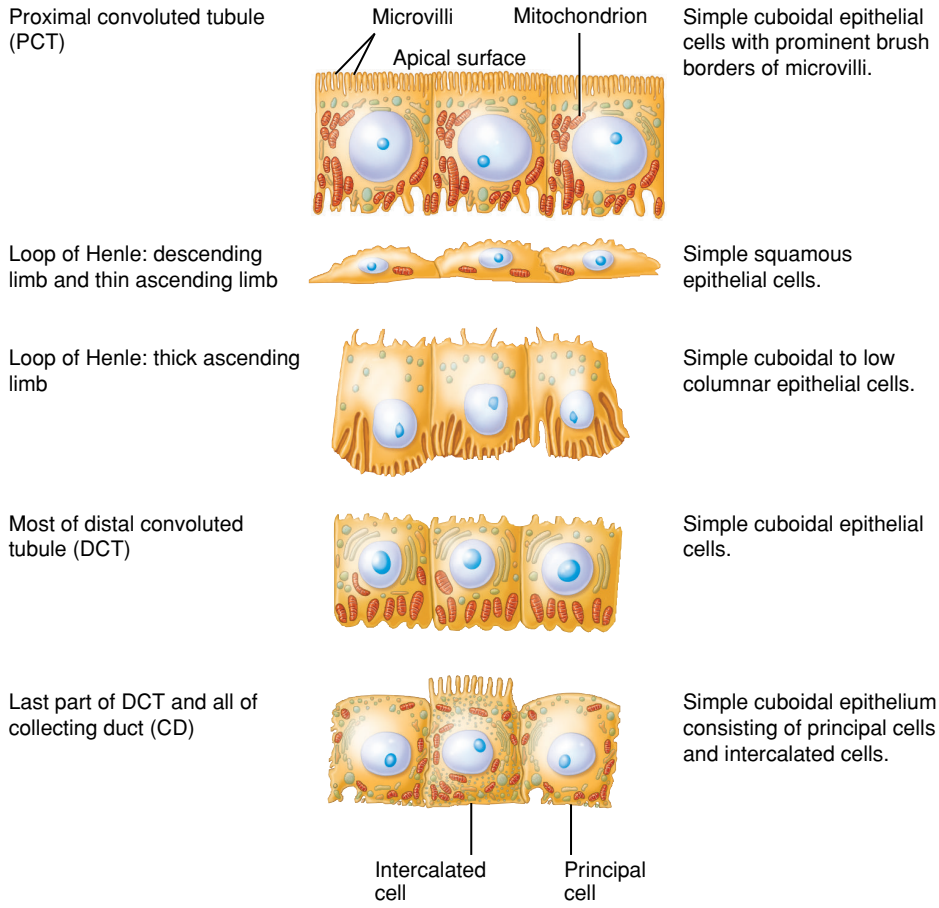


Figure 2.8 Histological features of the renal tubule and collecting duct.

Source: Tortora and Nielsen (2009) *Principles of Human Anatomy,* 11th edition. This material is reproduced with permission of John Wiley & Sons, Inc.

Secretion

The process of secretion occurs in both the proximal and distal tubules and involves the movement of substances from blood flowing through the peritubular capillaries, through the tubule wall cells, into the tubular fluid. In this respect, secretion is the opposite process to reabsorption. Substances that are secreted into the tubules are excreted in the urine. Though creatinine is freely filtered at the glomerulus, total creatinine excretion is increased by 20% by the process of secretion. Ions that are transported into the tubules by secretion are hydrogen, which is secreted in both the proximal and distal tubules and is important in acid–base control, and potassium, which is secreted in the distal tubule in exchange for sodium reabsorption. The hormone involved is aldosterone.

Excretion of drugs and drug metabolites

Many drugs and their metabolites are finally excreted from the body through the kidneys by the processes of glomerular filtration and secretion. Like other filtered substances, the rate of filtration of drugs will depend on their molecular size and charge:

smaller molecules are filtered more rapidly than larger ones. Drugs that bind to plasma proteins are filtered very slowly because of the size of the complex. Some drugs are cleared from the blood purely by glomerular filtration and thus the rate of clearance cannot exceed the GFR of 125 ml/min, whereas other drugs are excreted by a combination of filtration and secretion, such as benzylpenicillin, which achieves a total clearance rate of 480 ml/min (Shitara *et al.* 2006; Bennett and Brown 2008).

Concentration and dilution of urine

The components of the nephron that are involved in the concentration and dilution of the urine are the loop of Henle and the collecting ducts. The concentration of urine is measured in units of osmolality (mosmol/kg water). The most dilute urine that humans can produce is approximately 60 mosmol/kg water, but this situation occurs in the pathological condition of diabetes insipidus in which the pituitary gland fails to produce ADH. The most concentrated urine that can be produced is approximately 1400 mosmol/kg water, which is greater than four times more concentrated than plasma (plasma osmolality = 285 mosmol/kg water) and requires maximum ADH secretion. The average range of urine osmolality in people with normal kidneys is between 300 and 500 mosmol/kg water.

Countercurrent mechanism of urinary concentration

The countercurrent mechanism is a complex physiological process that will not be discussed in great detail.

In order to concentrate the urine the following factors are required:

- the creation and maintenance of a local environment in the kidney that allows large quantities of water to be reabsorbed by osmosis from the collecting duct back into the blood;
- a mechanism that can influence the opening and closing of water channels in the collecting ducts in order to control the exact amount of water reabsorbed.

Creation of the local environment

This local environment consists of an increasing hyperosmotic medullary interstitium as one moves towards the tip of the loops of Henle. In other words, the tissue spaces between the loops of Henle in the medulla of the kidney must be made hyperosmotic compared to the fluid in the collecting duct. As the collecting ducts pass through the medulla on their way to the renal pelvis, water can be pulled out by osmosis, resulting in less water entering the urine.

This hyperosmotic environment is created by the active and passive transport of ions (mainly sodium and chloride) out of the tubular fluid as it passes through the loop of Henle into the medullary interstitium. The buildup of ions here gradually increases and becomes more concentrated as the loop of Henle descends into the medulla. The tip of the medulla can reach osmolalities of up to 1400 mosmol/kg water. Water does not follow the transport of ions into the medullary interstitium by osmosis because the thick ascending limb of the loop of Henle is impermeable to water. Urea also makes an important contribution to the creation of the hyperosmotic environment. Urea can diffuse passively through the walls of the tubules at most points along the nephron, but urea diffusion is greatly enhanced across the collecting tubule wall in the presence of even small amounts of ADH. Thus large amounts of urea become concentrated in the medullary interstitium.

Maintenance of the local environment: the countercurrent mechanism

It could be thought that as fast as the hyperosmotic environment is created it will be washed out by processes of diffusion and reabsorbed back into blood. However, the environment is maintained because of the unique arrangement of the looped vasa recta capillaries around the loops of Henle (Figure 2.6). The vasa recta are only supplied with 1–2% of the blood entering the kidneys, so there is very little blood flow for ions to be reabsorbed back into. In addition, the vasa recta lie with their ascending and descending limbs in very close proximity. This close proximity allows for rapid exchange of water and solutes between the two limbs. So, as blood flows down the descending limb of the vasa recta, the high concentration of ions in the medullary interstitium enables ions to diffuse into the vasa recta (markedly increasing their concentration), and water to move out by osmosis, but as the blood moves into the ascending limb of the vasa recta, the high concentration of ions in the blood then enables ions to diffuse back out into the medullary interstitium (and water back into the blood), maintaining the hyperosmotic environment.

The regulation of body fluid volume and osmolality

Sodium is the main extracellular cation (positively charged ion) and is intimately related to extracellular volume. An increase in body sodium content could lead to an increase in extracellular fluid volume, leading to hypertension and oedema; and a decrease in body sodium content could lead to a decrease in extracellular fluid volume leading to hypotension and dehydration. Thus, it is vitally important that body sodium content is kept at a constant level if body fluid volume is to remain constant. Fortunately, the healthy kidney conserves sodium very efficiently in shortage, and can excrete 10–150 mmol/day when sodium is in excess.

Sodium levels, and hence fluid volume, are regulated by three hormones:

- ADH;
- aldosterone;
- atrial natriuretic peptide.

Antidiuretic hormone

ADH is secreted from the posterior pituitary gland in response to a rise in plasma osmolality. Osmoreceptors in the hypothalamus detect small changes in the plasma osmolality and send signals to the posterior pituitary to secrete more or less ADH. Since sodium, along with its associated anion (negatively charged ion) chloride (Cl^-), contributes approximately 95% of the extracellular fluid osmolality, sodium concentration of extracellular fluid is obviously important in determining ADH secretion.

ADH receptors are found in the collecting ducts of kidney tubules and ADH acts to open water channels found here. Remember that the collecting ducts pass through the inner medulla of the kidney – a region of high osmolality. If water channels in the walls of the collecting ducts open, water will move out of the collecting duct into the medullary interstitium and finally into the circulation. The fall in plasma osmolality then leads to a slowing-down of ADH secretion by negative feedback (Figure 2.9).

Aldosterone

Aldosterone is a steroid hormone secreted from the adrenal cortex. It has its effect on the distal tubule of the nephron: the more aldosterone is secreted, the more sodium is

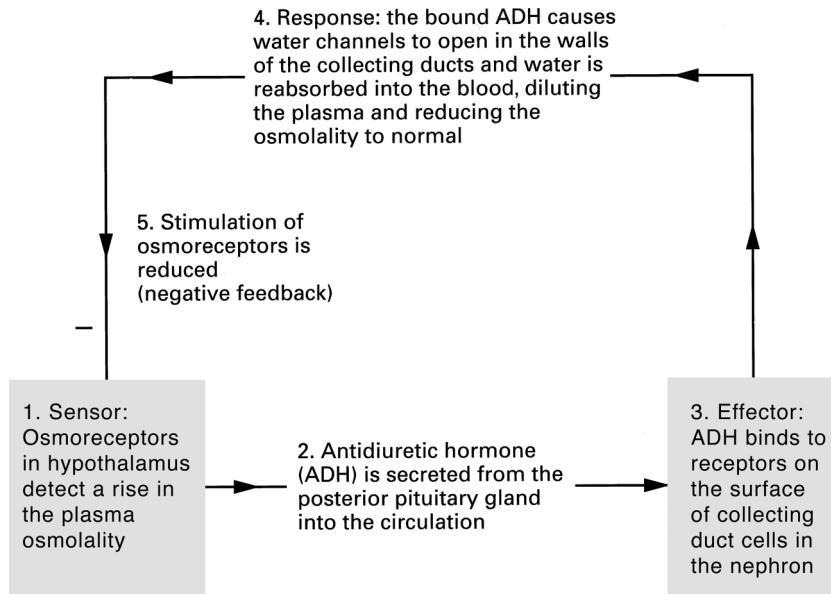


Figure 2.9 Negative-feedback loop for antidiuretic hormone (ADH) release and control of plasma osmolality.

reabsorbed. Aldosterone, however, is not the sole determinant of body sodium balance, although in extreme cases of oversecretion of aldosterone, such as in Cushing's disease, hypertension may result from over-retention of sodium and water.

The secretion of aldosterone, unlike ADH, is not directly triggered by extracellular osmolality, but is regulated by a peptide, angiotensin II. The function of this peptide is described in the section on the renin–angiotensin system, below.

Atrial natriuretic peptide

This peptide is released from cardiac atrial cells in response to an increased atrial stretch. It has five known major effects:

- inhibition of aldosterone secretion by the adrenal cortex;
- reduction of renin release by the kidney;
- reduction of ADH release from the posterior pituitary;
- vasodilation;
- natriuresis and diuresis.

All of these effects result in the excretion of sodium and water through the kidney, reducing the extracellular fluid volume back to normal. Other factors which may be important in sodium regulation are renal prostaglandins, kinins and the renal nerves. Failure to regulate the extracellular fluid volume occurs commonly in people with renal disease and leads to hypertension.

The renin–angiotensin-aldosterone pathway

The distal convoluted tubule forms a unique contact with the glomerulus, passing in the angle between the afferent and efferent arterioles. At this point, specialised cells

called the macula densa in the wall of the distal tubule make contact with cells in the endothelium of the arterioles which release a hormone called renin. The macula densa and the renin-releasing cells are collectively called the juxtaglomerular apparatus or complex (see Figure 2.5).

The juxtaglomerular apparatus is responsible for maintaining a constant blood flow through the glomerulus and thus a constant GFR despite fluctuations in arterial pressure. This is achieved through a tubule feedback mechanism in which a fall in GFR results in a fall in the chloride ion concentration in the distal tubule. This stimulates the macula densa cells which send 'signals' to the renin-secreting cells to release renin. Renin acts via the renin–angiotensin system (Figure 2.10) to produce both local vasoconstriction of the efferent arteriole (increasing GFR) and peripheral vasoconstriction to increase arterial blood pressure. In addition, salt and water retention increase due to the effects of aldosterone.

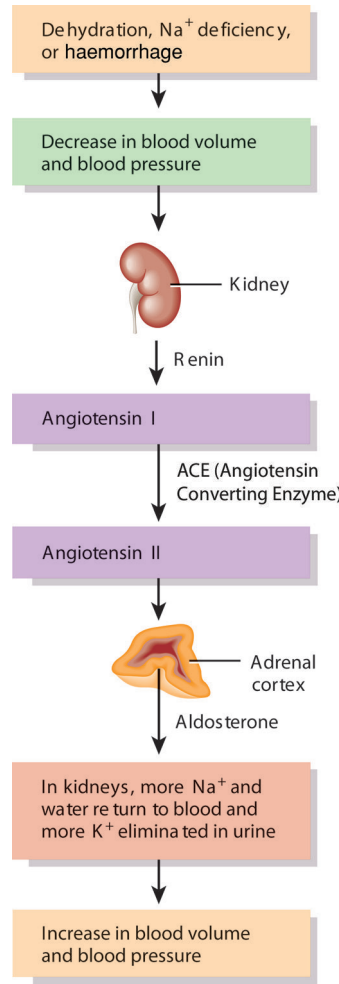


Figure 2.10 The renin-angiotensin-aldosterone pathway.

Source: Tortora and Derrickson (2007), *Introduction to the Human Body, The Essentials of Anatomy and Physiology,* 7th edition. This material is reproduced with permission of John Wiley & Sons, Inc.

Aldosterone and the control of body potassium content

Potassium is the main intracellular cation. Only about 2% of the total body potassium content is extracellular. Potassium ions are freely filtered at the glomerulus: 65% of reabsorption takes place in the proximal tubule. However, the renal handling of potassium ions is not as efficient as that of sodium, nor is potassium conserved so well when there is a shortage. The secretion of potassium is also linked to that of sodium and hydrogen ions. Unlike sodium regulation, where aldosterone is just one factor in the regulation of sodium content, aldosterone is the only hormone involved in the control of potassium content and thus has a very important regulatory role. Small increases in extracellular potassium concentration directly stimulate aldosterone secretion from the adrenal cortex. The effect of aldosterone in the distal tubule of the nephron is to increase the secretion of potassium into the urine. When aldosterone levels fall, the reverse occurs and less potassium is secreted. The release of aldosterone stimulated by rises in extracellular potassium concentration is strongly controlled by a negative feedback system. Once the potassium concentration returns to normal the stimulus to secrete aldosterone is quickly switched off.

The hormone aldosterone increases sodium reabsorption in exchange for potassium or hydrogen ions. If excess potassium ions need to be secreted, then fewer hydrogen ions can be secreted and vice versa. Clinically, this phenomenon results in an association between metabolic acidosis and hyperkalaemia (or conversely, metabolic alkalosis and hypokalaemia), because in patients with acidosis the distal tubules will increase the rate of hydrogen ion secretion (to prevent a fall in plasma pH) by reducing the rate of potassium ion secretion, resulting in the retention of potassium ions in the blood, leading to hyperkalaemia.

Hypokalaemia and hyperkalaemia

Potassium is important in maintaining the membrane potential of nerve and muscle cells and hence affects their excitability. Disturbances in potassium balance show their effects in abnormal nerve and muscle function and may be life threatening.

Changes in muscle tone and in the electrocardiogram (ECG) may indicate an altered potassium balance. The diet almost invariably contains adequate potassium, so hypokalaemia generally occurs due to excessive losses. Persistent vomiting, diarrhoea, or the use of certain prescribed diuretics are the most likely causes of low blood potassium. Dialysis using an inappropriate concentration of potassium in the dialysate may also result in hypokalaemia. Treatment of hypokalaemia by the administration of a potassium salt must be undertaken with care since this may result in hyperkalaemia. The uptake of potassium into cells is also dependent on the acid–base balance in the patient. Acidosis (low blood pH) causes the release of potassium from cells so acid–base disturbances must first be corrected.

Hyperkalaemia can occur as a result of decreased potassium excretion in the renal patient. Insulin promotes uptake of potassium into cells, so insulin deficiency may lead to hyperkalaemia, as can β-blockade (Laing 2011) and excessive tissue breakdown following trauma.

Regulation of calcium, phosphate and magnesium

Calcium and phosphate are the main mineral constituents of bone and thus the majority of calcium and phosphate in the body is found in the skeleton. However, small amounts of both these ions are found in extracellular fluid. Calcium exists in the

plasma in two forms. Approximately 50% exists in the free ionised form (1.25 mmol/l), and the other 50% in a bound form, mainly bound to protein, particularly albumin (1.25 mmol/l). Usually when serum calcium levels are measured, the total calcium concentration is measured (2.5 mmol/l). This total calcium is then 'corrected' depending on the blood albumin level, since it is the ionised form of the calcium that is important in the extracellular fluid in controlling nerve and muscle conduction. Any condition which leads to a fall in the ionised calcium concentration (even if total calcium remains normal) will lead to the classic symptoms of hypocalcaemia – tetany, muscle cramps and even convulsions. In situations of hypercalcaemia, the main effects seen are pruritus, extraskeletal calcification, renal calculi, peptic ulceration and changes in mental function such as memory loss and depression.

Inorganic phosphate (i.e. those ions carrying a charge) exists in several forms – 'acid' phosphate ($H_2PO_4^-$) and 'alkaline' phosphate HPO_4^-. The normal plasma range of total inorganic phosphate is 0.87–1.45 mmol/l. Phosphate is important in buffer systems to maintain the plasma pH and exists in equilibrium with calcium.

Both calcium and phosphate are freely filtered at the glomerulus. When the plasma phosphate level is below 1 mmol/l, all the filtered phosphate is reabsorbed in the early proximal tubule. However, once the plasma phosphate level rises above 1 mmol/l, the amount of phosphate excreted in the urine rises in proportion to the plasma concentration. Further excretion of phosphate in the distal tubule (by secretion) can occur in response to the rise in the circulating level of PTH. Calcium reabsorption is very similar to that of sodium, in that approximately 65% occurs in the proximal tubule, and a further 20–25% in the ascending limb of the loop of Henle, leaving around 10–12% of filtered calcium being delivered to the distal tubule. How much more calcium is reabsorbed in the distal tubule depends on the levels of circulating PTH.

Magnesium is an important intracellular cation involved in energy storage and production. In all, 55% of total body magnesium is found within bones, so it is not surprising that magnesium balance is linked to that of calcium.

Parathyroid hormone increases tubular reabsorption of magnesium. Under normal circumstances, gastrointestinal absorption and urinary excretion of magnesium are equal. Gastrointestinal disorders may therefore decrease magnesium uptake but this is matched by a decrease in renal excretion. Most diuretics, and alcohol, increase renal magnesium excretion.

The renal handling of calcium and phosphate – the roles of PTH, vitamin D and calcitonin

The mechanisms by which plasma calcium and phosphate are regulated are closely interrelated. The two major regulators are PTH and vitamin D. Calcium and phosphate can enter the plasma from the gut and from the bone. Indeed almost all of the approximately 1 kg of calcium in a 70 kg person is found in the bone. Of this, a few grams exchange daily with the plasma calcium pool. Calcium and phosphate can leave the plasma by being redeposited in bone, or by renal excretion.

PTH is secreted by the parathyroid glands situated next to the thyroid. Secretion is stimulated by a decrease in plasma calcium concentration, and reduced when plasma calcium levels rise. Its effect is to raise plasma calcium concentration, mainly by increasing bone breakdown (resorption), releasing calcium ions. PTH also acts in the kidney, stimulating one step in the conversion of vitamin D to its active metabolite, calcitriol or 1,25-dihydroxycholecalciferol, also known as 1,25-hydroxyvitamin D.

Vitamin D is a steroid that enters the body either through dietary intake or by the effect of sunlight on the skin. However, this is an inactive form of the vitamin called cholecalciferol. To become activated it needs to undergo two metabolic conversions, one in the liver

and one in the kidney. These conversions result in the formation of calcitriol. This active form has its effect in the gut, kidney and (in the presence of PTH) on bone, raising plasma calcium levels. The actions of vitamin D are summarised in Figure 2.11.

The effects of both vitamin D and PTH are to increase the plasma calcium concentration. However, these effects are carefully controlled by a negative-feedback system which prevents the calcium level rising too high. The negative-feedback system is outlined in Figure 2.12. Only if calcium levels suddenly rise high (as after a high-calcium meal) is calcitonin stimulated to be released from the C cells of the thyroid gland, causing calcium to be redeposited in the bone. This is a rapid and relatively short-acting effect. The control of calcium and phosphate levels is essential for the maintenance of normal bone. In renal disease the production of calcitriol is reduced, thus removing the negative feedback effect on PTH. The result is a rise in PTH leading to loss of calcium from bone and the complications of renal bone disease. Renal bone disease is discussed in Chapter 6.

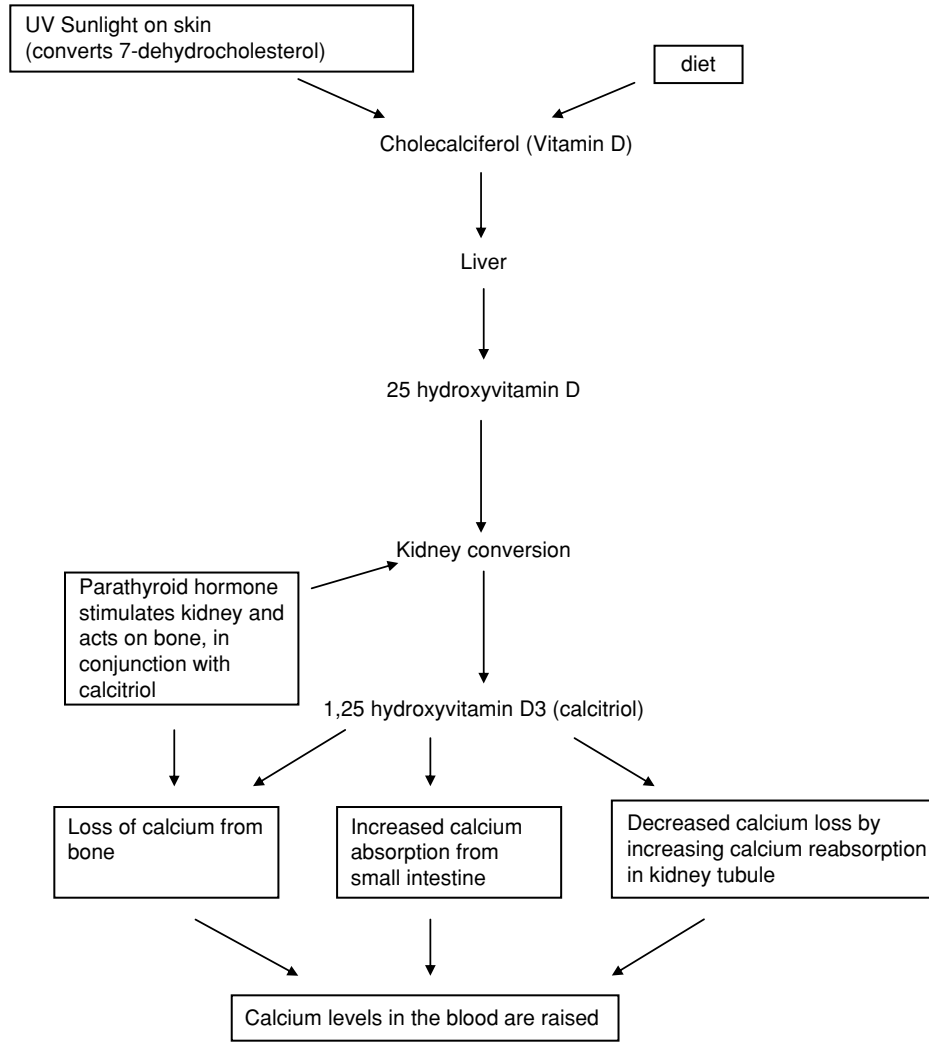


Figure 2.11 The actions of sunlight, vitamin D and parathyroid hormone (PTH) on blood calcium.

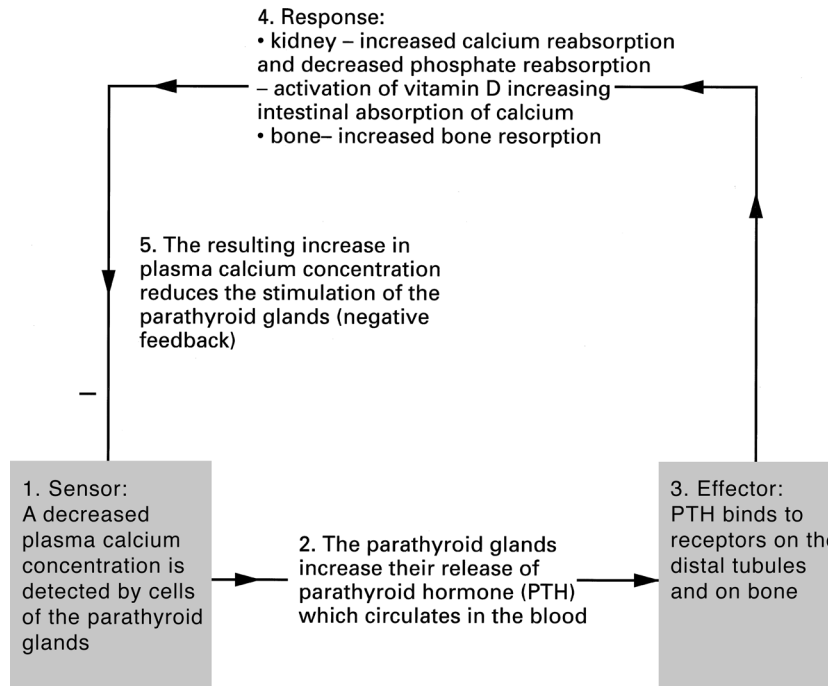


Figure 2.12 Negative-feedback loop for parathyroid hormone release and calcium and phosphate control.

Calcium ions play an important role in the regulation of nerve and muscle function and in blood clotting. Hypocalcaemia is characterised by increased excitability of muscles leading to tetany, when skeletal muscles go into spasm. Hypercalcaemia is a common finding in an individual with renal failure.

Acid–base control

Acid–base balance is about maintaining the constancy of the pH of the body's fluids. The pH scale is a logarithmic scale (range 1–14) that measures the concentration of free hydrogen ions in a fluid. In fact the scale is reciprocal, which means that as the pH becomes lower, the hydrogen ion concentration gets increasingly greater. Thus at acidic pHs (below 7), the hydrogen ion concentration of the fluid is very high relative to that at basic pHs (above 7). In fact, for each point on the scale there is a 10-fold difference in the hydrogen ion concentration. When we consider that the normal pH range of our bodily fluids is between 7.35 and 7.45, this appears very narrow but actually represents over a 20% difference in the hydrogen ion concentration! It is doubtful we would tolerate a 20% change in our sodium ion concentration with such ease.

So what are acids and bases? Simply put, acids are molecules that in the right environmental conditions will give up or donate a hydrogen ion to the solution they are in, and a base is a molecule that mops up or accepts free hydrogen ions from the solution. Thus, in order to maintain a constant hydrogen ion concentration (and hence constant pH), both acids and bases need to be present in the solution to donate or accept free hydrogen ions as required. Acids and bases working together in this way to minimise changes in pH are called buffers.

Though there are several buffering systems in the body, including haemoglobin, plasma proteins, organic and inorganic phosphates, the most important one physiologically is the bicarbonate buffering system and it is this one that will be described.

Bicarbonate buffering system

To understand the bicarbonate buffering system, the following reaction sequence needs to be understood:

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$$

This equation explains how the components of the buffering system are generated in the plasma. Carbon dioxide is generated by cells as an end-product of metabolism and diffuses into the plasma. The CO_2 dissolves in water to form carbonic acid (H_2CO_3), which is the acid component of the buffering system. The carbonic acid, in turn, is in equilibrium with the hydrogen (H^+) and bicarbonate ions (HCO_3^-). This forms the basic component of the buffering system. This reaction sequence can run in either direction, thus if there is a build-up of CO_2 in the plasma then more carbonic acid will be formed and the reaction will be driven to the right in order that more bicarbonate ions can be formed to minimise changes in the pH. However, if an excess of hydrogen ions builds up (from metabolic processes) then the reaction will be driven to the left, resulting in CO_2 and water forming. The excess CO_2 can then be blown off in the lungs. Since this reaction sequence constantly runs backwards and forwards to maintain a constant pH, then it follows that pH must be dependent on the relative proportions of CO_2 to bicarbonate ions. This can be shown in the following equation:

$$pH \propto HCO_3/PCO_2$$

Both components of this equation can be controlled by the body. The bicarbonate ion concentration is carefully controlled by the kidneys, whereas the PCO_2 is controlled by the lungs. Thus the lungs and the kidneys are the two main organs that together control the acid–base balance of the body.

Control of bicarbonate ion concentration by the kidney

Bicarbonate ions are freely filtered in the glomerulus. When the plasma bicarbonate concentration is normal (25 mmol/l) then all of the filtered bicarbonate is reabsorbed: 90% reabsorption occurs in the proximal tubule and 10% in the distal tubule. However, if plasma bicarbonate concentration is higher than normal then this excess bicarbonate is lost in the urine.

The reabsorption of bicarbonate ions in the nephron is not a straightforward transport of ions from the tubular fluid into the plasma as with other ions but involves various chemical reactions inside the tubular wall cells. The filtered bicarbonate in the tubule undergoes the whole reaction sequence identified above for the bicarbonate buffering system so that CO_2 and water are formed. This is catalysed by the enzyme carbonic anhydrase, which is found in the brush border of the proximal tubular cells. The resulting CO_2 then diffuses into the tubular cell where it undergoes the same reaction sequence, reforming the bicarbonate ion plus a hydrogen ion. The hydrogen ion is secreted into the tubule to be excreted and the bicarbonate ion diffuses into the plasma. This process is sometimes referred to as bicarbonate 'trapping' (Figure 2.13).

This process preserves bicarbonate ions in the blood, but to excrete excess hydrogen ions, substances must take up these ions in the kidney tubule to prevent their

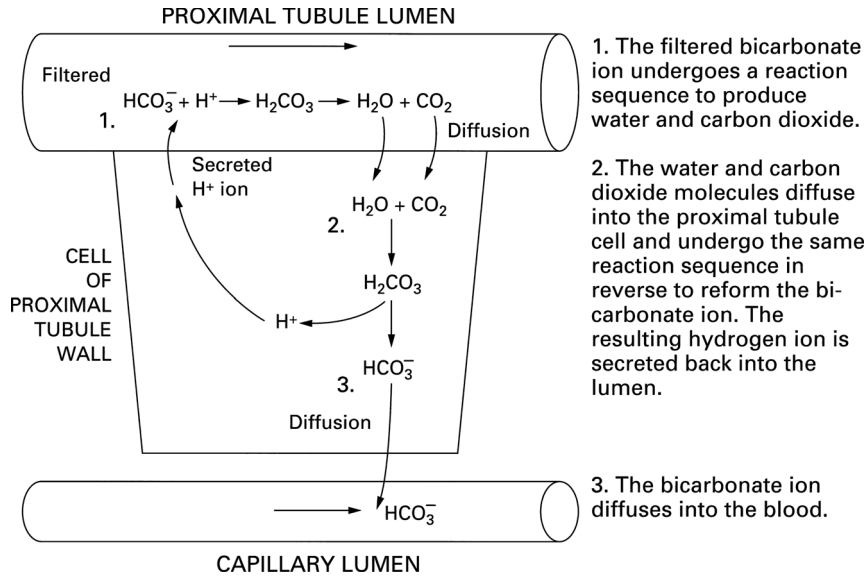


Figure 2.13 Bicarbonate reabsorption in the kidney tubules.

reabsorption into the blood. This is the role of the phosphate ions HPO_4^{2-} and the ammonia ions (NH_3), both of which take up one hydrogen ion to form $H_2PO_4^-$ and NH_4+ respectively. The process also generates HCO_3^- ions which can be reabsorbed. NH_4+ ions cannot readily diffuse back across cell membranes, so the H+ ions are effectively trapped in the tubule lumen.

Correcting acid–base fluctuations in the healthy individual

Fall in plasma pH

This is a condition called acidaemia or, more commonly, acidosis. This problem arises when there are excess hydrogen ions in the body fluids. In the absence of respiratory or renal disease, the initial response to control pH is for the excess hydrogen ions to drive the bicarbonate reaction sequence to the left to produce CO_2 and water. The lungs can then deal with this excess CO_2 by increasing the respiratory rate to 'blow off' the CO_2. This process gives a quick short-term compensation to the problem but not long-term correction. The rise in hydrogen ion concentration is then corrected by the kidneys secreting the excess hydrogen into the urine and in the process generating further bicarbonate for reabsorption into the plasma.

Rise in plasma pH

This condition is called alkalaemia or alkalosis, and arises when there is a reduction in the hydrogen ion concentration of the body fluids. The kidney plays the main role in correcting this problem by reducing the amount of hydrogen ion secretion. However, because hydrogen ion secretion and bicarbonate reabsorption are coupled together, this also results in a reduction in the plasma bicarbonate level. The plasma bicarbonate concentration is then corrected by a reduction in ventilation rate by the lungs, which leads to a build-up of CO_2, which drives the reaction sequence to the right to generate more bicarbonate ions.

Though the above compensatory and correction processes buffer the small fluctuations that occur in the acid–base balance in the healthy individual, larger fluctuations in acid–base balance tend to occur when there is either respiratory or metabolic disease. This is because the normal correction mechanisms are blocked. For example, in disorders of ventilation, a respiratory acidosis or, rarely, alkalosis may develop, whereas in disorders of metabolism (including renal disease) a metabolic acidosis or alkalosis may develop. Descriptions of these disorders are beyond this chapter, but the reader is referred to Box 2.3 for a brief outline of the causes and symptoms of the metabolic acidosis of kidney disease.

Erythropoietin production by the kidney

The final important role that the kidney has is the production of the hormone erythropoietin. Erythropoietin is a glycoprotein that promotes the proliferation and differentiation of erythrocyte precursors in the bone marrow. Thus, erythropoietin is necessary for the maintenance of a normal red cell count and prevention of anaemia. The erythropoietin-producing cells of the kidney have been identified as being peritubular cells, most likely cortical fibroblasts (Grupp and Műller 1999). Erythropoietin production is stimulated by hypoxia and inhibited when the hypoxia is corrected, thus its production is controlled by the negative-feedback principle. The kidney is not the only site of erythropoietin production. Approximately 20% of erythropoietin is produced at extrarenal sites, thought mainly to be the liver. However, in the presence of severe renal disease, this extrarenal production of erythropoietin is insufficient to maintain the red cell count at normal levels, achieving only one-third to one-half the normal level. Anaemia is therefore a problem in most patients with chronic and established renal failure, although this has now been overcome with the use of recombinant erythropoietin. See Chapter 6 for nursing management of anaemia in renal disease.

The relationship between blood pressure and renal function

Despite normal fluctuations in the systemic blood pressure, the kidneys are to some extent able to autoregulate the pressure of blood entering the glomerular capillaries. This ensures that the glomerular hydrostatic pressure remains constant and GFR is

BOX 2.3

Metabolic acidosis

Causes of acidosis in established kidney disease

- Reduced renal excretion of acids.
- Reduced renal reabsorption of bicarbonate.

Markers and symptoms

- Fall in plasma pH (as hydrogen ion concentration rises).
- Fall in plasma bicarbonate concentration.
- Increased anion gap (difference between the plasma concentration of cations Na^+ and K^+ and anions Cl^- and HCO_3^-).
- Possible hyperkalaemia which may lead to fatal cardiac arrhythmias.
- Depressed central nervous system causing coma.
- Respiratory compensation, hyperventilation (Kussmaul's breathing).
- Possible development of renal bone disease.

maintained. In addition the kidneys are the source of the hormone renin, which has a direct effect on blood pressure via the renin–angiotensin pathway (see Figure 2.10). If the blood pressure entering the glomerulus drops then more renin is released, resulting in a rise in systemic blood pressure.

If the filtering mechanism of the kidney is impaired by a drop in hydrostatic pressure within the glomeruli or by damage to glomerular tissue, the ability of the kidney to excrete nitrogenous waste products, and to regulate water and electrolytes may be impaired. This will ultimately result in symptoms associated with renal failure, including fluid retention which leads to hypertension.

Conversely, if blood pressure is persistently raised (hypertension), there is a risk of damage to blood vessels throughout the body, but particularly those in the brain (leading to stroke), coronary vessels and renal vessels. The renal artery, or smaller renal arteries, may become narrowed by arteriosclerosis (e.g. renal artery stenosis or renovascular disease). This will lead to impaired renal blood flow which will stimulate the release of renin, and the cycle of hypertension is worsened.

Hypertension may therefore be the cause and the result of kidney disease.

Blood pressure control

The control of hypertension is the treatment of priority in patients with chronic kidney disease in preventing the progression of renal failure and cardiovascular complications. Health education pertaining to cessation of smoking and alcohol, healthy eating and regular exercise for weight control is just as important in patients with chronic kidney disease as in other patients with hypertension.

Conditions causing Chronic and Established Kidney Disease

In this part of the chapter the reader is introduced to some of the common causes of chronic and established kidney disease and the altered physiology that results from, or may lead to, renal dysfunction. It is not intended as a complete guide to chronic kidney disease but as a starting point for understanding how important the kidneys are and how their function interacts with other body systems.

Chronic kidney disease is a result of a number of pathological processes causing irreversible damage to kidney tissue. There is a mass destruction of nephrons, so that the kidneys are unable to maintain fluid and electrolyte balance and excrete waste products from the body.

Chronic kidney disease is caused by a slow progressive decline over a course of many years (perhaps 10–20). There may be an insidious onset of renal failure with the minimum of symptoms developing in the patient on the approach to established renal failure. Unlike acute kidney injury, where a full recovery of renal function can occur, in chronic kidney disease the kidneys are permanently damaged and the disease is usually progressive. Chronic kidney disease is defined by the National Kidney Foundation Kidney Disease Quality Outcome Initiative (K-DOQI) as kidney damage for 3 months or more, with or without a decreased glomerular filtration rate, or a glomerular filtration rate of $<60\,\text{ml/min/1.73}\,\text{m}^2$ (for 3 months or more), irrespective of cause (Levey *et al.* 2005). See Chapter 6 for further explanation of stages 1–5 CKD.

The most common causes of established renal failure in the UK are diabetes mellitus (approximately 23% of all new patients), glomerulonephritis, pyelonephritis, polycystic kidney, renal vascular disease and hypertension (UK Renal Registry 2012).

Renal artery stenosis

Renovascular hypertension is high blood pressure due to narrowing of the arteries that carry blood to the kidneys. This condition is also called renal artery stenosis. In renal artery stenosis there is a major reduction in renal perfusion. This alteration results in increased renin secretion and activation of the renin–angiotensin system. If left untreated, accelerated hypertension will develop, resulting in further pathological changes and damage to the kidneys. Conditions causing renal artery stenosis include:

- Atherosclerosis: lipids and fibrous tissue lining the main renal artery and its larger branches.
- Fibromuscular dysplasia: narrowing of arteries in the kidney (and other vessels including the carotid arteries). This principally occurs in young women.
- Hyaline arteriolar sclerosis: thickening vessel walls due to the deposition of hyaline material, narrowing the lumen. This occurs naturally after 50 years of age but is also seen earlier in diabetes.

Obstruction to the renal blood flow can also be caused by:

- Vasculitis: necrosis and inflammation of the vessel walls because of immunological changes.
- Embolism: the kidney is a common site of embolism from circulating cardiac thrombi.
- Thrombosis: intravascular coagulation in the arterioles and glomerular capillaries of the kidney, which will result in renal tissue infarction (Figures 2.14–2.16).

Disease progression and prognosis

Hypertension resulting from renal artery stenosis may be treated by drugs to reduce blood pressure or by lipid-lowering treatment. The stenosis itself can be treated by angioplasty of the renal artery with intra-arterial balloon catheters, by insertion of a stent or by surgical bypass of the narrowed vessel (McLaughlin *et al.* 2000). Trials assessing medical versus surgical methods to treat renal artery stenosis have never been carried out, resulting in no one recommended method of treatment since the outcomes depend on so many variables. The European Society of Cardiology (2011) has produced some guidelines on treatment.

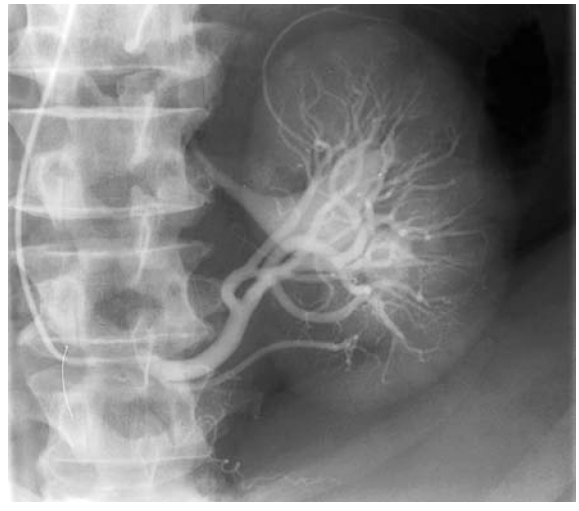


Figure 2.14 Conventional angiogram showing a normal right renal artery. Contrast material has been injected into the renal artery by means of a catheter, seen just to the left of the vertebral column.

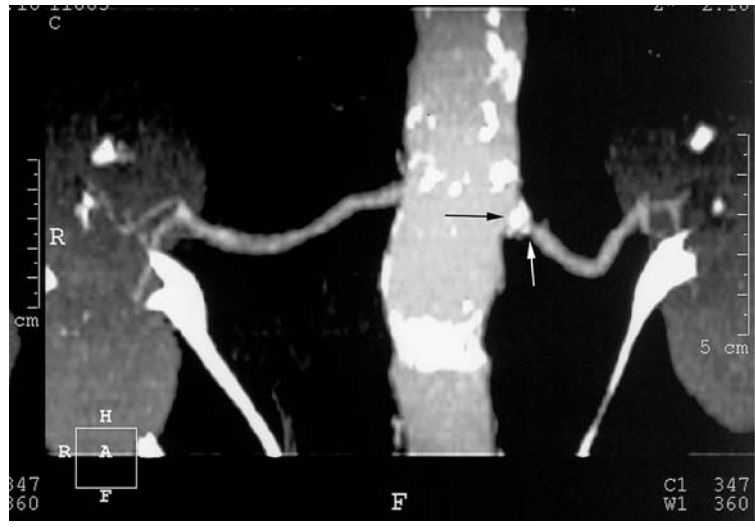


Figure 2.15 Computed tomography scan showing left renal artery stenosis. The black arrow points to a calcified plaque at the origin of the artery with narrowing of the artery distal to the plaque (white arrow). Heavy calcification is seen in the aorta (bright patches).

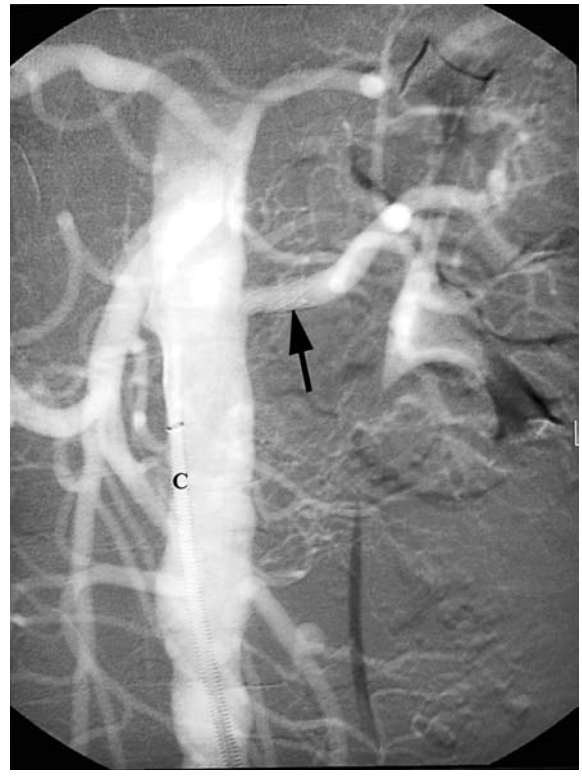


Figure 2.16 Digital subtraction angiogram of the same patient shown in Figure 2.15 following treatment by insertion of a metallic stent (black arrow) to improve the blood flow to the left kidney. C, catheter.

Nephrosclerosis

Hypertension can cause nephrosclerosis and is a major precipitating factor of renal disease. Hypertension that is not treated leads to sclerosis of the renal arterioles and the blood supply to glomeruli, tubules and interstitium gradually decreases. Scar tissue develops in the kidney, resulting in loss of renal function and eventually chronic kidney disease.

Nephrotic syndrome or nephrosis

The nephrotic syndrome is not a disease, but a collection of symptoms. It is characterised by:

- heavy proteinuria (greater than 3.5 g in 24 h)
- serum albumin <25 g/L
- urine:creatinine ratio >350 mg/mmol
- severe and generalised oedema.

The nephrotic syndrome may develop in a patient with a primary renal disease of unknown cause (idiopathic nephrotic syndrome) or it may be associated with other conditions in which kidney involvement is secondary, such as amyloidosis or diabetes mellitus (Figure 2.17).

Pathology of nephrotic syndrome

The nephrotic syndrome is the result of glomerular damage increasing the glomerular basement membrane permeability, allowing large amounts of small albumin molecules to pass through into the urine. It should be remembered that the size of the albumin molecule is just at the cut-off point in size of particle which may pass through the glomerular filter (see Figure 2.5). As the disease progresses, larger-molecular-weight proteins leak through the glomerular basement membrane and GFRs may also reduce as the glomerular damage increases.

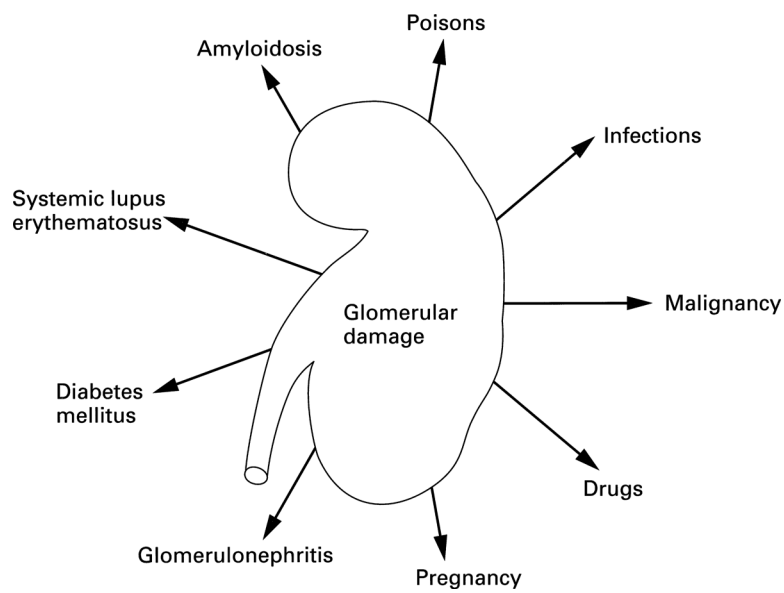


Figure 2.17 Causes of the nephrotic syndrome.

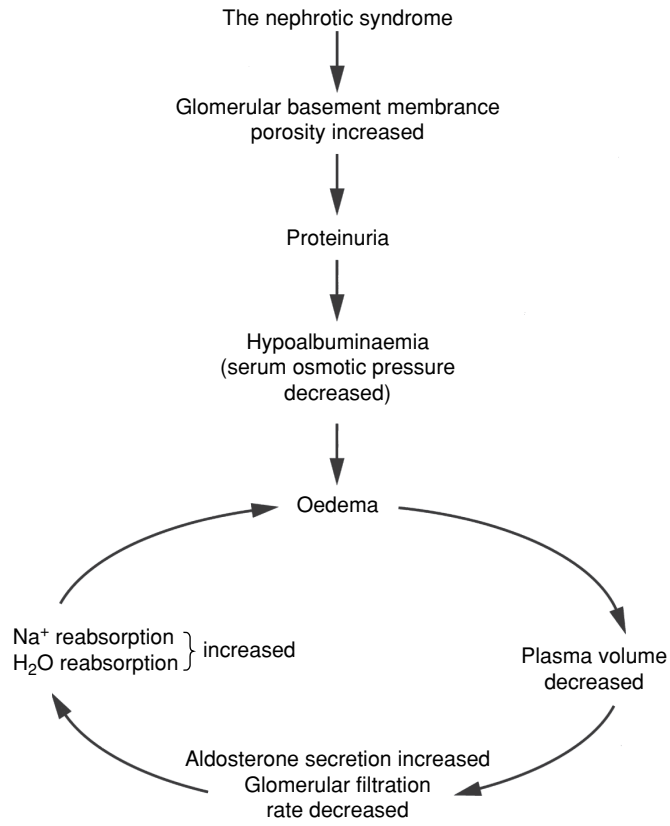


Figure 2.18 Oedema formation in the nephrotic syndrome.

As the protein continues to be excreted, the serum albumin decreases (hypoalbuminaemia). This in turn leads to a low blood colloid osmotic pressure and diffusion of fluid into the tissue spaces causing generalised oedema.

A reduction in the circulating blood volume stimulates the release of renin from the kidney, resulting in more aldosterone being released from the adrenal cortex, which is responsible for the retention of sodium and water. Retained fluid also passes out of the capillaries into the tissue, causing more oedema (Figure 2.18).

In the early stages of the nephrotic syndrome, the protein leak may be the only disorder of renal function, but with some glomerular lesions, the disease progresses and nephrons are destroyed. This will lead to established renal failure and the patient will require dialysis.

Clinical features and management of care of nephrotic syndrome

Oedema

In the early stages of the nephrotic syndrome, swollen eyes at the start of the day and swollen feet and ankles at the end of the day may be observed. As the disease progresses, or as a result of poor symptom control, the oedema becomes more generalised, causing pleural and peritoneal effusions resulting in breathlessness and congestion of the gastrointestinal tract.

Fluid removal will be the treatment of priority for patients, but diuretic therapy needs to be administered carefully as profound hypoalbuminaemia may cause a reduced circulating blood volume, triggering a hypotensive response in some patients following the administration of large doses of intravenous diuretics. Infusions of small volumes

of intravenous salt-poor albumin prior to the administration of diuretics will increase plasma volume and restore a diuretic response in the patient. In the majority of patients the albumin is excreted after 24–48 h.

All patients with severe oedema and receiving aggressive diuretics should be weighed daily and have four-hourly lying and standing blood pressure recordings to observe for deficits caused by a reduced plasma volume.

Proteinuria

Urine has a frothy appearance due to the high protein content (losses greater than 3.5 g in 24 h) and as a consequence hypoalbuminaemia develops. The loss of immunoglobulins increases the risk of infection. Hyperlipidaemia is also a clinical sign of the nephrotic syndrome, as a result of the liver synthesising more cholesterol and lipids. This makes the plasma milky in appearance.

Muscle wasting

The loss of skeletal muscles becomes apparent when the generalised oedema has subsided. Muscle wasting is a result of protein mobilisation into the blood to counteract protein lost in the urine.

Weight loss and malnutrition

Chronic nausea, vomiting and poor appetite may result from congestion in the gastrointestinal tract due to oedema. Weight loss also results from proteinuria and muscle wasting.

A dietetic referral should be made, and the patient encouraged to take a high-calorie diet with a protein allowance compensating for the protein loss.

Tiredness and lethargy

These symptoms may be attributed to a combination of reduced calorie intake, muscle wasting and the generalised oedema which may increase body weight by up to 10 kg.

Patients should be encouraged to take plenty of rest.

Intravascular clotting

There is a risk of spontaneous intravascular clotting in a patient with nephrotic syndrome due to the increase in circulating clotting proteins along with venous stasis in the legs and a reduction in plasma volume.

During episodes of hospitalisation and immobility, prophylactic anticoagulants may be used (for example, subcutaneous heparin). The use of antiembolic stockings increases venous return and reduces venous stasis.

Care for those with nephrotic syndrome can be very challenging for the renal care team.

Children

Nephrotic syndrome in children can lead to frequent infections, hypoproteinaemia and oedema. The use of corticosteroids has reduced mortality rates to around 3% (Hodson *et al.* 2007), although some cases are resistant to steroid treatment, in which case immunosuppressants may be used (Ulinski and Aoun 2012).

Diabetic nephropathy

Diabetic nephropathy is the term used to describe damage to the kidney structure and function that occurs as a result of the long-term complications of diabetes mellitus. Type 1 and Type 2 diabetes mellitus are characterised by raised blood glucose levels and sustained hyperglycaemia. This is associated with glycosylation of proteins, glycosylated haemoglobin (HbA_{1C}) being an example. These biologically active molecules are known as advanced glycosylation endproducts or AGEs, and it is these compounds which then cause vascular tissue damage. Patients with diabetes are therefore at increased risk of suffering renal and cardiovascular insufficiency (Makita *et al.* 1994). Diabetic nephropathy develops in 30-40% of patients with Type 2 diabetes and has become the single most common cause of established renal disease in the Western world (Rossing *et al.* 2005). There is evidence of 24 genetic variants associated with diabetic nepropathy (Mooyart *et al.* 2011).

Pathology

Patients initially develop microalbuminuria, i.e. 30–300 mg 24/h. This may not occur for up to 10 years after diagnosis of type 1 diabetes mellitus, but diabetes mellitus may go undetected for so long that microalbuminuria or proteinuria is present at diagnosis of diabetes. After 1–5 years, proteinuria becomes clinical, even to nephrotic levels (>3.5 g/day). With good blood pressure and glycaemic control, and with prescription of ACE inhibitors or angiotensin receptor blockers (ARBs), it is possible to delay the progression from micro to macroalbuminuria and to slow the decline in glomerular filtration rate. In practice there is little evidence that the incidence of diabetic nephropathy is declining (Steffes 1997). It is estmated (in the UK), that the incidence of kidney disease amongst patients with diabetes ranges from 18% to 27% (Min *et al.* 2012). The first line of treatment for controlling the progression of diabetic nephropathy is tight glycaemic control, along with the use of angiotensin-converting enzyme inhibitors (ACEI) to control blood pressure (Vivian and Rubinstein 2002).

The kidneys may be of normal size or slightly larger than normal. In Type 1 diabetes the most important structural changes involve the glomerulus, whereas in patients with Type 2 diabetes, tubulo-interstitial and vascular lesions are more common (Vestra and Fioretto 2003). The pathologies associated with diabetes mellitus are:

- pyelonephritis, the most common lesion found in those with diabetes mellitus, causing chronic kidney disease and a result of autonomic neuropathy in the bladder;
- diffuse intercapillary glomerulosclerosis, causing thickening and sclerosis of the basement membrane of the glomerular capillary and proliferation of the mesangial cells;
- the glomerulus becoming increasingly replaced and destroyed by the deposition of nodules of a glyocoprotein material – nodular glomerulosclerosis (or Kimmelstiel–Wilson nodules);
- arteriosclerosis develops in the arteries supplying the glomerulus due to hyaline deposits in the afferent and efferent arterioles, causing ischaemia and accelerating the disease process;
- papillary necrosis.

Diabetic nephropathy and glucose control

The kidneys have an important role in the metabolism of insulin and, as the GFR decreases in renal failure, so does the delivery of insulin to the proximal tubule cells where it is metabolised. Consequently, the circulating half-life of insulin increases with higher levels in the body after any given dose. Insulin requirements or oral hypoglycaemic agents should therefore be decreased so that hypoglycaemia does not occur.

Intensive diabetes management with the goal of achieving near normal blood glucose levels has been shown to delay the onset of microalbuminuria in Type 1 and Type 2 diabetes. The American Diabetes Association (2006) has published a position statement on diabetic nephropathy which has useful care recommendations. Early diagnosis of diabetes is also important. Finne *et al.* (2005) found that children diagnosed with diabetes before the age of 5 years have the most favourable prognosis in terms of progression to established renal failure.

Glomerulonephritis

The term glomerulonephritis covers a group of conditions in which inflammation in the glomerulus occurs, either as a primary disease, or as part of a systemic illness. It is therefore important to consider the possibility of an underlying systemic condition if glomerulonephritis is diagnosed. See Cunard and Kelly (2003) for further reading.

Glomerular disease occurs when the structure or function of the glomerular capillary network has been damaged as a result of antigen–antibody reactions in the glomeruli.

There are contributions from lymphocytes, macrophages, antibodies, immune complexes and inflammatory mediators. The glomerular cells may proliferate, basement membrane thicken or exudates of leukocytes and platelets build up in the glomerulus. These tissue reactions result in changes in the filtration properties of the glomerulus, leading to proteinuria, haematuria, impaired excretory renal function and hypertension.

Any age group may be affected, though some types are particularly common in children. The estimated incidence of glomerulonephritis in the UK is 17–60/million population. See Box 2.4 for histopathology.

Treatment

In some cases, an underlying cause of the autoimmune response can be identified and eradicated. For example, drugs, tumours or infectious agents (e.g. streptococci) may result in glomerulonephritis, which may resolve on removal of the tumour or drug. Treatment for glomerulonephritis tends to involve anti–inflammatory and/or immunosuppressive drugs. In rare conditions with rapid deterioration of renal function, plasma exchange may be used.

The prognosis depends to a large extent on the particular subtype of glomerulonephritis, identified by the pattern of glomerular injury involved.

Subtypes of glomerulonephritis

- Minimal-change glomerulonephritis (renal biopsy normal by light microscopy).
- Membranous nephropathy.
- Mesangial proliferative nephritis.
- Focal segmental glomerulosclerosis.
- Crescentic glomerulonephritis (associated with syndrome of rapidly progressive glomerulonephritis).
- Mesangiocapillary glomerulonephritis (MCGN).
- Post infection glomerulonephritis.

Minimal change glomerulonephritis

The condition is so named due the essentially normal appearance of the glomeruli under the light microscope. It most often presents in children aged between 2 and 4 years of age, and accounts for 90% of cases of nephrotic syndrome in children. The condition is very rarely associated with impairment of excretory renal function and is occasionally

BOX 2.4

Glomerular disease

Glomerulonephritis is the term used to describe a variety of disorders that principally affect the glomeruli in the kidney. Such glomerulopathies may arise as primary disorders of the glomerulus, or as part of a systemic disorder such as systemic lupus erythematosus (SLE) or diabetes mellitus.

Histopathology

Glomerular damage may be manifest as one or more of the following tissue reactions:

- Cellular proliferation – leading to an increase in the number of cells in the glomerular tufts.
- Leukocyte infiltration of inflammatory cells – mainly neutrophils and monocytes.
- Basement membrane thickening – as occurs in diabetes mellitus, or this may be a response caused by precipitated immune complexes.
- Hyalinisation and sclerosis – hyalinisation is the accumulation of homogeneous, amorphous substance in the glomerular tuft composed of mesangial matrix, basement membrane and plasma protein. Sclerosis is the total obliteration of structural detail in the glomerular tuft and is the end result of glomerular damage.

Clinical manifestations

Clinical presentation of glomerular disease may range from an acute onset of disease with a reversible outcome, to a chronic insidious onset that eventually leads to renal failure after several decades. A number of syndromes of glomerular disease are defined:

- Proteinuria – occurs if the glomerular basement membranes are damaged so that they leak protein.
- Nephrotic syndrome – occurs if the basement membranes are damaged more severely and increase the protein leak to greater than 3.5 g protein 24/h. This in turn induces a low serum albumin and generalised oedema. Hyperlipidaemia usually also occurs.
- Haematuria – occurs if capillary walls are disrupted, allowing red cells to pass into the urine. This may be microscopic or macroscopic. However, most forms of haematuria are non-glomerular in origin.
- Nephritic syndrome – occurs when basement membrane damage and red blood cell leakage are present together, leading to proteinuria and haematuria, accompanied by generalised oedema and mild hypertension.
- Established renal disease occurs when damage to the glomeruli is severe enough to impair the normal filtering function of the glomerulus, resulting in an accumulation in the blood of substances such as urea, creatinine and potassium.

Specific nursing observations

Parameter	Rationale
Temperature	Patients with nephrotic syndrome are prone to infection, which exacerbates the disease if not detected and treated promptly.
Blood pressure	Hyper- or hypotension may be present, dependent on the patient's fluid and cardiac status. One should also monitor for a postural drop.
Respiration	Rapid, shallow breaths may indicate pulmonary oedema. Severely acidotic patients may develop Kussmaul's respirations (deep, sighing hyperventilation).
Daily weight	Serial measurements of the patient's weight (at the same time each day) give the clearest indication of changes in fluid status.
Urinalysis	The urine should be tested for protein and blood as indicators of glomerular disease. Urinary volume should also be monitored, and the urine sent for culture if infection is suspected.
Skin	The skin should be observed for oedema, dehydration, pruritus, flaking and dryness, pressure sores and rashes. A skin rash may indicate a systemic disease such as SLE, vasculitis or Henoch–Schönlein purpura.

secondary to drug use (particularly nonsteroidal antiinflammatory drugs (NSAIDs)) or malignancy (e.g. lymphoma).

Severe oedema may be present but without associated hypertension.

Management of care Diuretic therapy will clear the oedema. Most patients respond to high-dose corticosteroids, but relapse is common as the dose is reduced, and up to 50% of patients remain corticosteroid-dependent. In these patients, alkylating agents such as cyclophosphamide are sometimes successful. Ciclosporin is also effective (Macanovic and Mathieson 1999).

Prognosis Subsequent relapses in the condition can be treated with similar protocols. Patients do not usually develop chronic kidney disease.

Membranous glomerulonephritis

These patients typically present with proteinuria which may be asymptomatic or severe enough to cause nephrotic syndrome. Microscopic haematuria, hypertension and/or impaired excretory renal function may also be associated. It is seen in adults rather than in children. Onset is insidious and the disease develops slowly, over the course of 20 years in some cases.

There is widespread thickening of the capillary wall in the glomerulus (but without proliferation of the cells), which seems to result from the deposition of immune complexes in the kidney. This can occur as a result of drug use (particularly nonsteroidal antiinflammatory drugs (NSAIDs), gold and penicillamine), secondary to tumours (e.g. carcinoma of bronchus or breast), infection (particularly hepatitis B) or hypothyroidism.

Management of care The prognosis of the secondary forms of the disease depends on the prognosis of the underlying condition. Complete resolution may be expected on withdrawal of the offending drug, whereas membranous glomerulonephritis, which is secondary to a tumour has a poorer prognosis unless the tumour is eradicated.

At least 25% of patients undergo spontaneous remission of proteinuria without treatment. For those with a poorer prognosis, a combination of treatment with a steroid and an immunosuppressant (chlorambucil) given in alternating cycles may prove beneficial. There is a particular risk of thrombosis in membranous glomerulonephritis, so anticoagulants may also be prescribed (Macanovic and Mathieson 1999).

Prognosis GFR may be normal for the first few years, but then may slowly deteriorate as the sclerosis of the glomerulus increases. If no primary cause of the disease is found and eradicated, dialysis or organ transplant may be inevitable in the long term.

Mesangial proliferative nephritis

This is the most common type of glomerulonephritis worldwide. Patients present with haematuria, sometimes with associated proteinuria, hypertension and impaired renal excretory function. The immunoglobulin IgA is deposited in the glomerulus, and there is sometimes proliferation of the glomerular cells. The cause of the deposits is not known, but it seems the problem is in the IgA system rather than in the kidney. An associated glomerular change is seen in Henoch–Schönlein purpura, a condition more common in children which is associated with a purpuric rash, joint and gastrointestinal involvement.

Management of care There is no proven treatment for this form of glomerulonephritis, although in patients with heavy proteinuria, steroids may be used successfully to reduce the protein loss. Antihypertensives (for example, angiotensin-converting enzyme (ACE) inhibitors) may also be used.

Focal segmental glomerulosclerosis

This condition is named after the areas of scarring which occur in the glomeruli. The sclerotic changes affect some glomeruli but not others (focal) and may affect only parts of each glomerulus (segmental). The patient will typically present with nephrotic syndrome (hypertension, haematuria, impaired excretory renal function).

Management of care and prognosis for the patient Treatment with prolonged courses of corticosteroids may induce remission of nephrotic syndrome, but the disease often progresses and established renal failure develops in about 50% of patients within 10 years.

Crescentic glomerulonephritis

Also known as rapidly progressive glomerulonephritis, this condition is associated with rapid but progressive deterioration in renal function and the presence of oliguria or anuria. Haematuria and proteinuria also occur. In Goodpasture's syndrome, autoantibodies are directed against collagen- a major structural component of the glomerular basement membrane. Up to half of those with Goodpasture's disease also have pulmonary haemorrhage. Without effective treatment, established renal failure will develop in weeks and months, rather than years.

Acute inflammation in the glomerulus is the underlying cause, sometimes with the formation of crescents when the glomerulus is squashed by cells which fill the Bowman's space. In some cases, antibodies to the glomerular basement membrane are present but, in most cases, no immunoglobulin is identified in the glomerulus.

Management of care and prognosis Plasma exchange followed by corticosteroid and immunosuppressant therapy will remove the offending antibodies and prevent further proliferation. The prognosis in these cases is directly related to the amount of damage already done to the glomeruli.

Mesangiocapillary or membrane-proliferative glomerulonephritis

Three subtypes of this condition are recognised, identifiable only by electron microscopy. In all cases the presentation of the patient is similar, with proteinuria, haematuria, hypertension and impaired renal function. There are no known causes. All types tend to have a progressive course, and up to 50% of patients develop chronic kidney disease within 10 years.

Treatment focuses on blood pressure control and use of corticosteroids.

Postinfection glomerulonephritis

Poststreptococcal glomerulonephritis (for example, following a throat infection) was a common cause of renal failure in the preantibiotic era and is still common in some parts of the world. Immune complexes which arise following infection with group A haemolytic streptococci deposit in the glomerular capillary wall, resulting in proteinuria, haematuria and hypertension.

Glomerulonephritis may complicate infection with a range of organisms. Infection with *Staphylococcus,* influenza B, hepatitis B and C and human immunodeficiency virus (HIV) may all result in renal damage.

Pyelonephritis

This is a bacterial infection of kidney tissue, with the infection beginning in the lower urinary tract and ascending to the kidney(s). Acute pyelonephritis is commonly associated with pregnancy, obstruction, instrumentation or trauma to the urinary tract and in patients with a chronic illness.

Chronic pyelonephritis is the result of repeated infections of the urinary tract. There is widespread destruction of nephrons and replacement with scar tissue, which eventually causes established renal failure. For the majority of patients, the disease starts in early childhood and is due to ureteric reflux and infection, but symptoms of the disease may not present clinically until adulthood. In adults, chronic pyelonephritis is a complication of obstruction in the renal tract, because stone formation and structural abnormalities both cause stasis of urine.

Clinical features and management of care

The patient will present with pyrexia and rigors and loin pain over the affected kidney(s). Symptoms of a lower urinary tract infection may also be present.

Antibiotics can be given to treat the acute phase of the infection, but there is little evidence to prove that prophylactic antibiotics slow down the onset of chronic kidney disease. A high fluid intake (up to 3 l/day) is important.

Disease progression and prognosis

If the chronic infections are only affecting one kidney, the disease is usually prolonged but benign. Bilateral chronic infection will ensure that chronic kidney disease is of rapid onset.

Reflux nephropathy is a congenital anatomical abnormality where there is incompetence of the sphincter at the junction of the ureter with the bladder, allowing the reflux of urine back up the ureter and into the renal pelvis. Infection may develop and the formation of scar tissue will eventually cause chronic kidney disease. If identified early, surgical correction will be needed. Recurrent urinary tract infection during childhood should always be fully investigated and treated.

Polycystic kidney disease

Polycystic kidney disease is one of a number of cystic diseases of the kidney. Polycystic disease refers to two hereditary cystic diseases – autosomal recessive polycystic kidney disease and autosomal dominant polycystic kidney disease. Both conditions may occur in children, although the recessive disease is more commonly seen in this age group. The following descriptions will refer to autosomal dominant polycystic kidney disease, one of the most common genetic disorders which is responsible for approximately 10% of patients with established renal failure.

Genetics

The autosomal dominant form of the disease is one of the most common genetic disorders, affecting an estimated 1:400–1000 of the population (Harris and Torres 2009). The condition occurs equally in men and women and is transmitted by both sexes. If one parent is affected, 50% of the offspring will develop the disease, although symptoms may not develop until patients reach their 20s. The mean age of starting dialysis treatment is 57 years. However, by the age of 80, virtually all individuals who carry the gene will manifest some form of the disease. Mutations in either of two genes (PKD1 or PKD2) are responsible for the condition (Calvet and Grantham 2001).

Autosomal recessive polycystic kidney disease (ARPKD) is a severe, inherited disorder of the kidney that typcially presents in the neonatal period with an incidence of approximately 1/20 000. Most affected children die within the first few hours of life, although a number of patients present in later childhood, or as adults. The affected gene (PKHD1) has been identified, located on chromsome 6 (Zerres *et al.* 1994).

Pathology

Both kidneys are considerably enlarged and consist of a compact mass of cysts which are scattered equally throughout the cortex and medulla (Figure 2.21). The cysts increase in size and eventually rupture, allowing infection and scar tissue formation, and reducing the number of functioning nephrons. The enlarged cysts compress the normal renal tissue and hypertensive changes and glomerulosclerosis occur. Cysts are filled with watery fluid which may be clear, blood-stained from a recent haemorrhage, brown from an old haemorrhage or filled with pus (Figures 2.19–2.21).

Liver cysts may be found in patients with polycystic kidneys and there is also a significant association with aneurysms of the cerebral arteries.

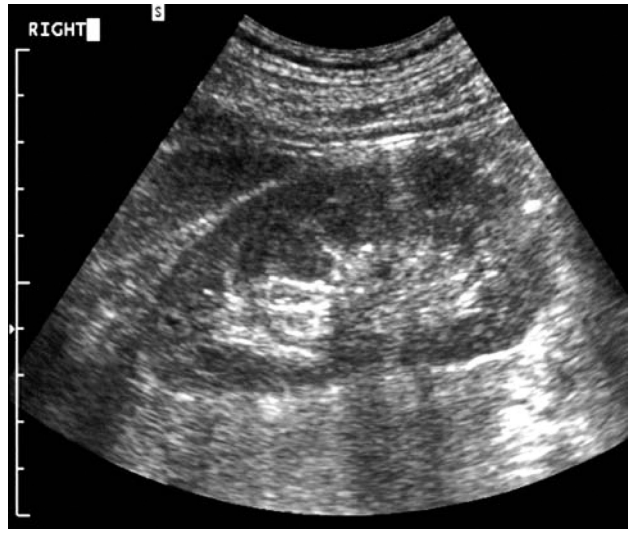


Figure 2.19 Ultrasound of a normal left kidney.

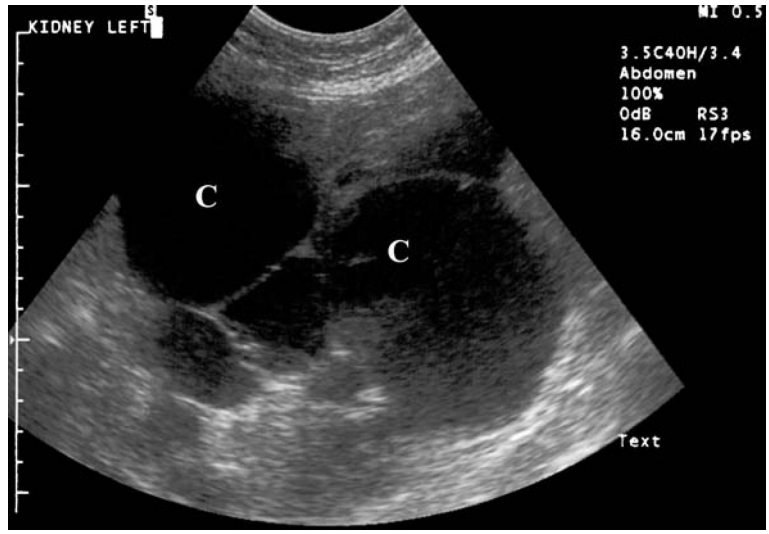


Figure 2.20 Ultrasound of a polycystic kidney showing how the normal tissue is replaced by multiple fluid-filled cysts (C).

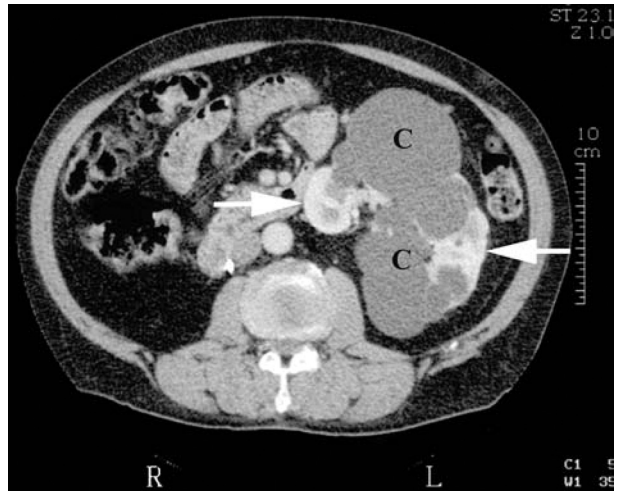


Figure 2.21 Computed tomography scan showing a polycystic left kidney; the cysts are marked by C. The white arrows point to normal renal tissue. The right kidney has been removed.

Clinical features and management of care

1. Pain: the patient may complain of abdominal distension or discomfort following minor physical trauma and this may cause frank or microscopic haematuria. Pain in the flank is associated with the large cysts rupturing and any blood clots that are passed will cause the patient to experience colic. Mild analgesia may be sufficient to relieve discomfort, but pain caused by cysts rupturing or from clot retention may require opiates.
2. Haematuria and proteinuria: microscopic or frank haematuria is seen in more than 50% of patients. Chronic blood loss does not usually result in anaemia because the erythropoietin production by the kidneys is increased. Patients may be advised to alter their lifestyle if they are prone to physical abdominal trauma which may cause cysts to rupture. Mild proteinuria is always present in the mid to late stages of the disease and may be the first abnormality that draws attention to the condition during a routine medical examination.
3. Urinary tract infections: repeated urinary tract infections are common complications, and may affect the cysts. Unnecessary urological investigation should be avoided and female patients should receive health education regarding perineal hygiene. All patients should be advised on the importance of a high fluid intake to prevent urinary stasis and how to recognise the signs of a urinary tract infection.
4. Hypertension: secondary hypertension is common in patients with polycystic disease and may deteriorate as established renal failure approaches. It is treated aggressively, not only because it may accelerate deterioration of renal function, but because it may increase the risk of intracerebral haemorrhage in these patients (Ecder *et al.* 2000).

Multisystem diseases affecting the kidney

The kidney may be affected in many ways by disease processes that are not directly associated with renal function. This vulnerability is, in part, due to the high blood supply of the kidneys; together the kidneys receive 25% of the cardiac output. The glomerular capillaries, because of their filtering properties, come into close contact with all blood constituents.

The effects of diabetes mellitus and of systemic infections in the kidney have already been mentioned. The following are some more examples of multisystem diseases which may affect the kidney.

Systemic lupus erythematosus

This is an autoimmune inflammatory disease which affects joints, blood vessels, skin and the nervous system, as well as the kidneys. Glomerular inflammation may result in proteinuria, haematuria and hypertension; renal involvement often occurs within 3 years of diagnosis of the disease. Nonrenal manifestations of the disease are usually present, such as arthralgia, rash and haematological disorders. It can be treated using plasmapheresis and immunosuppressants (Haris *et al.* 2011).

Renal amyloidosis

Amyloidosis is the term given to a group of chronic infiltrative disorders characterised by the presence of deposits of an abnormal protein called amyloid. Two groups of protein deposit exist, AL amyloid or AA amyloid, but renal involvement occurs with both. AA amyloid deposits are a complication of many chronic inflammatory diseases, occurring in up to 10% of patients with rheumatoid arthritis; AL amyloid deposits may occur secondary to myeloma or as the primary condition, AL amyloidosis. This is a systemic disease which affects the heart, peripheral nervous system, liver and kidney.

A common site of deposition of the insoluble amyloid fibrils is in the walls of the renal arterioles and glomerular capillaries. The result is usually nephrotic syndrome followed by progressive renal failure. Ten-year individual survival rate is about 20% (Sasatomi *et al.* 2007).

Scleroderma or systemic sclerosis

This is a multisystem condition which causes gradual hardening and tightening of the skin and increased binding to subcutaneous tissue. Renal involvement is one of the less common but most serious complications of the disease and, in the past, was a major cause of mortality. Patients often present with the features of malignant hypertension and rapidly deteriorating renal function. Diastolic pressure may exceed 130 mmHg. Antihypertensives, particularly ACE inhibitors, improve the renal outlook of these patients, but there is no treatment for the underlying condition.

Polyarteritis nodosa

More common in men than women, this condition usually presents in later life. It is characterised by widespread inflammation of small and medium arteries and aneurysm formation. Thrombosis in these arteries can lead to complications which particularly affect the gut, peripheral nervous system and kidneys. The renal presentation is that of progressive renal impairment caused by renal infarction and hypertension. Treatment is with corticosteroids, and renal prognosis depends on early diagnosis and treatment since organ damage is irreversible.

References

American Diabetes Association (2006*) Standards of Medical Care in Diabetes: Nephropathy Screening and Treatment Diabetes Care,* **29,** supplement 1, p.521, http://care.diabetesjournals.org/content/vol29/suppl_1/ (accessed 20 May 2013).

Bennett, P.N. and Brown, M.J. (2008) *Clinical Pharmacology,* 10th edn, Churchill Livingstone, Edinburgh.

Calvet, J. and Grantham, J. (2001) The genetics and physiology of polycystic kidney disease. *Seminars in Nephrology* **21** (2), 107–123.

Cunard, R. and Kelly, C.J. (2003) Immune-mediated renal disease. *Journal of Allergy and Clinical Immunology* **111** (2), S637–S644. DOI:10.1067/mai.2003.126.
Ecder, T., Edelstein, C.L., Fick Brosnahan, G.M. *et al.* (2000) Progress in blood pressure control in autosomal dominant polycystic kidney disease. *American Journal of Kidney Disease* **36,** 266–271.
European Society of Cardiology (2011) ESC guidelines on the diagnosis and treatment of peripheral artery diseases. *European Heart Journal* **32,** 2851–2906.
Finne, P., Reunanen, A., Stenman, S. *et al.* (2005) Incidence of end-stage renal disease in patients with type 1 diabetes. *JAMA* **294** (14), 1782–1787.
Grupp, C. and Mùller, G.A. (1999) Renal fibroblast culture. *Experimental Nephrology* **7,** 377–385.
Haris, A., Aranyi, J., Braunitzer, H. *et al.* (2011) Role of plasmapheresis in immunological kidney diseases. Experience from 1050 completed plasmapheresis treatment sessions. *Orvosi hetilap* **152** (28), 1110–1119.
Harris, P.C. and Torres, V.E. (2009). Polycystic kidney disease. *Annual Review of Medicine* **60,** 321–337. DOI: 10.1146/annurev.med.60.101707.125712.
Hodson, E.M., Willis, N.S. and Craig, J.C. (2007) Corticosteroid therapy for nephrotic syndrome in children. *Cochrane Database of Systematic Reviews*, Issue 4. Art. No.: CD001533. DOI: 10.1002/14651858.CD001533.
Jenkins, G.W. and Tortora, G.J. (2013) *Anatomy and Physiology from Science to Life,* 3rd edn, John Wiley & Sons, Inc.
Laing, C. (2011) Clinical approach to electrolyte abnormalities. *Medicine* **39,** 325–332.
Levey, A.S., Eckardt, K.U., Tsukamoto, Y. *et al.* (2005) Definition and classification of chronic kidney disease: a position statement from Kidney Disease: Improving Global Outcomes (KDIGO). *Kidney International* **67,** 2089–2100.
Macanovic, M., Mathieson, P.W. (1999) Glomerulonephritis. *Medicine* **27,** 59–62.
Makita, Z., Bucala, R., Rayfield, E.J. *et al.* (1994) Reactive glycosylation endproducts in diabetic uraemia and treatment of renal failure. *The Lancet* **343,** 1519–1522
McLaughlin, K., Jardine, A.G. and Moss, J.G. (2000) ABC of arterial and venous disease. Renal artery stenosis. *British Medical Journal* **320,** 1124–1127.
Min, T.Z., Stephens, M.W., Kumar, P. and Chudleigh, R.A. (2012) Renal complications of diabetes. *British Medical Bulletin* 1-15. DOI: 10.1093/bmb/lds030.
Mooyart, A.L., Valk, E.J., van Es, L.A. *et al.* (2011) Genetic associations in diabetic nephropathy: a meta-analysis. *Diabetologia* **54** (3), 544–553.
National Kidney Foundation (2000) *Kidney Disease Outcomes Quality Initiative Guidelines 2000*, www.kidney.org/professionals/KDOQI/guidelines_commentaries.cfm (accessed 20 May 2013).
Rossing, K., Mischak, H., Parving, H.-H. *et al.* (2005) Impact of diabetic nephropathy and angiotensin II receptor blockade on urinary polypeptide patterns. *Kidney International* **68,** 193–205.
Sasatomi, Y., Sato, H., Chiba, Y. *et al.* (2007) Prognostic factors for renal amyloidosis: a clinicopathological study using cluster analysis. *The Japanese Society of Internal Medicine* 46 (5), 213–219. DOI: 10.2169/internalmedicine.46.1690
Shitara, Y., Horie, T. and Sugiyama, Y. (2006) Transporters as a determinant of drug clearance and tissue distribution. *European Journal of Pharmaceutical Sciences* **27,** 425–446.
Steffes, M.W. (1997) Diabetic nephropathy: incidence, prevalence, and treatment. Editorial. *Diabetes Care* **20,** 1059–1061.
Tortora, G.J. and Derrickson, B.D. (2007) *Introduction to the Human Body, The Essentials of Anatomy and Physiology,* 7th edn, John Wiley & Sons, Inc., Hoboken, NJ.
Tortora, G.J. and Nielsen, M.T. (2009) *Principles of Human Anatomy,* 11 edn, John Wiley & Sons, Inc., Hoboken, NJ.
UK Renal Registry (2012) *The Fifteenth Annual Report of the UK Renal Registry,* http://www.renalreg.com/Reports/2012.html (accessed 10 June 2012).
Ulinski, T. and Aoun, B. (2012) New treatment strategies in idiopathic nephrotic syndrome. *Minerva Pediatrics* **64** (2), 135–143.
Vestra, M.D. and Fioretto, P. (2003) Diabetic nephropathy: renal structural studies in type 1 and type 2 diabetic patients. *International Congress Series* **1253,** 163–169.
Vivian, E.M. and Rubinstein, G.B. (2002) Pharmacological management of diabetic nephropathy. *Clinical Therapeutics* **24** (11), 1741–1756.
Zerres, K., Mücher, G., Bachner, L. *et al.* (1994) Mapping of the gene for autosomal recessive polycystic kidney disease (ARPKD) to chromosome 6p21-cen. *Nature Genetics* **7,** 429–432.

Resources

www.renal.org (accessed 20 May 2013)
www.diabetes.org.uk (accessed 20 May 2013)
www.kidney.org.uk (accessed 20 May 2013)
www.patient.co.uk (accessed 20 May 2013)

CHAPTER 3

Patient and Carer Involvement in Renal Nursing Care, Education and Research

Ratna Das, Brian Gracey, Linda Gracey, Fiona Loud[1] and Shahid Muhammad[2]

[1]*Kidney Alliance, Lister Area Kidney Patients Association, West Herts Hospital, UK*

[2]*Renal Patient Support Group, UK*

Learning Outcomes

- To explain what is meant by patient involvement.
- To understand the challenges faced by patients and carers during predialysis, dialysis and transplantation.
- To identify how patients and carers can be involved in renal nursing education.
- To review the policy guidance on involving patients and carers in renal nursing research.

Introduction

This chapter aims to provide the reader with an insight into how patients and carers can have a more participatory role, not only in the planning, delivery and evaluation of their care but also in teaching of nurses and involvement in renal research programmes. It has been written by people who have kidney disease and who feel passionate about improving the nursing care that is given to everyone with the condition, whether they be contemplating dialysis options, undergoing dialysis or receiving a kidney transplant. Parts of the chapter have been written in the first person as they are based on personal experiences and it was felt that key messages in this chapter are powerful if described in this way.

The chapter includes case studies and learning activities that will assist the reader to make sense of, and learn about, patient and carer partnership and involvement. The driving theme is that there should be 'no decision about me, without me', epitomised in the White Paper, *Equity and Excellence: Liberating the NHS* (Department of Health 2010), which emphasised shared decision-making and promotion of partnership.

Renal Nursing, Fourth Edition. Edited by Nicola Thomas. Published 2014 by John Wiley & Sons, Ltd.

Patient Involvement in Care

'Patient involvement' is a complex concept, and the term is sometimes used interchangeably with 'partnership' and 'participation', although these similar terms are slightly different. Generally, patient involvement can be described as 'approaches which engage individual patients in the management of their health and healthcare, and in the decisions that are made in the course of it' (National Voices 2012).

Recently, the Care Quality Commission in England patient surveys have shown that 48% of inpatients and 30% of outpatients want more involvement in decisions about their care (Care Quality Comission 2011). It is important to note, of course, that not everyone, whether patient or carer, wants to be involved in their healthcare: the extent to which involvement is desired can depend on the contexts of type and seriousness of illness, various personal characteristics and patients' relationships with professionals (Thompson 2007).

Although most nurses, if questioned, have welcomed the idea of patient involvement in their care, many patients may not see it that way. The chapter includes three case studies (Case Studies 1 to 3) where the patients, and in one instance a carer, describe care and management that did not always involve them and discuss ways in which the nursing care could have been improved. It also includes a case study (Case Study 4) on patient and carer involvement in research / quality improvement.

Introduction to case study 1

Case Study 1

I have had kidney disease for 37 years. Having been diagnosed with renal arteriolar stenosis in 1977, I received my first kidney transplant from my mother in 1988. That kidney settled down within 12 months and I was fortunate to spend the following 18–19 years in relative good health, working, helping my wife bring up a young family and travelling the world over. In 2006, my kidney began to fail and I took early retirement from my job in June 2007. I went into end stage renal failure in 2008 and began what turned out to be three-and-a-half years of haemodialysis. Late in August 2011, I received a call to say that there was a possibility of a kidney for me. Twelve months after the operation, I began to lead a new life again with my wife, with the opportunity once again to travel and to do those things that I have been unable to do for so long.

I would like to share my experiences of the care I have received over the years, both of the good things, of which there have been many, but also those things that I believe could be improved.

Renal care has different requirements from many other medical conditions, in as much as it very often supports a situation that is chronic and does, therefore, enable a whole life relationship to develop between the patient and the medical team. This, to me, should be the core of renal care. Over the years I have received excellent care, but there have been occasional lapses. It is rarely due to a lack of medical knowledge or experience; it is much more a straightforward lack of understanding of the patient's needs and concerns. Although I will largely restrict myself to my more recent experiences, it is worth recalling my shock and horror when I was told, having been an out-patient for a number of years in the mid-1980s and fully believing that I could happily continue as an out-patient, that I would have to receive dialysis or a kidney transplant relatively soon in the future. I had had no idea about this and was convinced that my life was at an end. I had two very young boys at the time and I found it very difficult to come to terms with this news sitting on my own facing the consultant and with no idea what to ask, what to say and how to respond. We have come a long way since those days, but some of the lessons today are not that different.

Predialysis

My first kidney began to deteriorate in late 2006 and the standard of care I received was excellent. I was then transferred to a different section of the renal team, whose expertise was in attempting to preserve failing kidney function for as long as possible. My wife was fully involved in the discussions and we were both kept informed of the progress, or otherwise, of the kidney. I

knew long before it was required, that I would need dialysis. Of the various options for dialysis, it was explained to me that haemodialysis was likely to be the only reasonable option for me and although I understood the medical mechanics of dialysis, that it purified the blood and removed excess fluid, I had no appreciation of the psychological impact of dialysis and I was given very little help in trying to understand its impact. My introduction to haemodialysis was a brief visit to an acute dialysis unit where I was shown patients attached to bleeping machines, all looking pretty poorly. The unit was full, noisy and it appeared to me to be barely organised chaos. I was not given the opportunity to talk to any patients in a similar position to mine and I found the visit quite disturbing. I think it was predominantly for that reason that I delayed the decision to start dialysis for longer than was medically advisable.

At each of my visits to the unit in the months leading up to starting dialysis in May 2008, I was asked how I felt and I would say I was OK, but I knew in my heart of hearts that I wasn't. I was very tired all the time. I was not able to do much around the house, I slept most of the time, my feet and legs, particularly, were very swollen and I became very breathless every time I walked more than a few hundred metres, but making that final, irrevocable decision to commence dialysis was something that I wanted to put off for as long as possible. It seemed such a big and irreversible step to make. It was my wife, at one of our regular visits, when I had responded, again, to the doctor that I was OK, who said, 'No, you are not. It is time to start dialysis.' She was right but I had left it very late and I was found to be carrying in excess of 10 kg of fluid when we tried to establish my dry weight.

Starting dialysis

There is more than one means of vascular access and the options were explained to me well. In my particular set of circumstances, there was a possibility of receiving a kidney from my brother and it was therefore suggested to me that I have a permcath installed, which is a simple procedure and which enables the patient to begin dialysis immediately. After some discussion, I accepted this option and the procedure took place in mid-May 2008 and I began dialysis that same day.

It was always made clear to me that I would receive a couple of sessions at the main hospital before a more permanent slot was found for me elsewhere. Within a month I was given Tuesday, Thursday, Saturday evening slots at a local hospital, which were convenient for me and enabled me to drive to and from the hospital. Although it would be ideal for patients to be given a choice as to which slots they might prefer, in reality that is not possible. Each of the units I attended over the years was simply too busy and, if you were to be relocated, the choice of slot was determined by what was available, not necessarily what was ideal for the patient. I did, however, request an alternative time, since I found the evening slot difficult to adjust to. I often suffered from cramp and found it difficult to sleep when I arrived home. I was eventually given morning slots on Mondays, Wednesdays and Fridays and that was to be my schedule until I moved to home dialysis.

My experience at the hospital was not always good. Renal care enables a closer relationship between patient and provider to develop than is often the case with other medical disciplines. This is particularly the case with patients on dialysis, where they will see the same nurse or group of nurses, week in week out. A good relationship between patient and nurse is, therefore, desirable and it should, self-evidently, be combined with care and compassion. None of these qualities requires intensive training; all require a particular attitude of mind and this, in my experience, was not always there. In addition, I could see how some simple changes could improve the lot of patients on the ward but I became increasingly frustrated at my inability to get any changes introduced while I was on dialysis.

Communication and empowerment

It is important for patients to feel that they are more than just an object that needs to be treated. It can help a patient gain some self-respect if he or she assists in preparing for their treatment. This might mean taking their weight, their temperature and perhaps their blood pressure. It could also mean learning a little about lining the machine, getting your tray ready with dialyser, needles, swabs and so forth. Although this might mean a small investment in training from the nurses in the short term, it will help them in the longer term and it will also give patients a feeling of empowerment, which is so important for long-term treatments such as dialysis. This, though, was

(Continued)

not my experience and it was left to patients as to whether or not they were able to assist. The view from the nurses was that they were too busy to do anything other than connect and disconnect the patients.

Because the patients are likely to see the same nurses week in, week out, it is not only possible but also desirable to develop a good relationship between the nurse and patient. In my experience, this did not happen until I was transferred to the self-care unit prior to dialysing at home. It was often the practice of nurses, having put the patient 'on', to sit at the computer where it was clear that they were not always working! All I am suggesting is that the nurses talk to their patients and get to know them better. It will help the nurses understand the concerns of their patients better and it will certainly help the patients feel that they 'matter' and are not simply objects to be processed.

Monitoring

Regular visits from the consultant did not take place. Those consultations that did take place invariably took place at the bedside, rather than in the more discreet confines of the consultant's room. Although I was told I had a nominated nurse, which is a sensible concept, even when she was on duty she did not look after her nominated patients. I never managed to understand what the role of my nominated nurse was. I was on the transplant list for the time I was dialysing and was told that I should have antibody checks carried out regularly. This was not done and I found it very difficult to get these blood tests done in the satellite unit although I was told it was important to monitor them.

Infection control

Insufficient care and attention was given to monitoring for infection. In my case, I developed a nasty infection around my permcath but, despite regular attention given to that area by the nurses, as they attached and detached my line to/from the machine three times a week, it was my wife who noticed the infection, as a result of which I was immediately admitted to hospital as an in-patient and I was given large doses of antibiotics to stem the infection. I had the old line removed from my right jugular vein and a new one installed in my left jugular vein. How is it possible for a nurse not to notice something that he or she looks at so regularly when they should be specifically trained to be aware of the risk of such infections in a patient with a permcath?

Cannulation

Cannulation protocols vary considerably between nurses. It was only when I started training for home dialysis that this issue was explained to me. The two main techniques are 'button hole' and 'rope ladder'; each has its advantages and disadvantages but none of this was explained to patients in my unit. Without careful needling, a patient can end up with very 'lumpy' access points, which may not be necessary and can be cosmetically very disturbing. It appeared to me that the nurses would 'needle' wherever they could, rather than following one or other of the main techniques.

Holidays

Holidays are very important for dialysis patients. It is, reasonably enough, a patient's responsibility to organise whether or not a slot is available at a particular centre, but procedures were not in place when this initial research had been done, to set the medical requirements in train. It was often not clear which nurse was responsible for liaising on my behalf with the holiday centre and it happened more than once that my unit contacted me on the eve of a short visit away for information on exactly where I was staying, who the contacts were and what was needed. This is very frustrating, given that trips have to be arranged at least six weeks in advance and dialysing away from your main base can itself be stressful.

Home dialysis

After two years or so of increasing frustration, I asked one of the nurses if there were any alternatives to dialysing at the hospital three times a week. One of the better informed nurses suggested that I might enquire about dialysing at home. This seemed to me to be an excellent option and I was able to get the assistance of a nurse recently transferred from another hospital to teach me to line the dialysis machine and, much more importantly, to needle myself. It was only now that

I learnt the differences between the various needling techniques, which, in my view, all renal nurses should know about and discuss with their patients. Training was slow at the satellite unit and there were various parts of the process that I could not be taught as there was never enough time between the am/pm and pm/evening dialysis sessions for the nurses to take the time to explain to me what I needed to do.

I was, however, finally transferred to the main hospital and I became part of the local self-care unit. Dialysis patients there were able to manage their own care at a level that suited them. Some patients dialysed at the unit independently of the nurses who simply kept a watching brief over their patients, while others were at various stages of training prior to beginning dialysis at home.

Since I had already had some basic training, I quickly completed my training and, having arranged through the hospital for an appropriate machine to be installed at home and all the necessary kit to be delivered, I began dialysing at home in November 2011 and I can quite honestly say it that it changed my life. I was given excellent care from both the nursing staff and the technical support team. Each month a nurse would visit me at home and take my blood for analysis. I was also able to arrange regular visits with the consultant. More importantly, I felt I had regained a greater control over my own life, which is so important for patients with chronic conditions. I began dialysing every other day, which meant I'd be doing a Monday, Wednesday, Friday rota one week and a Sunday, Tuesday, Thursday Saturday rota the following week. I was, therefore, dialysing one session per fortnight more than previously, which helped me to feel a little better and relax a little more with my fluid and dietary allowances. Dialysing at home also meant that I could set my own dialysis times to suit myself and my wife, rather than following a hospital routine, which enabled us to manage our lives better and helped me to 'dialyse to live', rather than 'live to dialyse'.

It was a very positive step for me to be able to dialyse at home. It is not an option for all patients, however, and it is dependent partly on the patient's willingness to take greater control over their lives but also on their particular domestic situation.

I would recommend that the renal nurses should be trained always to consider which of their patients might be suitable for dialysing at home and to broach the subject with suitable patients. Many patients will not want to go down this path but, with the help also of patients who are already dialysing at home, it is always worth discussing it because it is clear that the long-term outcome for home dialysis patients can be better than for those in hospital. This may require an investment in terms of time and money but it is one that I believe will pay dividends in the medium to long term.

I found the most difficult thing to come to terms with was self-needling but this is not always essential. In the self-care unit it was possible to do everything for yourself, except self-cannulation. At home it is possible to train your carer to undertake the cannulation if he or she is prepared to take on the responsibility.

In my case my wife was not involved in my training until I actually came home, when she learnt from me how to line the machine, prepare the tray, and so forth. Because dialysis takes up so much of one's life together it is important, in my view, to involve one's partner in the training from the beginning. It is easier to learn with someone else and it also gives two heads the opportunity to learn what to do should something go wrong.

Patient choice and shared decision making

As I researched options for dialysis, it became clear that other options to dialysing three times a week in hospital did exist – home dialysis (as I have discussed above), but also nocturnal dialysis and using a portable dialysis machine, for example. In addition, there are options available for patients to improve their chances of receiving a transplant through the swap, or paired, scheme. It may be unreasonable to expect all nurses to have knowledge of all these issues but in my experience, none of the nurses knew about any of them. It was only when I asked some specific questions that I was told about home dialysis. This information ought to be included in basic nursing renal training, in my opinion.

Best practice and peer review

As a dialysis patient I visited the units in Penzance, Truro, Jersey, Norwich, Edinburgh (the Holiday Dialysis centre), Inverness and Elgin. All the units were different, in a number of ways, from

(Continued)

my home base and in each case each unit could have benefited in some way from the experiences of others. In my view, periodic meetings of senior nurses with their peers could only be beneficial and they could discuss a whole range of issues such as exercising while on dialysis, transport, the provision of food during dialysis sessions, how personal care plans are used, the role of the social worker and whether there might be a role for a patient representative. I am sure that there are many other subjects that would be of relevance to both nurses and patients.

Transplantation

When I finally received the call from the hospital in August 2011, it came as a complete shock. After so many years of dialysis, it was no longer at the forefront of my mind and I was pretty much resigned to leading a life of dialysis. After a mad rush through the night, my wife and I arrived at the hospital at 7:00 in the morning and we spent a whole day undergoing a variety of tests. We were also aware that another couple had been called. Depending on the outcome of the blood tests, one of us would be offered the kidney. This was very difficult for both of us and for some of the time both couples even shared the same waiting room. During the day we were given a little information about the donor and the family and the circumstances surrounding the donor's death. It was explained that there was a risk, albeit a very small one, that the kidney might not work and that, if it did work, it might take some time to 'wake-up' – possibly six weeks or more. This presented my wife and me with a bit of a problem. I was pretty stable on dialysis and we were managing our lives as well as could be expected. Our concerns were that, having waited nearly four years for this kidney, if it did not work, this might have an impact on my antibody levels and my chances of getting another kidney in the future. These were impossible questions to answer but they had to be asked. The general view, however, from the doctors was that there was only a small risk of the kidney not working. I should go for it. Thus, when it became clear that I was to be the fortunate recipient, we did go ahead and I went up to theatre at about 21:00 that evening.

My experiences as an in-patient immediately post my transplant operation, and during the follow-up clinic appointments were generally good.

Care as an in-patient

On the wards, the 'three Cs' are of paramount importance: Care, Compassion and Communication. The standard of nursing care on the wards varied considerably from shift to shift and from day to night. In general, the day staff were more proficient than the night staff. They had a better understanding of the patient's illness, were more likely to talk to their patients (although this was still uncommon in my experience), they were more attentive, responded better to patient requests and often had a little more time to spend with their patients.

Hygiene standards on the ward were mixed. Not all nurses or doctors wore gloves when taking blood, for example. Blood pressure cuffs were never wiped before taking a patient's blood pressure. What most shocked me, however, was when breakfast was handed out, and my Weetabix was handled with bare hands.

Some nurses would offer the patient a bed bath, but most did not. Some would actively encourage the patient to move, get up from the bed and walk around the ward, but most did not. One nurse only in my experience went to the trouble of introducing herself to me as the patient. This is such a simple issue but so important from the patient's perspective. You really want to know who is looking after you so that you can speak to the right nurse if you want some advice, help and so forth.

Out-patient care and immunosuppression

As an out-patient, I was very well treated and felt in good hands most of the time. When it is time to be discharged, there are always delays, which often seem to be the responsibility of pharmacy. This, I am sure, is difficult to avoid but I am also sure that there must be a better, more efficient way of organising a patient's departure. This is in the interests of the patients themselves but must also be in the interests of the ward in freeing up a bed promptly.

The importance of taking one's antirejection drugs is paramount. If you fail to take them you may lose your kidney. This needs to be stressed over and over again. I am constantly amazed at the number of patients who 'forget' to take their drugs! In addition, it is always important to emphasise the side effects of the drugs. Again, in my experience, this is done but particular

attention should be given to the effect the antirejection drugs can have on one's skin and on one's susceptibility to infection.

Rejection is a constant worry. There are no guarantees with transplantation. This is another issue that needs to be highlighted. In my experience, this is done competently. My one additional comment in this area is that there is very little attention given to the psychological needs of the patient post-transplant. Initially, it is a very worrying time. You attend clinic three times a week and there can so often be setbacks, that the whole process can be a real roller-coaster. Little thought, however, is given to this area. The appointments concern themselves with the medical side of things only. I do not know whether a counsellor is even available.

As visits to the clinic become less frequent, it becomes increasingly important for a patient to be able to monitor his or her blood results. Patients are understandably concerned about their progress and, although I was told that the hospital would contact me if there were any issues, there are sometimes occasions when issues escape the attention of the experts and, in my case, my very low white cell count was not picked up sufficiently quickly and I ended up attending hospital on a Saturday morning for an emergency procedure.

Case study 2: thoughts of a carer

My husband was diagnosed with kidney disease in 1977, the year we met – thus my experience of living with a partner who has kidney disease has been long and varied. He told me about his medical condition right at the beginning of our relationship, but I think we were both very naïve about the implications for our future together. His condition was managed conservatively for the next nine years. It was always there in the background but did not impact hugely on our life.

The big change came when he was told his kidney function was deteriorating and he should start on a low-protein, low-sodium and low-potassium diet. This was quite hard to manage whilst providing for our two young children, as we had very little advice about how to do this. Essentially just a few diet sheets and prescriptions for the relevant special foods required. These foodstuffs were mostly unpalatable and difficult to prepare. I remember crying over the first meal that I made because it looked so meagre and awful. Thankfully these (Giovanetti) diets are no longer used.

Transplantation

Transplantation followed about nine months later, in January 1988, when my husband's mother donated one of her kidneys. Living transplants at the time were very unusual, with only about 5% of the total being performed in this way. Two major operations within six weeks and various complications over the following year, resulting in a third operation, finally stabilised my husband's condition. It was a rollercoaster, never knowing what would crop up next and not quite daring to believe that eventually it would be alright.

I can remember a mother at the school gate saying that she didn't know how I could cope with all that was happening. I thought to myself that I didn't know either, but I didn't have much choice! We did have kind friends and family but it was still a challenging time, trying to be supportive to my husband who was struggling to maintain a positive outlook, balanced with keeping life as normal as possible for our children aged four and two. The culture at the time was very much 'stiff upper lip and get on with it'. In retrospect it would have been lovely to have someone to voice my concerns to, who understood the road we were travelling.

Eventually we went on to have 19 wonderful years of normal family life, the only reminder of the transplant being the various medications that my husband took daily and the three monthly hospital visits. However, transplantation does not cure kidney disease; it only gives respite from dialysis for the lifetime of the replacement kidney.

Advanced kidney disease

By 2006 my husband's kidney function began to deteriorate and with it his overall condition. Having to take early retirement on health grounds in 2007 was a real blow to his self-esteem; he

(Continued)

had loved his working life. Early retirement can be a difficult transition in normal circumstances but when you feel unable to enjoy the new freedom that retirement brings because you are too tired it is very frustrating. As his condition worsened, our lives became very restricted. We were unable to do much because he felt so unwell and tired all the time. Just climbing the stairs was making him breathless and he began to dread the short walk to the station to travel for his fortnightly hospital appointments.

My husband developed sleep apnoea, which meant we could not share the same bedroom. Snoring is often joked about but sleep apnoea is not funny – it gets to the point where you spend your whole time lying there waiting for the person next to you to take their next breath. A 24-hour monitor revealed that he was suspending his breathing up to 40 times per hour. No wonder he was exhausted all the time when he could not get any proper rest. It was not until dialysis commenced that this problem began to resolve itself, as the large amount of excess fluid he carried was gradually removed.

Hospital-based haemodialysis

Starting dialysis is a huge step for both the patient and the carer and should not be underestimated by clinicians. Psychologically it feels like the end of normal life, no matter how limited that 'normal life' has become. The thought of being dependent on a machine for the rest of your life unless you are fortunate enough to receive a new kidney, is very daunting. The information that you receive at this stage is critical to the way that you adjust to your new life and how you cope physically and emotionally. I'm sure most patients at this stage will feel depressed, quite justifiably.

Once the decision was taken to dialyse it all happened very quickly but with little preparation in terms of what we could expect. It was very bewildering and scary. I tried to be positive and encouraging because my husband was too poorly to do it for himself.

In retrospect I felt totally unprepared for it all. I knew that it was the right thing to be doing and hoped that my husband would feel better soon, but I felt totally out of my depth. A permcath line was put in and looked a mess with bleeding and bruising all around the site for almost a week. Dialysis started immediately with the first sessions being unpleasant because he suffered from bad cramps. I dreaded asking how it had gone because I knew it was probably painful. My husband could not tolerate having much fluid removed in one go, so it took quite a while to establish his 'dry weight'. I felt helpless and didn't know what to do or say to support him, except that it could only get better.

If we had been able to talk to a patient who was living well with dialysis at that time it would have made all the difference – to see that one can regain control of one's life and return to a reasonable level of health.

For two years my husband attended the local hospital for treatment and became increasingly frustrated with the time it took and the lack of interest in him as a person. There was no attempt to get to know him or anything about his life outside. It was as if he was a body on a bed that needed to be attached and then detached from a machine at a time that suited them. This may sound very harsh, but I can't understand why you would choose to be a dialysis nurse if you have no interest in your patients as people when by the nature of the job you are spending long periods of time with those people every week!

In stark contrast we have met some wonderful dialysis nurses throughout various parts of the country as my husband received treatment on holiday. Without exception, they were kind, caring, proficient and, crucially, interested in him as an individual. Those nurses learnt more about him in a week as a holiday dialysis patient than most of those at the home unit learnt in the whole time he was there.

Home haemodialysis

We were eventually made aware that home dialysis might be an option and this was a real turning point. From a slow start, we eventually reached the stage where my husband could start dialysis at home. A spare room in the house was adapted and the relevant equipment was installed by the hospital. We had wonderful support from the home dialysis team but it was still quite nerve wracking when we dialysed for the first time on our own. I would say that it took about three months for us to gain confidence.

It was a big change for me as my life became much more restricted. Before, my husband would leave for the hospital at 19:00 and return at about 13:00, which did not affect me at all. I would either be at work or doing my own thing. Once the home dialysis began, I had to be at home and available the whole time that my husband was attached to the machine. I had not fully considered the implications of this and it was quite hard to adjust. He was advised that increasing the amount of dialysis he performed would improve his overall condition, which made sense, so he decided to dialyse every other day. This meant that we were on a two-week rotation, which was fine, but it also meant that I could not have the freedom to attend a regular evening class or meeting because I would not be free on the same evening every week. As I was working part time we had to dialyse in the evening when I got home. This also meant that I spent every other evening by myself as my husband preferred to be on his own during his sessions. I would be downstairs with a two-way radio so that he could call me if he needed anything. He was always hungry whilst dialysing and I would provide sandwiches, toast and biscuits as required!

Having said all of that, home dialysis brought huge benefits and we were so pleased to be able to take advantage of the opportunity offered. The freedom to dialyse to suit our life gave us the ability to travel and visit friends and family more easily. Taking control of the treatment rather than being dependent on the hospital was very liberating. We were free of the risk of hospital-acquired infections and, apart from the occasional visit from the home dialysis sister to take blood samples and follow up hospital checks, we were living our own lives again. Life was at home rather than the hospital.

My husband had been on the transplant list for over four years and, having exhausted all other potential options, we began to accept that dialysis might have to be a permanent part of our lives. We decided to try and do as much as we possibly could within its constraints, including travelling to America to visit family. We continued to travel within the UK receiving hospital dialysis in the local units. We found an equilibrium that gave us a good quality of life.

Transplantation

When a call finally came I felt totally unprepared. My husband had gone away on a walking trip for a couple of nights and I took the call in the early hours of the morning. My first reaction was that one of our elderly relatives must have been taken ill. As soon as the caller said that she was a doctor from the hospital and asked for my husband, I realised what this might mean. The range of emotions that I experienced at that moment included, shock, excitement, fear, disbelief, anxiety and, most strongly of all, sadness for the donor's family.

My husband has already described the hours that we waited to find out if the kidney would be suitable. We decided not to tell any friends or family what was happening, not wanting to raise anyone's expectations, let alone our own, just in case it did not go ahead. Then the huge sense of relief and the ensuing anxiety when we were told it was a suitable match, with the excitement of contacting everyone. Thank goodness for text messaging and email! The operation went ahead that night and I remember saying goodbye to my husband in the anaesthetic room, thinking 'please God let it all go smoothly.' To my amazement I received a call at about 01:00 from my husband saying that it was all done and he was back in the ward. When I visited him the next morning he had no recollection of making the call!

From then on I spent every day driving to and from the hospital, spending as much time with my husband as was allowed. At home I was receiving all the wonderful calls with enquiries and good wishes but it was very tiring. Unfortunately, both of my sons and most of our good friends that I might have called on were away at the time, so it was a great relief when they all began to return and I didn't feel so alone.

My husband recovered well and focussed on getting mobilised as quickly as possible, but every day we were hoping for that precious moment when he needed to pee! It finally came on day six after the operation. I was at home and received a text from my husband as he was too emotional to speak. It is difficult to explain the relief that I felt at that moment, but it was as though a huge burden was being lifted from my shoulders. I sent out a mass text message around the world to friends and family. My son's girlfriend was on holiday with her family and burst into tears when she read it, as did her mother and sister! Never were a few mls of urine so welcomed!

(Continued)

My husband continued to make a good recovery and was discharged home nine days after the operation. It was so good to have him at home and be able to care for him myself.

Post-transplant follow-up

Follow up for patients after transplantation is very intense, requiring hospital visits three times per week for blood tests, weight and blood pressure measurement. This was tiring for my husband and he was anxious about travelling by train and being exposed to all the coughs and colds of other passengers with his immune system suppressed.

Over the following weeks and months there were various setbacks, mainly related to getting his immunosuppression drugs properly balanced, but eventually my husband's condition stabilised and we began to enjoy the new-found freedom that the transplant gave us. To be able to enjoy the simple things, like going out for a lovely cup of coffee and a cake! The fluid restriction and low potassium diet had meant this was impossible before. We were able to visit friends and family when we liked for as long as we liked and it was, and still is, wonderful.

My thoughts to you as nurses

Kidney disease is with the patient and their families for the rest of their lives and each one has their own individual circumstances. Learn as much as you can about them as individuals and their particular condition and you will help transform how they cope with their disease.

As a patient on hospital-based dialysis it is very difficult to comment if things are not right, as you feel very vulnerable. Criticism, however constructive, is not always well received and therefore things that could be improved go unchanged because of lack of trust.

Being confident that those who care for you really know you will develop a sense of trust that will enable concerns to be raised and addressed.

- In the early days of diagnosis and dialysis, patients may feel very unwell, frightened, depressed, that their life is over. There may be anxieties about their employment, finances, housing, family and so on, which may affect their overall health.
- Spend time to get to know your patients as well as possible, understanding their home and family circumstances, their fears and concerns. Understand what they enjoy and what they can do, not what they cannot.
- Use language that can be easily understood.
- Become their advocate.
- Encourage independence, teaching them all the things they can do to help themselves. Many patients could manage some or even most of their dialysis given the right encouragement. Some could have dialysis at home with the right support.
- Recognise that renal disease, and dialysis in particular, has a huge impact on the patient's partner and immediate family.
- Encourage and enable the patients to take holidays by facilitating dialysis at other centres.
- Be knowledgeable about what is available. If the patient is on the transplant register make sure they are aware of the various options available through live transplantation. Encourage discussion with friends and family.
- Emphasise that you 'dialyse to live, not live to dialyse.' There is still so much that they can do.

Being the partner/carer for someone with kidney disease can be very challenging and lonely at times, as it can be hard for friends and family to understand the complexities of the disease and all the challenges that it brings. My plea would be to ensure that the carers are looked after too. Small acts of kindness and a comforting word will go a long way. Information about local kidney patient associations, support groups and online forums can provide a lifeline.

As I write this, we are now almost 18 months on from the transplant and our life is very busy and wonderful. We are so grateful to the family who had the courage to donate the organs of their loved one. I do hope that knowing other lives can continue restored to good health will be of some comfort to them.

Case study 3: communication

Case study 3

I have been a patient with kidney disease for over 20 years and have been on dialysis for a large part of that time. As a result of my scientific background, I took interest in renal failure and haemodialysis by reading up on it further and asked nurses and doctors about different aspects of renal medicine. I have learned a lot and gained an insight into renal care and medicine. In addition, there are aspects of renal practice which I have able to identify that can be improved and enhanced, thus addressing the importance of the continuity of care.

One aspect that I feel could be improved is communication. On a haemodialysis unit, there seems to be a setup where there is a peak-time when the nurses put on patients on the machine and then promptly return to the nurses' station. After this period, there is a length of time where the nurses update their work and each nurse is assigned a particular duty e.g. stock, transplantation bloods. The other peak-time rush starts again when patients start to come off the machine. On some days, this can be more hectic than other days, due to staff pressures but the question is why some nurses do not seem to want to engage with the patients when they are less busy during the middle of the dialysis shifts.

Each patient is assigned a named nurse in the dialysis unit. In my experience, it seems that many patients do not know who their named nurses are. The nurses should be introduced to their respective patients since it is the nurses who have the most interaction with the patient as opposed to other healthcare professionals. Nurses should be able to explain the results of monthly bloods (e.g. full blood count, urea and electrolyte levels) to their patients and time should be taken for this. I feel nurses could give us a brief session explaining the parameters of the haemodialysis machine e.g. what is a good pump speed for efficient dialysis, reasons why the machine alarms. Once patients are more comfortable about their knowledge of renal care and medicine, nurses can encourage them, depending on the patient's circumstances, to undergo self-care.

Transfer between dialysis units

As a dialysis patient of 12 years, I have moved between dialysis units twice. When it came to the first move, no meeting about the move was arranged with the patients and it was as if we were to accept the move without having enough time to process all the information. Dialysis becomes a way of life for the time they are on this routine so just like moving house is stressful, moving dialysis units has its own anxieties. Due to such moves, transport can be a concern as well, especially getting to the dialysis on time, safely and smoothly. Nurses should be able to alert patients in good time, of when such changes are likely to occur so that patients can be reassured that the running of any procedures will be smooth.

Psycho-social issues

Many patients are not aware of the kinds of help that are available to them, which is the reason why renal social workers should come to the dialysis unit regularly for patients to avoid patients making separate trips to the hospital to see them. Renal social workers should come at least twice a week to accommodate for the patients who come on different days and conduct a ward round like doctors do, so each patient is aware of their service.

Some patients have the right to hospital transport for their treatment so when administrators are not available to sort out issues such as delayed transport, the nurses should be able to have involvement in such situations.

Reflection

After reading the case studies above, think about similar situations when you might have been the provider of the care to these patients. Reflect carefully and consider the following points:

- What skills do you have (or what do you need to acquire) to enable a true partnership with patients?
- How far you do actively include patients and family members in decisions about their care?

- How could you make the best use of quiet times during a dialysis shift (such as assessment, supporting self-management, education, decision-making with patients)?
- In what ways could you engage with patients and their families to measure the level of patient involvement in your unit?
- How far does your unit give a true choice to patients when they are contemplating long-term renal replacement therapy?

Patient Involvement Using Social Media: The Renal Patient Support Group (RPSG) Facebook and BlogSpot

Background to social media

Since the 1990s, technology such as the Internet, Email and Instant Messaging (IM) facilities on mobile phones, digital cameras and computer scanners, have provided a way to communicate, produce original media footage and access information at a rapid pace. Using technology has advanced the way we gather data and information such that we no longer really require to be at a specific place at a given time. For example, we don't really need to purchase a newspaper at the local newsagent, or a book at a local book store, or even do our daily groceries by going to the local supermarket. Now, many people are equipped with 'Smart or Android Phones', which have applications ('apps'), which can provide us with access to daily news through a news app – for example BBC News, which is purchased or available to download for free via our phone network providers accordingly. To this end, the general public can have a variety of 'apps' on their phones, which are continuously updated through a phone network contact and subscriptions.

Academic institutions, through traditional means (i.e. attending lectures), now also enhance their teaching programmes by allowing students and educators to learn and lecture accessing online-based facilities using advanced software programmes. Some web sites may require a small fee to retrieve information but, on the whole, from doing the daily shopping through to academic learning and getting the information required, this can all be done in real time and almost at the touch of a button. The majority of us are now becoming more knowledgeable in the way we retrieve information and connect with family, friends, and colleagues on a daily basis using such media as Facebook and Twitter. This section provides some insight on the variety of social media forms that are useful in healthcare, and describes the very successful Renal Patient Support Group (RPSG) on Facebook and Blogger (BlogSpot).

Facebook

Facebook is a modern social media/networking platform, which has massive capacity allowing people to communicate and interact. Facebook launched in 2004 and has over 900 million active users; more than half of them utilise a Facebook 'app' on a smart or android phone. Facebook has various additional tools such as chat facility where there is opportunity to communicate with family, friends or colleagues on a one-one basis and also through group discussion. Facebook can be used personally or for business to reach a larger audience in a much shorter time. The NHS has recently joined Facebook and this has helped to

- engage with followers in order to share information on the NHS, their products, services and latest news;

- share advice and information about important health issues, and where appropriate, may link to major health stories in the news;
- point people to the correct channels to get opinions heard. NHS Blood and Transplant (NHSBT) are also using Facebook to highlight the importance of organ donation.

Twitter

Twitter is an online social networking service and micro-blogging service that enables its users to send and read text-based posts of up to 140 characters, known as 'tweets'. The service rapidly gained worldwide popularity, with over 140 million active users as of 2012, generating over 340 million tweets daily and handling over 1.6 billion search queries per day. It has been described as 'the SMS of the Internet'. Unregistered users can read the tweets, while registered users can post tweets through the web site interface, SMS, or a range of apps for mobile devices.

Blogger/BlogSpot

A blog can be a personal journal published on the Internet consisting of discrete entries ('or posts'). Blogs are usually the work of a single individual, or occasionally of a small group, and often are themed on a single subject. The emergence and growth of blogs in the late 1990s coincided with the advent of web publishing tools that facilitated the posting of content by nontechnical users.

Most good-quality blogs are interactive, allowing visitors to leave comments and even message each other on the blogs. It is this interactivity that distinguishes them from other static web sites. Indeed, bloggers do not only produce content to post on their blogs but also build social relations with their readers and other bloggers. Many blogs provide commentary on a particular subject; others function as more personal online diaries. A typical blog combines text, images, and links to other blogs, web pages, and other media related to its topic. The ability of readers to leave comments in an interactive format is an important part of many blogs. Most blogs are primarily textual, although some focus on art (art blog), photographs (photo-blog), videos (video blogging), music (MP3 blog), and audio (podcasting). Microblogging is another type of blogging, featuring short posts.

The Renal Patient Support Group (RPSG) on Facebook

The RPSG is a voluntary (nonfunded) Facebook group initially developed by three individuals (two patients and one carer in October 2009). The initial intention of the RPSG developers was to help support other patients with kidney disease, relatives and carers following routine clinical outpatient appointments at the North Bristol NHS Trust. The RPSG developers knew that it would be a challenge to provide support to fellow patients face to face in the outpatient setting owing to the limited time and the general rush in the clinical environment. The RPSG developers decided to explore an online platform and Facebook was a fitting choice because it is a social media platform recognised on a global scale and allows the sharing of 'real-time' lived experiences. The RPSG offers online peer support globally, with members sharing and caring.

Since the RPSG allowed the developers to interact with patients from the local NHS Trust, using Facebook further attracted patients, family members and friends from

various regions of the UK and beyond, thus allowing everyone to gain a better understanding of chronic kidney disease (CKD) and end-stage renal disease (ESRD) from various parts of the world and thus where everyone is able to interact, ask questions and post messages, retrieving instant responses. The RPSG developers also want to see that patients become more active with their local kidney patient associations (KPAs), as they support renal patients via the requests of health professionals in a given NHS Trust.

The great advantage of the RPSG has now been that other patients from the UK can gain more insight into CKD in other parts of the world and vice versa. In 2013 the group had over 1600 members at various stages of CKD and has ten members in the administration team who have several additional roles. Administrative members consist of people from the UK, Italy, Australia and USA who give their time and dedication in seeing that the group is facilitated.

What's on the RPSG?

- Patients sharing real life experiences and supporting each other.
- Helpful links for all.
- Video links that may be of interest.
- Academic/ Research Papers that may be of interest.
- Research Folder consisting of supporting projects and collaborations.
- Voluntary patient activity opportunities.
- A list of Kidney Patient Associations (KPAs) and related groups and pages.
- Event Posters/ Flyers folder.

Some of the RPSG's projects and activities include the following:

- Renal Patient View service evaluation (NHS Kidney Care Project Support).
- Record access (Royal College of General Practitioners/ NHS Connecting for Health Project Support).
- Improving Shared Decision Making For Renal Dialysis – A Call to Action (NHS Institute for Innovation and Improvement Project Support).
- Patients Receiving Kidney Care: How Technology Helps (University of Brighton Project Support)
- Bringing Carers into Kidney Care Project (NHS Kidney Care Project Support)

World Kidney Day, 2011–2012

One of the great advantages of being a social media platform is that the RPSG has successfully raised CKD awareness through many opportunities. In its second year, the RPSG ran a social event in support of World Kidney Day, 2011, in Bristol, United Kingdom. The event aimed to hand out renal health literature to the general public and also generally help the public understand what it means to live with kidney disease. The RPSG Facebook Events page was used to advertise this social event by the RPSG Social Events Coordinating team.

The RPSG also had media coverage where the local newspaper (*Bristol Evening Post*) provided a segment on the efforts of the social media platform group. The RPSG World Kidney Day, 2011, was a success and the general public welcomed the information that was given to them as a team answered questions on the importance of keeping healthy kidneys. After the social media event, a member of the RPSG research team was invited to speak on BBC Radio Bristol on the events of World Kidney Day and the importance of renal awareness and the general public signing up to the organ donation register.

Following the success of the World Kidney Day, 2011, and RPSG using a social media platform, in 2012, the RPSG collaborated with NHS Kidney Care to host a series of

RPSG WebEx e-sessions inviting patients and professionals to present insights on CKD awareness. The World Kidney Day, 2012, e-sessions were conducted over four days and there were nine speakers. Over 120 people expressed their interest in attending between the four e-sessions and the great advantage of implementing an online tool for learning is that it allows people to gain knowledge in the comfort of their homes.

RPSG E-seminar sessions

The RPSG continues to be a 'place' where members can gain real insights allowing everyone to learn and share experiences from across the globe. Following the successes of supporting World Kidney Day, one of the RPSG research facilitators initiated a simple survey 'Would you like access to your records online?'

The RPSG hosted another series of e-sessions including *Enabling Patients to Access their Electronic Health Records*. The RPSG e-sessions implemented the Skype online communication facility and a RPSG researcher invited primary care health professionals such as GPs and professionals from NHS Connecting for Health to present research and get real patient views on the advantages/ disadvantages of having control of their own health records. Results showed that 76% (n = 84) would like to have access to their health records. Further information can be found here http://shahidrpsg.blogspot.co.uk/2012/03/rpsg-record-access-ra-report.html (accessed 20 May 2013).

The Renal Patient Support Group (RPSG) on BlogSpot

The BlogSpot was set up in January (2012) and in addition to some of the material and information already on the Facebook page, the Blogger allows members and nonmembers of the RPSG to gain more insight into kidney disease. On the Blogger there are a number of blogs, web site links to documents/guidelines and much more. This social media platform allows general internet users to understand more about what is happening surrounding kidney health. The RPSG developers would like to see more people use this facility widely.

RPSG – the future

The RPSG continues to grow gaining membership from various parts of the world. Some of the prospective events and programmes the RPSG team has considered include:

- the RPSG 7-Step Strategy Organ Donation Campaign Proposal in support of World Kidney Day, 2013;
- World Kidney Day (2013) Organ and Transplantation Educational E-Seminar;
- further qualitative research collecting data on advanced topics surrounding CKD/ESRD by way of professional collaborations.

Recommendations for practice

Where renal peer support programmes within NHS Trusts have been piloted and fully implemented, senior staff should also consider implementing a social media platform to allow shared caring and learning. Research is an important element of the RPSG. The RPSG is the only renal Facebook support group that collects data and publishes information for its members. The RPSG continues to use social media platforms to raise CKD awareness and to also encourage researchers and health professionals to get involved for potential collaborations.

The RPSG continues to expand. Health professionals should grab opportunities provided by social networks to improve the health of their patients, and do their utmost to ensure that the highest quality of health information and access to treatment is there for all.

Information on the RPSG can be found at

RPSG Facebook: www.facebook.com/groups/RPSGroup/

RPSG BlogSpot: http://shahidrpsg.blogspot.co.uk/ (accessed 26 May 2013)

Summary

As a nonfunded voluntary group, at three years post development, the RPSG has successfully raised CKD awareness and prevention using social media. The success is partly due to the fact that there are no formal constitutions and regulations, which would otherwise restrict members to use the group. The RPSG however does have a general disclaimer informing members not to provide any specific clinical or medical advice. The running and success of the RPSG has been achieved through Facebook, BlogSpot, WebEx and Skype e-sessions. The RPSG has also successfully allowed a platform for interaction providing insight to 'hard-to-reach' populations and thus also distributing information on CKD to Facebook users.

Patient and Carer Involvement in Renal Nursing Education

Many providers of higher education are involving patients and carers in curriculum planning and teaching activities. The value of involving users and carers in the education of health and social care professionals has long been recognised (Levin 2004). Research on the involvement of users in education has demonstrated that it can challenge entrenched perceptions and attitudes of health professionals (Katan and Prager 1986) and help break down barriers of hierarchical and paternalistic services and produce practitioners capable of delivering improved and more relevant outcomes for users and their carers (Tew *et al.* 2004). Service user involvement in curricula development was analysed in a recent review (Morgan and Jones 2009) and it was found that, despite a limited and weak traditional evidence base on impact on students' knowledge and practice, both students and service users identify benefits from engagement. Another paper (Gutteridge and Dobbins 2010), which was part of a larger evaluation study, described how members of staff in a faculty of health were interviewed about the impact of service user and carer involvement on learning and teaching. Semi-structured interviews were used to explore current levels of involvement, barriers and solutions and findings suggested that staff recognised the need to involve service users and carers in their learning activities but a number of barriers were found.

One example of a renal user and carer group in higher education is the 'Kidney Research and Education Initiative' (KREI) at City University London (Noble *et al.* 2010). The main aim of the initiative is to become a centre of excellence for kidney care, education and research that has a particular focus on patient participation in research and teaching. The KREI was launched in 2010 and the launch event was attended by representatives from the Kidney Alliance, the National Kidney Federation, the British Kidney Patients Association and local Kidney Patient Associations.

The KREI has an advisory group whose members are patients and carers. The advisory group meets twice per year and activities include involvement of patient members

in curriculum design and teaching of pre-registration students, in addition to contributing to research grant applications (Chamney *et al.* 2012).

Pre-registration teaching

An interesting teaching session had taken place back in June 2011 which was designed for year 2 student nurses and taught by a renal nursing lecturer. Patients and carers from the advisory group were invited to review what was taught and how the lecture was conducted. Patient and carer participation was encouraged at this session as it was felt that the student nurses required examples of first-hand experiences from renal patients and carers in order to supplement and enhance their learning. An evaluation was carried out following the session where the patients and carers were able to provide feedback with regards to the format/structure of the modules based on renal care. Such evaluations provided positive changes to the renal care modules and encouraged motivation and interest in renal care from student nurses.

After further discussions, the members of the KREI decided to involve patients in all future teaching sessions. The first teaching session that involved patients and carers followed a few months later. The views on all sides of patient, carer and students were very positive. All enjoyed the session and the evaluation from students felt it was very useful since it gave them a strong insight into what it is like to have kidney disease.

Of the 48 students attending the lecture, 46 gave feedback and 100% of the feedback was positive. Examples of the comments made include:

> 'I felt like I was present in the treatment and now know how it feels to be a renal patient.'
> 'It was interesting, concrete. It should be done as much as possible to give a human face to conditions.'
> 'It brings the subject to life. It teaches me more than what the lecturer teaches.'
> 'It was really helpful to have an insight into the patient's experience.'
> 'If we are to become good nurses we need to listen to our patients. This should start now as we train.'

The response to the involvement of patient/carer in all the lectures was overwhelmingly positive. The nurses were able to obtain a first-hand view of the experiences of a renal patient together with a carer, enabling them not only to learn about renal disease from an academic perspective but also to learn the impact this has on patients from a personal level. Many students commented on the greater impact of a session where they could understand the patient's journey and the involvement, and importance, of a carer in his/her life. It was also felt that the practice of involving a patient at such sessions should be extended to other medical disciplines. Overall, the sessions were enjoyable for the students and they appreciated patients/carers coming to their session and showed gratitude. For the patients/carers it was very positive to know that to the best of their ability, they helped give an informative outlook on what it is like to have kidney disease.

Summary

If setting-up a similar project in your school or university, then it is important to consider the following:

- all lecturers/practitioners must be committed to the meaningful involvement of patients in teaching and learning;
- patients and carers need to be reimbursed for their time and expenses (see guidelines on this in following section);

- a formal advisory group needs to be set up with written 'terms of reference';
- patients and carers may need support and/or training in teaching skills and techniques.

McKeown *et al.* (2010) have written a comprehensive guide to service user and carer involvement in education for health and social care if further information is required.

Patient and Carer Involvement in Renal Nursing Research

A recent review provided evidence of a range of benefits to researchers and participants of public and patient involvement (PPI) in health research (Staley 2009) and the importance of this approach to the NHS has long been recognised (Boote *et al.* 2002). There is a long history of PPI in particular fields, such as in mental health (Mental Health Research Network; Mental Health Foundation, SURE) and Cancer (National Cancer Research Network; Macmillan Cancer Support). However, user and carer research collaboration between members of the public, researchers and clinicians in the field of kidney care is still relatively new. Staley (2009) reports that one of the impacts of public involvement in health research is that members of the public and researchers develop a more constructive and ongoing dialogue.

Although there are national initiatives to involve patients in research, the number of health researchers actively involving the public in research appears to be limited (Thompson *et al.* 2009). In addition, there is little research specifically addressing the attitudes of health researchers towards involving the public. One qualitative study (Thompson *et al.* 2009) suggested varying constructions of public involvement in research, based on moral and political principles.

A more recent study (Barber *et al.* 2011) investigated the process and progress of service user involvement in research and also identified perceived benefits to research, researchers and service user researchers that endorsed previous findings. However this study also demonstrated the benefits of allowing time for patients' structured reflection on their involvement and this is an important message for those working in renal care.

Case Study 4: patient and carer involvement in research/quality improvement

In 2010 Kidney Research UK, with a grant from the Health Foundation, led a project (named ENABLE-CKD) to improve the variability in managing early CKD by using a quality improvement intervention called a care bundle (a set of evidence-based activities grouped together and carried out at the same time) (Thomas and Loud 2012). The care bundle comprised three clinical interventions, plus one self-management intervention developed and delivered by a Patient Advisory Group.

A patient advisory group was set up and comprised six people with various long-term conditions (kidney, diabetes, heart disease). The group was led by an expert patient, previously known to the renal community and with a background in management. The members of the Patient Advisory Group had some common characteristics, including a shared goal of wanting to help others. The Chair of the patient group created role descriptions in conjunction with team members (see Box 3.1), setting expectations in both the project and patient team that all were to be treated as equals and professionals in the project. Honoraria were paid at the same rate as professionals on the team, further demonstrating the value of working together in this way (Loud *et al.* 2013).

BOX 3.1

Role description for patient advisory group members

Duration
The term of office is the duration of the project, due to be completed in October 2012

Background
This group consists of people who support the aims of the project and who:

- have experience of kidney disease as service users or carers;
- represent kidney organisations;
- represent nonkidney organisations from related medical disciplines such as vascular care and diabetes care.

Role
- To guide and influence the effectiveness of delivery and propagation of educational tools for patients to improve patient care.
- Assist with measurement methods of the quality and effectiveness of tools (with reference to the expected benefits).
- Monitor and review output as tools are applied.
- Alert core team to potential risks.
- Contribute to possible Practice training.
- Use work from other disease areas.
- Consider all work with reference to propagation in other disease areas.
- Use personal networks to spread awareness of the programme.

The group will meet two or three times each year.

Principal responsibilities
1. To attend Patient Group meetings.
2. To contribute during Patient Group meetings.
3. To take part in group communications.
4. To deal with the associated paperwork related to the project.
5. Support others in the group.
6. Confidentiality.

Benefits to group members
- Personal development: through involvement in the full range of patient group activities, members will be offered opportunities to develop knowledge and skills in areas related to the project.
- Personal satisfaction in making a much-valued contribution to a project of potential benefit to kidney patients in the United Kingdom and beyond.
- Payment: members can claim reimbursement of travel expenses and a daily fee In accordance with INVOLVE guidelines (http://www.invo.org.uk/posttypepublication/payment-for-involvement/ [accessed 24 May 2013]) for attendance at project meetings.

The members of the Patient Advisory Group themselves benefited from their participation in the ENABLE-CKD project, gaining skills in training of professionals, confidence in their own condition and satisfaction from helping others. Regular communication between Advisory Group members was important to project success, as was understanding and support from each other when Advisory Group members had their own health challenges.

Over two years the team worked alongside the clinical team and the GP practices using a quality improvement approach: Plan, Do, Study, Act (Institute for Health Improvement 2012).

(Continued)

Training healthcare professionals

The team co-developed and delivered training to 29 GP practices in how to help people to self-care. Healthcare professionals appreciated the training and materials; as they were developed by people of long term conditions it added a level of experience to the project. They valued learning how to explain kidney disease and how to support their patients to self-care.

An information booklet for patients

The team co-developed a patient information pack which the trained doctors and nurses would give to people with CKD who said they wanted the self-management information. A diet sheet was later added to the pack, on request from both patients and professionals. The pack included information about CKD and where to find further information and a DVD called 'Living with CKD'. At the end of the project all these materials were amended following patient evaluation

Education for people with CKD

The patient team co-developed and delivered patient education sessions (for people with stage 3 CKD) at selected GP practices, focusing on how people could help themselves. They explained what self-care is and what an individual can do to help themselves. The education session comprised:

- description of self-care and exploration of benefits;
- areas on which to focus for self-care;
  - blood pressure;
  - blood sugar;
  - smoking;
  - diet;
  - exercise;
  - taking medication and why it is important;
- limited consultation time with doctors/nurses – making the best use of it.

All the materials from this project including teaching slides, notes, and patient information materials are available for free download (following registration) from https://support.kidneyresearchuk.org/ckd/packageofinnovation (Accessed 1 Sept 2013).

INVOLVE Guidelines

INVOLVE is a national advisory group that supports greater public involvement in NHS, public health and social care research. INVOLVE is funded by and part of National Institute for Health Research (NIHR). INVOLVE shares knowledge and learning on public involvement in research and has a useful resource centre to help researchers and clinicians involve patients and carers in their research programmes www.invo.org.uk/resource-centre/ (accessed 20 May 2013).

Conclusion

This chapter has highlighted the critical importance of involving patients and carers in renal practice, education and research/quality improvement programmes. It is hoped that nurses reading this chapter will reflect very carefully on what has been written and evaluate how far they facilitate a true partnership with patients and their families on a day-to-day basis. A three-year vision and strategy for nursing, midwifery and care staff that aims to build the culture of compassionate care in all areas of practice was launched in 2012 (Department of Health 2012). The vision is underpinned by six fundamental values: care, compassion, competence, communication, courage and

commitment, all of which have been highlighted in this chapter. Do take time to read this document and make sure that you have these values uppermost in your mind when caring for people and their families.

References

Barber, R., Beresford, P., Boote, J. ***et al.*** (2011) Evaluating the impact of service user involvement on research: a prospective case study. *International Journal of Consumer Studies* **35** (6), 609–615.

Boote, J., Telford, R. and Cooper, C. (2002) Consumer involvement in health research: a review and research agenda. *Health Policy* **61** (2), 213–236.

Care Quality Commission (2011) *Surveys,* www.cqc.org.uk/public/reports-surveys-and-reviews/surveys (accessed 20 May 2013).

Chamney, M., Cook, T., Das, R. ***et al.*** (2012) Renal health care professionals, patients and carers collaboration to improve education and research. *Renal Society of Australasia Journal* **8** (3), 120–125.

Department of Health (2010) *Equity and Excellence: Liberating the NHS,* The Stationery Office, London.

Department of Health (2012) *Compassion in Practice. Nursing, Midwifery and Care Staff: Our Vision and Strategy,* The Stationery Office, Leeds.

Gutteridge, R. and Dobbins, K. (2010) Service user and carer involvement in learning and teaching: a faculty of health staff perspective. *Nurse Education Today,* **30** (6), 509–514.

Institute for Health Improvement (2012) *Science of Improvement: Establishing Measures,* www.ihi.org/knowledge/Pages/HowtoImprove/ScienceofImprovementEstablishingMeasures.aspx (accessed 20 May 2013).

Katan, J. and Prager, E. (1986) Consumer and worker participation in agency-level decision making. Some considerations of their linkages. *Administration in Social Work* **10,** 79–88.

Levin, E. (2004) *Involving Service Users and Carers in Social Work Education,* SCIE, London.

Loud, F., Jain, N., and, Thomas N. (2013) How to develop a patient and carer advisory group in a quality improvement study. *Journal of Renal Care* **39**(suppl. 2), 2–9.

McKeown, M., Malihi-Shoja, L. and Downe, S. (2010) *Supporting the Comensus Writing Collective. Service User and Carer Involvement in Education for Health and Social Care,* Wiley-Blackwell, Oxford.

Morgan, A. and Jones, D. (2009) Perceptions of service user and carer involvement in healthcare education and impact on students' knowledge and practice: a literature review. *Medical Teacher* **31** (2), 82–95.

National Voices (2012) Accessed from www.nationalvoices.org.uk/patient-involvement (accessed 20 May 2013).

Noble, H., Chamney, M., Jones, J. and Thomas, N. (2010) A new initiative in renal research and education. *Journal of Renal Nursing* **2**, 142–145.

Staley, K. (2009) *Exploring Impact: Public Involvement in NHS, Public Health and Social Care Research,* National Institute for Health Research, Eastleigh.

Tew, J., Gell, C. and Foster, F. (2004) *A Good Practice Guide. Learning from Experience. Involving Users and Carers in Mental Health Education and Training,* Mental Health in Higher Education / NIMHE, London.

Thomas, N. and Loud, F. (2012) Managing chronic kidney disease in primary care: a quality improvement study. *Renal Society of Australasia Journal* **8** (3), 152–157.

Thompson, A. (2007) The meaning of patient involvement and participation in health care consultations: a taxonomy. *Social Science and Medicine* **64** (6), 1297.

Thompson, J., Barber, R., Ward, P.R. ***et al.*** (2009) Health researchers' attitudes towards public involvement in health research. *Health Expectations* **12** (2), 209–220.

Resources

HealthTalk Online offering patient information, patient stories and patient blogs: www.healthtalkonline.org (accessed 20 May 2013).

INVOLVE supporting greater public involvement in NHS, public health and social care research: www.invo.org.uk/resource-centre/ (accessed 20 May 2013).

MAGIC programme – Health Foundation: www.health.org.uk/areas-of-work/programmes/shared-decision-making/ (accessed 20 May 2013).

Self-management support: http://selfmanagementsupport.health.org.uk/ (accessed 20 May 2013).

Shared decision making: www.rightcare.nhs.uk/index.php/shared-decision-making/ (accessed 20 May 2013).

CHAPTER 4

Psychological Perspectives

Fiona Murphy
Trinity College Dublin, Ireland

Learning Outcomes

- To explore the psychological issues that patients may present with whilst preparing for and undertaking renal replacement therapy.
- To identify the means of support for patients and their families / carers / partners whilst undertaking renal replacement therapy.

Introduction

The variety of psychological effects that patients face when living with chronic kidney disease (CKD) is well documented. This chapter aims to address the psychological challenges that patients face, along with those that may be experienced by their partners / families / carers when living with CKD. It will highlight the various psychological effects that can impact upon patients, along with management strategies that may assist patients and their partners/ families and carers to cope with this chronic illness. The role of the various members of the renal healthcare team will be highlighted together with ways in which they can assist patients and families to cope with the various facets of treatment modalities for renal disease.

It is vital that the psychological perspectives of patients with renal disease are not underestimated. Hope, a patient living with CKD, identifies the need for more action to support the reduction of mental health problems for those living with long-term conditions (Hope 2012) following the recent report from the UK Department of Health (2011). This patient identifies the need for a robust campaign to highlight more awareness – among renal healthcare providers, patients and carers – of the cause, prevalence and frequency of renal replacement therapy (RRT) and its complications, including depression, anxiety and poor coping mechanisms that some patients face. There must also be recognition of the interrelationship between mental and physical health.

Hope (2012) further calls on the need to target what really is relevant to all patients across the age divide, which is quality of life (QoL). He asserts that by concentrating on

Renal Nursing, Fourth Edition. Edited by Nicola Thomas. Published 2014 by John Wiley & Sons, Ltd.

QoL, both physical and mental health can be delivered to patients where it is relevant in their lives when they are not receiving direct care. There is also a need to prioritise treatment modalities such as self-care in satellite units, home haemodialysis, continuous ambulatory peritoneal dialysis (CAPD) and pre-emptive transplantation, which provides patients with improved control over their lives and enhances overall QoL, along with mental and physical wellbeing. Finally, there is a need to recognise that kidney failure is a family concern as it can affect carers / family members' mental health, along with patients; it is important that patients and families / carers are all supported (Hope 2012).

Dixon (2012) identifies self- management and patient empowerment as familiar concepts in the management of CKD. It is untenable for the healthcare service not to prioritise and direct these concepts given the ageing population along with the number of people diagnosed with CKD and their subsequent demand on healthcare service. It is well documented how self-management promotes both physical and psychological wellbeing in individuals with chronic health illness. However this remains a challenge for both patients along with healthcare providers to create sustainable strategies. Living with CKD involves many challenges apart from the psychological impact of having a noncurable and life-threatening illness; these include illness-induced interruptions to day-to-day activities, interests and lifestyles. Patients need both psychological and social support to prevent them from assuming a fatalistic perspective and a view that they have no control over their circumstances – surrendering control. Emotional responses such as anxiety, depression, fear and uncertainty are commonly expressed by individuals living with CKD. There are many patients who do not have the self-confidence to self-manage their illness (self-efficacy), which has been related to emotions such as powerlessness and depression. However, psychological and social support are important factors in improving self-efficacy, which has been highlighted as the only independent predictor of self-care/ self-management. There is a need for a high input of psychosocial support including practical and financial advice for the many challenges that renal patients face on a daily basis if high levels of self-efficacy and sustainable self-care / self-management are to be achieved. In current recessionary times, it is important to recognise that both psychological and social support care delivery could be affected in favour of the physical aspects of renal care delivery. The relevance of self-care must not be underestimated in patients living with CKD as they are inescapably their own carers and they need this psychological support. If this area of support delivery is reduced it could negatively affect clinical care outcomes along with patients' overall wellbeing and QoL (Dixon 2012).

Chronic Kidney Disease

The majority of patients with CKD stage 4–5 (estimated glomerular filtration rate (eGFR) $<30\,\text{ml/min/1.73}\,\text{m}^2$) or with CKD stage 3 and rapidly deteriorating renal function should be referred to a nephrologist for assessment (see Chapter 6). Ideally, patients should be referred at least a year before it is considered that they need RRT (Farrington and Warwick 2009). Fischer *et al.* (2011) assert that interventions are badly needed to diminish late referrals for treatment and enhance patients' health when living with CKD. Smart and Titus (2011) assessed the impact upon clinical outcomes of early versus late referral of patients to renal services. They highlighted the advantages of early referral, including enhanced survival and reduced hospital stay. It must be recognised, however, that the percentage of people who are referred to renal care late (that is, within three months of requiring dialysis) has diminished since the early 2000s, possibly due to the introduction of eGFR and better identification of people at risk of progressive CKD by primary care practitioners. See Chapter 6.

The NICE guidelines (National Institute for Health and Clinical Excellence 2011) highlight that patients and their families must be provided with both oral and written information concerning pre-emptive transplant, dialysis and conservative care to enable them to make informed choices about their treatment. Patient-centred care must be provided that takes on board patients' unique needs and preferences. The management of care must be maintained by evidence-based information, which enables patients to make informed decisions concerning their care. There must be effective communication with all the relevant parties involved. Patients and partners/ families and carers must be giving the opportunity to participate in decision making concerning their treatment and care (National Institute for Health and Clinical Excellence 2011).

There are many challenges facing individuals living with end stage renal disease (ESRD), particularly those receiving dialysis. Patients usually undertake dialysis three times per week for 3–5 h each time, or undertake peritoneal dialysis exchanges three to four times daily or attached to a machine at night time, for many years consecutively. This all indicates having to manage major stressors including symptoms of CKD, and the related problems psychosocial consequences. Patients are often confronted with limitations in food and fluid intake with symptoms such as itching and lack of energy, with psychological stressors such as loss of self-concept and self-esteem and feelings of uncertainty about the future (Kaptein *et al.* 2009).

Patient Choice

There are two main types of dialysis available: haemodialysis (HD) and peritoneal dialysis (PD). Each of these can vary – for example, there can be home haemodialysis, in-centre haemodialysis along with CAPD, assisted peritoneal dialysis (aPD) and automated peritoneal dialysis (APD). It is important to explain all of the treatment options that are available. The major considerations that determine the best form of dialysis for individuals with CKD are their preferences concerning which therapy suits their daily life best, the choices that are available within their renal unit and clinical contraindications. Other considerations concerning PD that patients and families / carers should take into account include the skill to undertake this form of dialysis themselves; social support to assist them to undertake PD; incorporation of dialysis within personal and professional activities; opportunities to retain social connections; potential adaptations to their home; the time and distance journeying to hospital; flexibility of daily therapy; nutritional and medication regimens and potential alterations to body image and physical pursuits due to dialysis access points (National Institute for Health and Clinical Excellence 2011).

Haemodialysis

According to Wadd *et al.* (2011) there is a paucity of literature that has examined the experiences of parents receiving haemodialysis. Related research has identified vital themes such as restricted lives; relationships; changes; ramifications and future outlook. Parents experience numerous illness-related symptoms, including fatigue and uraemia. These can impact upon their ability to provide both physical and emotional support to their children. The time spent with dialysis treatment can minimise time spent engaging with children in both play and school activities along with other day-to-day activities such as work and household responsibilities. Wadd *et al.* (2011) asserts the necessity for further research in this area to ascertain the experiences from parents' viewpoint.

In the study by Harwood *et al.* (2009) an instrument (CKD stress inventory – CKDSI) was developed to measure the stressors of CKD patients, the identification of these stressors, and to ascertain what coping strategies were used and effective. The CKDSI is a 34-item instrument, which is classified into logistical, psychological and physiological stressor subscales. The most recurrently reported stressors were fatigue, difficulties in sleeping, peripheral neuropathy, muscle cramps, restless legs and shortness of breath. The most frequently and effective coping strategy was optimism. Other effective and commonly utilised strategies were confrontation (such as challenging a stressor head on), supportant (accessing support from others), and self-reliance, whilst emotive, fatalistic and evasive strategies were less routinely used. There was a positive association between stress and coping with less stress reported by older adults and those with more kidney dysfunction.

It has been highlighted that renal healthcare providers need to create strategies that promote patients to use humour effectively, along with positive thinking, whilst concurrently educating patients to use strategies that assist them to maintain normality within their life as much as feasible. It is also important that staff recognise those individuals that react more emotionally and demonstrate more stressors and less effective coping strategies. A collaborative team approach may assist these individuals using an educational and supportive care plan that can assist them to both adapt and manage their CKD (Harwood *et al.* 2009). It must be recognised, however, that those who are not coping do not always show emotion.

Harwood *et al.* (2012) hypothesised that increased stressors and maladaptive coping responses would impact upon the selection of dialysis modality, specifically home HD. This study highlighted that individuals on home dialysis versus in-centre haemodialysis reported significantly fewer predialysis stressors, although coping was not associated with dialysis modality. The authors concluded that predialysis stress levels predicted dialysis modality and recommended further interventional studies to address chronic kidney disease stressors with the aim to improve home-dialysis usage.

An arteriovenous fistula (AVF) is ideally the vascular access of choice for haemodialysis, followed by the arteriovenous graft (AVG), with the least preferred option being the central venous catheter (CVC) (Murphy 2011a). Preparation for AVF access should follow when patients are at stage 4 CKD (eGFR less than 30 ml/min/1.73 m^2). The AVF should be created three months (minimum) before the initiation of HD, although ideally not in excess of one year from the expected date of HD. However, it can be difficult to predict the rate of progression in some patients, thereby making the timing of access placement problematic (Fluck and Kumwenda 2010).

Patients should be involved in their illness pre- and post-vascular access insertion and long-term management. There can be significant problems related to vascular access resulting in increased morbidity and mortality if not properly treated. It can be very difficult for patients to adapt to having a chronic illness and the prospect of having HD treatment. There must be continuous education and psychological support provided to the patients and partners/ family members.

Patients can experience body-image concerns, self-concept, and anxiety regarding their vascular access (Dinwiddie 2008). Patients must remain at the centre of care delivery as vascular access is their lifeline to haemodialysis treatment. The renal healthcare team, especially the nurse, play a vital role in the management of patients' vascular access (Murphy *et al.* 2011).

Peritoneal dialysis

Keddo (2010) asserts that the nurse's attitude and confidence during the initial meeting with the patient and his or her family is vital as it could make the difference between

a successful PD assessment and one that is not. This could be said with any meeting with patients and their partners/ families and carers to discuss treatment options. There are many psychosocial challenges whilst trying to adapt to PD. This includes language, literacy, limited memory and family support. Language can be a challenge and an impediment to learning if, for example, the patient does not speak the native language (Thomas 2009). McClure (2010) concurs that there are additional challenges for those patients who do not speak the primary language that the nurse or trainer speaks. Factors such as previous learning experiences, ability to learn and repeat skills, uraemia levels when training occurs, comorbid problems, amount of fatigue and current health beliefs may all contribute to patients difficulties in learning the information required.

The physical environment where the teaching sessions are conducted must be quiet and free from disturbance and distraction. This environment can affect both the mental and emotional environment. The nurse must build a trusting relationship and achieve the means of communicating effectively using a culturally competent approach to enhance the chance of success. There can be limited resources available concerning translation services. This being the case, the onus is usually placed upon a younger member of the family such as a son or daughter to translate for the patient. This presents its own challenges as it can be difficult to ascertain whether the patient has grasped the information or whether it is the translator (family member) only (Thomas 2009). Various educational support materials can be used to support the information process including DVDs, technical manuals and picture guides. It is important to ensure that renal healthcare providers have specialist knowledge concerning CKD and the essential skills to encourage decision-making. This can include skills in promoting and using decision aids to assist patients make decisions concerning their care and treatment (National Institute for Health and Clinical Excellence 2011).

Depression

Depression can be experienced in 2–10% of the general population; however, it is prevalent in 20% to 30% of patients on dialysis. Dobbels *et al.* (2010) asserts that symptoms of depression, along with specific depressive conditions, are prevalent both in patients on dialysis as well as following kidney transplant. Patients that are depressed often have reduced quality of life, further functional impairment, compounded pain, and worse concordance with medical treatments. Furthermore they have more episodes of hospitalisation and greater mortality.

Depression is diagnosed and managed only in a minority of patients, regardless of the high predominance and poor outcomes related to depression in dialysis (Holley 2013). Holley (2013) asserts that depression can impact upon the patient and his / her partner / family's response to management and participation in advance care planning. Recognising depression in a dialysis patient consequently can impinge upon overall treatment and quality of life along with physical symptoms and reactions to dialysis care.

It is worth considering screening for depression in patients on dialysis, due to the significant effect upon patient outcomes and overall goals for treatment. There are a number of recognised validated tools that are used for screening depression including the Beck Depression Inventory (Beck *et al.* 1961), and the Centre for Epidemiologic Studies Depression Scale (Radloff 1977). The majority of these tools can be completed in a number of minutes and, with some individuals, this screening is an essential addition to screening for diminished cognition. The physical symptoms that are typical of depression and may be more common in patients on dialysis include reduced energy, fatigue, sleep disorders, reduced appetite and difficulty concentrating. However in order

to diagnose depression these physical symptoms must be accompanied by either feelings of sadness or lack of interest (Holley 2013).

Renal healthcare providers may play a pivotal role in establishing coping strategies. One of the treatment strategies for depression is to identify previously used coping strategies. Coping strategies are usually categorised as task oriented or emotion oriented. The individual must ascertain the stressor, initiate alternative solutions and reduce the expectations in task-oriented coping strategies. Some personality traits such as extraversion and frustration tolerance are related to task-oriented coping, whilst emotion-oriented coping strategies aim to influence the emotions affected by the stressors (Yeh *et al.* 2009). Keskin and Engin (2011) aimed to assess depression and suicidal ideation and coping strategies with stress in patients undergoing haemodialysis therapy. They found that patients firstly selected task-oriented coping strategies, followed by emotion-oriented coping strategies and finally dysfunctional coping strategies. Both levels of depression and thoughts of suicide were high among patients who had lower education status and were receiving dialysis treatment for one to five years.

It is vital that nurses assess their patients using a holistic approach and consistently manage depression symptoms and suicidal ideation so as to improve quality care delivery. Nurses using integrated evaluation, are vital in enhancing the mental health of patients living with ESKD (Keskin and Engin 2011).

Sexuality

It has been identified that there is a high prevalence of sexual difficulties in patients with CKD, with 75% of men receiving dialysis experiencing erectile dysfunction and 30 to 80% of women with symptoms associated with sexual dysfunction. Navaneethan *et al.* (2010), in their systematic review and meta-analysis of observational studies, highlighted that, despite the incidence and clinical importance of this area, there were many limitations to the studies reviewed, including a poor response rate and lack of validated tools to assess sexual difficulties. There were also limited studies addressing this area in women with CKD, who were not dialysis dependent. The development and expression of sexuality is influenced by biological and psychosocial factors. Sexuality can be a challenging concept to define. It is a multidimensional concept that incorporates a wide range of enjoyable sexual activities that may or may not include coitus but also touching, kissing and embracing. It also includes body image, self-esteem, self-image and how other individuals perceive us. It can be viewed that being a sexual individual is healthy. Therefore, participating in sexual intimacy might permit a means of helping individuals who are living with chronic illness to feel 'normal' (Sheils 2003; Lemieux 2004; Murphy 2011b and 2012; National Kidney Foundation 2011).

There are a number of contributory factors that can lead to the development of sexual difficulties in patients living with renal disease; these are medications, alterations in hormones, vascular, neurological and psychological factors (Navaneethan *et al.* 2010). Table 4.1 indicates the numerous physical and psychosocial sexual concerns associated with living with renal disease. These sexual concerns do not just impact upon patients but also their spouses/ partners / significant others. It can affect their overall QoL and can impact significantly upon their personal and overall family relationships. It can also be challenging for patients who are not in a relationship and who may be looking to meet a partner, or for those that are content not being in a couple, as overall body image can be altered when living with renal disease.

Table 4.1 Male and female physical and psychosocial sexual concerns living with ESRD

Men	Women	Both men and women
Tiredness	Tiredness	Anxiety, stress and depression
Decreased libido	Decreased libido	Fear of failure
Sexual arousal difficulties	Sexual arousal difficulties	Struggle in relationship with spouse/ partner
Erectile dysfunction	Absence of vaginal lubrication	Roles changes leading to reliance
Premature or delayed ejaculation	Pain during intercourse	Sense of guilt towards spouse/ partner
Difficulty in achieving orgasm	Difficulty in achieving orgasm	Diminished confidence in sexual identity
	Altered menstrual patterns	Changes in body image and reduced self-esteem
	Anovulation	
	Fertility problems	

Source: adapted from Auer (2008) and Levy *et al.* (2009).

Body image is intertwined closely with sexuality. Patients living with PD and HD require vascular access surgery, which can lead to scars and potential deformities. There is also the psychological impact on how patients feel with a potential foreign body in terms of a PD catheter inserted into their abdomen or living with a central venous catheter (CVC) in the neck or an AVF in the arm. Patients may feel that such vascular access is a constant reminder of living with their chronic illness. It has been regarded as the patient's 'lifeline' and therefore must be monitored carefully. Concurrently patients can feel unattractive and self-conscious of these 'lifelines' and may alter their self-image accordingly, for example avoiding wearing short-sleeve tops or keeping their shirts or tops buttoned up to avoid showing their central lines or fistulae when out in public, in case they attract stares. They may also find it difficult to undress in front of their spouses / partners or become intimate, for fear of being rejected by them. This may be a more significant issue in patients living with PD in terms of their abdominal catheter and positioning it when trying to be intimate with their spouses / partners.

Furthermore, patients can complain of abdominal discomfort and distension with dialysate fluid, which can impair their body image with regard to clothes size having to be increased to accommodate an extended abdominal girth. This can, again, all impact on their self-esteem and overall body image, leading to patients potentially feeling unattractive, unwanted and depressed – and leading to social isolation. One could argue that there is a double-edged sword with regards to the use of some medications that patients have to take to manage their treatment, such as antihypertensive drugs, and possible side-effects such as erectile dysfunction. The use of immunosuppression medications post-transplant can result in side effects that can affect body image such as hirsutism and weight gain. Sexuality is not just relevant with patients who are receiving dialysis but also those that have chosen conservative management. It can remain an integral part of their lives and should not be assumed that it is not relevant towards end of life care. The concept of emotional connection may take priority over the physical aspect of sexuality at this stage (Murphy 2011b and 2012).

The management of these sexual difficulties includes optimising dialysis treatment, addressing dietary, anaemia, endocrine abnormalities and hyperparathyroidism issues, and reviewing drug therapy and erectile dysfunction and psychosocial issues (Levy *et al.* 2009). It is important to broach this sensitive subject with patients as if members of the renal healthcare team, especially nurses, do not do so there can be a strong possibility that patients will not introduce this subject as they could feel embarrassed and

uncomfortable in discussing it. Renal nurses must be comfortable with their own sexuality in order to discuss this subject and put aside their own preconceived ideas. They must be good communicators and be able to recognise when some patients do not want to discuss this subject, watching for verbal and nonverbal cues and being mindful of cultural issues and the physical environment at the time in terms of privacy. Not all patients identify sexual concerns as being an issue for them; this must be also acknowledged by nurses. However, the matter should be introduced and then it should be ascertained whether this is an issue for further discussion. It is important to involve the spouses / partners as much as feasible to enable them to feel included in this process and to ascertain their experiences. Patients must be educated in how to manage these sexual concerns and where to seek further assistance and advice, as nurses are usually not trained counsellors. The renal healthcare team also needs to be educated in how to discuss this subject and to recognise that it is a real and valid concern for their patients. The renal healthcare team must recognise that this area is an intrinsic part of the patients care delivery. If it is not addressed and managed by nurses – as they are usually at the centre of the patients' care – patients could needlessly suffer in silence (Murphy 2012).

Patient Education

Shared decision making is vital for renal care delivery. A recent group has formed in the UK representing people living with CKD, including patient organisations, nurses, physicians, experts and researchers in shared decision making. This is being assisted by the National Health Service Institute for Innovation. The aim of this group is to ensure that individuals with advanced CKD will be supported in making choices regarding their treatment. They and family members / carers they wish to include will receive information regarding every clinical appropriate option for the management of their kidney disease. There will be training and support provided to clinicians in the provision of decision support and information along with the usage of readily accessible tools (MacManus *et al.* 2012).

MacManus *et al.* (2012) assert that these aims will be readily accomplished if clinicians can take action. The actions that will make a significant change include clinicians being prepared to use decision aids when discussing patients' treatment choices along with the provision of this information through the use of different formats. This will assist individuals with advanced kidney disease to comprehend the various clinically appropriate options available to them. Clinicians should also be able to assess the degree to which individuals are included in decision making concerning their care and to use this assessment to improve the service provided (MacManus *et al.* 2012). The decision aids for dialysis can be found at http://sdm.rightcare.nhs.uk/pda/established-kidney-failure-dialysis/ (accessed 20 May 2013).

The importance of early patient education cannot be underestimated. An Australian review by Strand and Parker (2012) compared the effectiveness of multidisciplinary care with traditional medical care on the progression of CKD stages 3 to 5. The multidisciplinary model of care is organised to provide individualised care to delay or prevent the advancement of CKD along with addressing the areas essential to attain a higher level of well-being or QoL for patients living with CKD. This review highlighted that education is a vital component that must be incorporated within multidisciplinary care.

There are many difficult challenges facing patients living with CKD; those patients that are approaching RRT have monumental decisions to make as to what treatment

modality to opt for (Harwood and Clark 2011). All the current guidelines, including the European Best Practice Guidelines, the Canadian guidelines for CKD management and the Caring for Australians with Renal Impairment (CARI) guidelines, recommend the importance of educational programmes to enable patients to make informed choices of treatment options. Education can be regarded as the most substantial intervention enabling patients (Harwood and Clarke 2011).

Farrington and Warwick (2009) advocate that all patients should be encouraged to undertake home dialysis therapy where feasible, as part of an integrated management to RRT. They suggest that, where home dialysis is not feasible, patients and their partners/ carers should be actively included in their dialysis treatment, be supported to perform as much self-care as feasible and be engaged in every facet of their treatment including the management of medication and alterations in diet and lifestyle (Farrington and Warwick 2009).

It is recommended that all patients with severe CKD (progressive stage 4 and stage 5), along with their families and carers, should be provided with a suitable education programme aimed at enhancing their knowledge and comprehension of their condition, and of the choices for treatment. Education programmes should be multidisciplinary, multifaceted, individualised to the needs of the patient, and grounded on adult learning principles. There are a number of educational methods that should be accessible, including individual conversations, group work, written resources, DVD/CDs and contact with expert patients, along with opportunities for informal follow up. The information delivered must be pertinent to the individual, with the approach, balance, speed and extent of the delivery being matched to the individual's learning style, ability and preferences. The education programme must also include provision for the education of patients who are referred late to dialysis, and commence dialysis in an unplanned way (Lecouf *et al.* 2013). Prerenal replacement therapy education programmes for patients and their families and carers should be sustained into the treatment period, with the purpose of enhancing patient involvement in their own care, increasing treatment concordance, and promoting good communication and cooperative relations with caregivers (Farrington and Warwick 2009). See Chapter 6.

Self-Care

The concept of self-care is now extensively encouraged for the management of chronic illness. Some good examples of where self-care can be taught are those of home dialysis therapies (either HD or PD); where patients can learn to manage their often complex treatment. This is in contrast to many patients that attend both large centre and satellite HD units who can become very reliant on the renal healthcare providers and their partners/ families. This may be partly associated with their co-morbid conditions but may also be pertinent to the concept of 'learned helplessness', which was highlighted in the initial days of dialysis; this concept is, however, more pertinent currently with the advancing age of the RRT population. The concepts of enhancing both self-care and self-efficacy have become more prominent in recent years amid patients with CKD.

There are a number of dialysis units in the UK where patients who have hospital-based therapies are encouraged to take greater involvement in their dialysis from the initial diagnosis and ongoing to patients undergoing RRT (Appleby 2013). Should patients not accept the gravity and the chronicity of their illness it can lead to difficulties in accomplishing educational goals and concordance with the rigour of the treatment. Additionally, individuals learn more efficiently when information is accessible in

a manner which concurs with their own learning style and choices; using a number of teaching methods should assist patients to learn (Farrington and Warwick 2009).

Cove (2012) highlights the importance of psychological preparation in the care of patients in their adjustment to major changes in both health and treatment status from stages 4 and 5 CKD, to transition to ESKD and RRT and renal transplant. The lack of psychological preparation can lead to adverse patient outcomes, including late initiation on RRT with related risks such as cardiovascular disease (CVD). Limited psychological preparation with renal transplantation can lead to acute rejection incidences along with the possible loss of the graft. Renal healthcare providers can assist patients through these challenges; however, there are patients that struggle. Adapting to their disease progression may require more intensive treatment (Cove 2012). The transtheoretical model of behaviour change or stages of change model ascertains a person's willingness to move towards healthier behaviour through a progression of psychological stages (see Box 4.1).

BOX 4.1

Transtheoretical Model of Behaviour Change (Prochaska and DiClemente 1984; Cove, 2012)

- Pre-contemplation (not ready). Here patients do not plan to take action concerning their health in the foreseeable future and are not aware that their behaviour will cause problems (for example a patient not accepting yet that he/she requires RRT in the near future).
- Contemplator (getting ready). Here patients are starting to identify that their behaviour is not helping them; they can begin to consider the advantages and disadvantages of their actions.
- Preparation (ready). Here patients intend to take action in the near future and start taking small steps in changing their behaviour.
- Action: here patients make precise overt behaviour modifications or in attaining new healthy behaviours.
- Maintenance: here patients are able to maintain action for a while and work towards preventing a relapse.

Conservative kidney management (nondialytic options)

It is important that patients with advanced CKD have all treatment options discussed with them and their partners / families. There are a large number of older people presenting for dialysis who can be frail, require assistance and have co-morbidities such as heart disease and diabetes. With some older patients dialysis may be a difficult treatment option and may not necessarily lead to an improved QoL along with prolonged survival.

Choosing a treatment option is a very personal decision. For some patients, haemodialysis might be desirable whereas others might prefer peritoneal dialysis. Other patients who present with serious medical problems might be better advised to manage their symptoms. Conservative kidney management is where the patient opts not to have dialysis but will have continual assistance from the multidisciplinary team in terms of symptom management and control, along with palliative care and social work support (Alston and Farrington 2012).

The decision to commence RRT in individuals with CKD stage 5 should be founded on a thorough discussion with the patient to ascertain the risks and benefits of RRT, taking

into consideration the overall signs and symptoms of renal disease, co-morbidities, nutritional and functional status, along with the psychosocial and physical implications of commencing dialysis for that individual. The care needs should be prioritised for those patients with advanced kidney disease (CKD stage 4 and 5) who have chosen not to commence dialysis and who are undertaking conservative kidney management.

It is especially important for those patients who have imminent end-of-life care needs. Those patients who are failing despite dialysis and are finding it very difficult to cope with long-term treatment due to advanced decline of underlying, irrevocable clinical conditions or an acute condition, for example a severe stroke, should be acknowledged as being in imminent need of end-of-life care. These patients should have an advance care plan and these discussions must be made mutually by the patient and the care team in consultation with partners / relatives and carers, in collaboration with the family GP. There must be a full assessment conducted to assess the patient's competence along with the formal exclusion of depression. In the last few days of the patient's life there must be the appropriate relief of symptoms, along with psychological, spiritual and cultural care as applicable to the dying patient and his/ her family; this may be at home, at a hospice or a hospital setting as applicable. See Chapter 10. There must be a provision of a suitably cultured bereavement support for the family and carers (Farrington and Warwick 2009). See Chapter 11.

Transplantation

It is vital to maintain the patients' wellbeing whilst waiting for a kidney transplant (Murphy *et al.* 2011). All suitable patients should be listed for cadaveric transplantation six months prior to the expected commencement of RRT. The advantages of pre-emptive transplantation should be advised to all patients that are medically fit for surgery. There should be efforts made to detect a potential donor to enable pre-emptive transplantation prior an individual's requirement for RRT (Farrington and Warwick 2009).

Living kidney donation enables arrangement of a transplant at a period when the recipient is in the best medical and psychological condition (Dudley and Harden 2011). The living kidney donor gains no physical advantage from the transplant operation, however he/she generally gains psychological benefit knowing that their gift has provided an opportunity to improve the QoL of a partner/ family member, friend, or in the case of a stranger, altruistic or paired donation. If a donation does not occur (for whatever reason) a potential living donor may be psychologically affected (British Transplantation Society and the Renal Association 2011).

The potential living donor should not feel pressurised to participate with the transplant procedure: who apart from the actual donor him / herself can establish that his/ her consent to surgery is 'freely given'? It may be possible for the renal healthcare providers to recognise a donor who has visibly been put under pressure from either the potential recipient or from members of the applicable family. However, understated demands may exist in various situations that the donor does not disclose and the renal healthcare providers do not discover. This may make it challenging or unfeasible for a potential donor not to continue with the transplant procedure (British Transplantation Society and the Renal Association 2011).

It is vital to identify that there be numerous variants of informed consent 'freely given' as with paired donor-recipients. In a paired donor exchange, two kidney recipients essentially 'swap' willing donors. While medically eligible to donate, each donor has an incompatible blood type or antigens to his or her intended recipient. In the majority of circumstances both the intentions and autonomy of the potential donor will

be without question. However, there may be situations that could be more problematic to ascertain if consent is both cognisant and freely given.

This remit may be operated by a more formal independent third party, known as the Independent Assessor or by a living donor coordinator. There is therefore a recommendation for independence between the healthcare providers responsible for the donor and the recipient; this may be known as a donor advocate. It is vital that this partition of responsibility remains customary and is applicable to every potential living donor. The donor advocate will be an informed renal healthcare professional who is not directly included with the recipients' care. He / she will answer any unresolved questions, worries or challenging issues, and this empowers the donor to make a sincere autonomous resolution. It must be recognised that it may not always be feasible to isolate the donor and recipient healthcare professional teams even though it is regarded as best practice.

It is important for the potential donor to comprehend that he / she is not the only potential transplant source. This may be more specific when a potential recipient is deemed as unsuitable for inclusion on the deceased donor waiting list but is deemed as an acceptable risk for a planned living donor transplant. The donor in this situation must not feel obliged to donate. The donor may also feel that there would be family conflict if he / she does not wish to donate but remains anxious that refusing to donate would impact upon family dynamics. In this situation the donor advocate must engage in discussions to reduce any potential damage to family relations. It is ideal from the start of this process to foster open and frank discussions between the donor and the recipient. This pre-emptive discussion assists in ensuring that both donor and recipient are fully aware how information will be managed by their own renal healthcare teams and in reducing the possibility of conflict (British Transplantation Society and the Renal Association 2011).

It must be recognised that not all recipients wish to receive a living donor transplant. Healthcare professionals and family members may assume that the patient will be willing accept a living donation but this is not always the case. This decision should be respected by all concerned as long as the patient has made an informed choice. In these situations, patients may require additional support and guidance to decline the offer without resulting in distress or relationship difficulties with the potential donor. There should be good support available where potential recipients have built positive relations with the transplant team. However an independent third party provides a different facet; this may be more relevant with young adults. There can be an opportunity here for an environment where patients can potentially feel less pressurised and be in a position to express their concerns regarding accepting a kidney (British Transplantation Society and the Renal Association 2011).

Support for the recipient of a transplant can be divided into two major components: the psychosocial evaluation for transplant candidacy and symptom management post-transplantation. There is a bidirectional association between mental illness and kidney disease. Poor transplant outcomes are related to co-occurring psychiatric conditions. This has been ascribed to behavioural influences such as nonconcordance (nonadherence) along with physiologic factors for example alteration of immunologic and stress reactions.

There is a need for a biopsychosocial evaluation of patients post-transplant, addressing issues such as mood or worries, changes in perceptions, morose thoughts concerning self-harm or harm to other individuals, behavioural symptoms including concordance, taking risks, substance abuse, along with environmental and personal stressors. These areas may be tempered by positive influences including social support, perception, spirituality and the usage of adaptive coping methods (Danovitch 2010a).

It is recommended that kidney transplantation should be the RRT of choice for those patients with CKD stage 5 who are considered both suitable for major surgery and for

chronic immunosuppression. Every individual that is expected to have an improved life expectancy post-transplantation should be assessed for transplantation (Dudley and Harden 2011). The UK Renal Association clinical practice guidelines also recommend that all transplant units should have written standards for approval onto the waiting list. Both the advantages and possible risks associated with transplantation should be fully explained both verbally and in writing to each patient and his/ her partner and family. Potential transplant recipients should be advised of all donor options, including living related and unrelated donation (Dudley and Harden 2011).

Dialysis can be a period of 'marking time' when waiting for a kidney transplant (Auer 2008). For most patients living with progressive CKD, kidney transplantation has the best prospect for re-establishing a healthy constructive life and can be regarded as a 'symbol of freedom' (Danovitch 2010b; Hersh Rifkin 2010). It is well documented in the literature that kidney transplantation can be regarded as having many benefits including:

- freedom from undergoing dialysis and its associated restricted diet and lifestyle;
- increased energy along with enhanced mental wellbeing;
- better opportunity to return to work;
- increased capability to maintain sexual relations along with the possibility of having a family for women of child bearing age (Auer 2008; Wilkinson 2010; Hersh Rifkin 2010).

Generally QoL is better for recipients of transplants compared with QoL on dialysis, with 80% of transplant recipients performing at normal levels psychosocially in comparison with 50% of patients on dialysis. This is partly because patients are not spending copious amount of time undergoing dialysis treatments – each month, patients can spend typically 40 to 50 hours on haemodialysis, 60 to 70 hours undertaking CAPD exchanges, 280 hours with automated peritoneal dialysis and an average of 50 hours with self-care home haemodialysis therapy. Transplant recipients have therefore more time to spend away from managing their condition, along with increased stamina and energy. This can lead to greater opportunities to return to work along with more time spent with family and personal issues (Hersh Rifkin 2010).

However, it must be remembered that transplantation does not occur in clinical isolation, as the majority of pretransplant patients have been exposed to CKD and all its associated complications (Danovitch 2010b). It is important that there is a continuous multidisciplinary alliance when discharging patients from the transplant unit home and into the primary care setting (Murphy *et al*. 2011). There are two main stages in the first-stage management of kidney transplantation – avoiding acute rejection and avoiding opportunistic infection. The purpose of the second or later stage is to retain good graft function along with deterring the long-term consequences of immunosuppression such as infection, malignancy and premature cardiovascular disease (Baker *et al*. 2011). The foundation for the care of kidney transplant recipients is that of education, as patients need to acquire self-care skills. (Murphy 2007). Patients must be able to recognise and act upon the signs and symptoms of rejection. They must know to contact the transplant unit should they have any concerns. The self-care regime includes how to monitor their blood pressure, weight, temperature, urinary output and glucose levels as applicable. It is vital that patients understand the signs and symptoms to look out for in terms of rejection (Wilkinson 2010). See Chapter 10.

Patients' experiences after transplantation are multifaceted. Prior to transplantation they have mixed emotions contemplating their current situation (i.e. dialysis treatment) versus their concerns for their new life after transplantation, which are affected by their former experiences. Concerns include hope for a better quality of life after

being advised that they will receive a kidney. They have mixed feelings such as shock, potential doubt and uncertainty that the donor kidney will provide the desired effect for positive changes in their lives (Wiederhold *et al.* 2011). There were a number of themes described by Wiederhold *et al.* (2011), who discussed the patients' experiences after transplantation. These were *experience of positive changes, dealing with the organ; experiences of impairment and worries; experience of self-confidence; experience of the need for support* and finally *patient education*.

Patients indicated that if the transplant is a success then this is a new phase in their lives and the transplant is viewed as a gift. They expressed their sincere appreciation toward the donor and his / her family who permitted the transplantation to proceed. The theme of the *experiences of positive changes* highlighted the joy and happiness for patients who experienced a new-found freedom from dialysis restrictions, along with hope for more independence and better performance in both personal health and professional lives. The theme of *dealing with the organ* addressed the difficulties that patients face in this initial stage trying to adapt emotionally and psychologically to the new situation. The patients realised that they must take care of themselves on a day-to-day basis, now with added responsibility of caring for the transplanted kidney.

The theme of *experience of impairments and worries* addressed the concerns that patients face, including resuming their previous employment if feasible, potentially minimising their working hours or even postponing the resuming of their working life in order to maintain the longevity of the transplant. The theme of *experience of self-confidence* highlights patients' abilities to adapt with the situation as a result of great self-confidence. In the first few weeks after transplantation there is a period of enjoyment with the new transplant, where patients reclaim their independence and quality of life. All of these positive changes empower patients to regard their new and unaccustomed situation with optimism and both family and the social environment support are regarded as vital in assisting patients to adapt.

This study showed that patients had little idea of how to adapt with their new kidney and there was a need for support and education in managing the transplant. Patients discussed the concept of trying to understand their new medications whilst the renal healthcare providers reiterated the importance of taking them constantly. In addition, there were many alterations concerning eating and drinking. The final theme discussed by these patients was *patient education*; this highlighted that patients identified the desire for real, substantial and daily practice recommendations with educational sessions facilitated in either one-to-one or group sessions (Wiederhold *et al.* 2011).

Patients may encounter numerous psychosocial risks after transplant, which may have a negative impact upon all concerned. Patients' family dynamics and working background may be changing, with some patients finding it challenging to move away from the dependent 'sick role' that they experienced on dialysis. The new associated freedom that comes with a transplant could be a risk to those patients who identified themselves within the sick role and it can be challenging to make the transition to health.

Guilty feelings may be expressed by patients who have received a kidney instead of another person. However there is a need to re-emphasise to patients that these emotions are common and that they are worthwhile in terms of receiving this altruistic donation from the donor and his/ her family.

The social aspects of dialysis sessions may be missed by some patients. All of these issues and concerns may result in personal relationship difficulties with partners and family members, along with anxieties about entering the workplace or genuine concerns about losing financial assistance such as potential disability benefits (Hersh Rifkin 2010).

It can be uncertain how patients will adapt to the medication regime and the associated side effects. Physical side effects including hirsutism, possible weight gain and gum overgrowth, which can all affect the body image of patients and how they relate to their partners/ significant others. These side effects are usually temporary and can be managed but this must be explained to the patient and family. Body-image concerns may not always be obvious to patients and their spouses; they might not be discussed or addressed by either party or with the transplant unit. There is a need for sensitivity and open discussion by the renal healthcare providers (Hersh Rifkin 2010; Murphy 2012).

The side-effects mentioned above could cause patients to not take their medications as prescribed, so it is important to assess the patient's opinions towards these side-effects. Some of the side-effects can be reduced by concentrating on lifestyle, including diet and exercise. Patients can be encouraged to self-manage their care instead of expecting failure. The issue of concordance can be a major concern due to its high associated threat for both acute rejection and graft loss. It is recommended to identify factors (see Box 4.2) that are associated with nonconcordance and identify the necessity for a care pathway that would assist those patients who are regarded as an increased risk or with recognised nonconcordance (Hersh Rifkin 2010; Kidney Disease Improving Global Outcomes (KDIGO) 2010; Baker *et al.* 2011).

Education, prevention and treatment strategies can be provided to minimise nonadherence. Individual counselling sessions may be necessary to assist patients and partners to deal with the life-changing event that transplantation presents. Patient support groups can also assist patients (Hersh Rifkin 2010).

BOX 4.2

Risk factors for nonconcordance of medication (KDIGO 2010)

- History of nonconcordance behaviour preceding transplantation.
- Mental health illness.
- Personality conditions.
- Reduced social support.
- High risk behaviour such as substance abuse.
- High education level.
- Teenager.
- Period since transplantation.
- Limited sufficient after care with transplant specialists.
- Inadequate education prior to transplant.
- Challenging medication regimens.
- Numerous adverse effects from medications.

Conclusion

This chapter has addressed the various psychological challenges that patients and their family members face when trying to cope with CKD and the treatment options. The challenge is for renal healthcare providers to enable patients to learn to adapt and try their best to live with the treatment modality chosen. There must be appropriate care pathways for each individual patient. Positive partnerships with patients and their family members can foster increased shared-decision making and self-care. Many patients do require psychological support from the renal healthcare team and it is important to recognise this early.

References

Alston, H. and Farrington, K. (2012) What I tell my patients about conservative kidney management? *British Journal of Renal Medicine* **17** (3), 15–17.

Appleby, S .(2013) Shared care, home haemodialysis and the expert patient. *Journal of Renal Care* **39** (Suppl.1), 1–6.

Auer, J. (2008) Psychological perspectives, in *Renal Nursing* (ed. N. Thomas), 3rd edn, Balliere Tindall Elsevier, Edinburgh, pp. 73–102.

Baker, R, Jardine, A and Andrews, P. (2011) *Post-operative Care of the Kidney Recipient,* 5th edn, www.renal.org/Clinical/GuidelinesSection/Post-operative-Care-Kidney-Transplant-Recipient.aspx (accessed 20 May 2013).

Beck, A.T., Ward, C.M., Mendelson, M. *et al.* (1961) An inventory for measuring depression. *Archives of General Psychiatry* **4,** 561–571. DOI:10.1001/archpsyc.1961.01710120031004. PMID 13688369.

British Transplantation Society and The Renal Association (2011) *United Kingdom Guidelines for Living Donor Kidney Transplantation,* 3rd edn, www.renal.org/Libraries/Other_Guidlines/BTS_and_RA_Guideline_on_Living_Donor_Kidney_Transplantation_3rd_Edition_April_2011.sflb.ashx (accessed 20 May 2013).

Cohen, S.D. Holder-Perkins, V. and Kimmel, P.L. (2007) Psychosocial issues in end-stage renal disease patients, in *Handbook of Dialysis* (eds J.T. Daugirdas, P.G. Blake and T.S. Ing), 4th edn, Wolters Kluwer/ Lippincott Williams & Wilkins, Philadelphia, pp. 455–461.

Cove, J. (2012) A new approach to psychological support in the renal setting. *Journal of Renal Nursing* **4** (1), 6–11.

Danovitch, I. (2010a) Psychiatric aspects of kidney transplantation, in *Handbook of Kidney Transplantation.* (ed. G. Danovitch), 5th edn, pp. 389–408, Wolters Kluwer Lippincott Williams & Wilkins, Philadelphia.

Danovitch, G.M. (2010b) Options for patients with end-stage renal disease, in *Handbook of Kidney Transplantation* (ed. G. Danovitch), 5th edn, Wolters Kluwer Lippincott Williams & Wilkins, Philadelphia, pp. 1–18.

Department of Health (2011) *No Health without Mental Health: A Cross-Government Mental Health Outcomes Strategy for People of all Ages,* https://www.gov.uk/government/publications/the-mental-health-strategy-for-england (accessed 24 May 2013).

Dinwiddie, L. (2008) Vascular access for haemodialysis, in *Core Curriculum for Nephrology Nursing* (ed. C.S. Counts), 5th edn, American Nephrology Nurses Association, Pitman, NJ, pp. 735–765.

Dixon, M. (2012) Psychosocial support is the key to self-efficacy. *Journal of Renal Nursing* **4** (1), 4.

Dobbels, F. Duerinckx, N. Breunig, C. and De Geest, S. (2010) What every renal nurse should know about depression. *Journal of Renal Nursing* **2** (1), 6–11.

Dudley, C. and Harden P. (2011) *Assessment of the Potential Kidney Transplant Recipient*, 5th edn, www.renal.org/Clinical/GuidelinesSection/AssessmentforRenalTransplantation.aspx (accessed 20 May 2013).

Farrington, K. and Warwick, G. (2009) *Planning, Initiating and Withdrawal of Renal Replacement Therapy,* 5th edn, www.renal.org/Clinical/GuidelinesSection/RenalReplacementTherapy.aspx (accessed 20 May 2013).

Fischer, M. J. Ahya, S. N. and Gordon, E. J. (2011) Interventions to reduce late referrals to nephrologists. *American Journal of Nephrology* **33,** 60–69.

Fluck, R. and Kumwenda M. (2010) UK Renal Association Clinical Practice Guidelines. Vascular Access for Haemodialysis, www.renal.org/Clinical/GuidelinesSection/VascularAccess.aspx (accessed 12 June 2013).

Harwood, L. and Clarke, A. M. (2011) Understanding health decisions using critical realism: home-dialysis decision-making during chronic kidney disease. *Nursing Inquiry* **19** (1), 29–38.

Harwood, L., Wilson, B., Locking-Cusolito, H., Sontrop, J. and Spittal, J. (2009) Stressors and coping in individuals with chronic kidney disease. *Nephrology Nursing Journal* **36** (3), 265– 276.

Harwood, L., Wilson, B., Sontrop, J. and Clark, A.M. (2012) Chronic kidney disease stressors influence choice of dialysis modality. *Nephrology Nursing Journal,* DOI: 10.1111/j.1365-2648.2012.05943.x

Hersh Rifkin, M. (2010) Psychosocial and financial aspects of transplantation, in *Handbook of Kidney Transplantation.* (ed. G. Danovitch), 5th edn, Wolters Kluwer Lippincott Williams & Wilkins, Philadelphia, pp. 432–440.

Holley, J.L. (2013) General medical care of the dialysis patient: core curriculum 2013. *American Journal of Kidney Disease* **61** (1), 171–183.

Hope, J. (2012) Call for action on mental and emotional health. *Journal of Renal Nursing* **4** (1), 5.

Kaptein, A.A., van Dijk, S. Broadbent, E. *et al.* (2009) Behavioural research in patients with end stage renal disease: a review and research agenda. *Patient Education and Counseling* **81,** 23–29.

Keddo, M. (2010) Assessing renal patients for their suitability for peritoneal dialysis. *Journal of Renal Nursing* **2** (1), 24–27.

Keskin, G. and Engin, E. (2011) The evaluation of depression, suicidal ideation and coping strategies in haemodialysis patients with renal failure. *Journal of Clinical Nursing* **20,** 2721–2732.

Kidney Disease Improving Global Outcomes (KDIGO) (2010) *Managing your Adult Patients who have a Kidney Transplant,* www.kdigo.org/pdf/KDIGO_TX_PCP_Tool.pdf (accessed 20 May 2013).

Lecouf, A., Ryckelynck, JP., Ficheux, M. *et al.* (2013) A new paradigm: home therapy for patients who start dialysis in an unplanned way. *Journal of Renal Care* **39** (Suppl.1), 50–55.

Lemieux L. (2004) Sexuality in palliative care: patient perspectives. *Palliative Medicine,* **18,** 630–637.
Levy, J., Brown, E., Daley, C. *et al.* (2009) *Oxford Handbook of Dialysis,* 3rd edn, Oxford University Press, Oxford.
Lewis, A.L., Stabler, K.A. and Welch, J.L. (2010) Perceived informational needs, problems, or concerns among patients with stage 4 Chronic Kidney Disease. *Nephrology Nursing Journal* **37** (2), 143–148.
MacManus, B., Macdonald, J., Matthews, B. *et al.* (2012) Shared decision-making in kidney care: a call to action. *Journal of Renal Nursing* **4** (2), 58–59.
McClure, D.L. (2010) Training challenges: when the patient speaks a different language. *Advances in Peritoneal Dialysis* **26,** 88–90.
Murphy, F. (2007) The role of the nurse in post-renal transplantation. *British Journal of Nursing* **16** (11), 667–675.
Murphy, F. (2011a) The ongoing challenges with renal vascular access. *British Journal of Nursing* **20** (4) (suppl.), 6–14.
Murphy, F. (2011b) Sexuality issues in end of life care, in *Conservative Management in Advanced Kidney Disease. A Guide to Clinical Practice* (eds K. Jenkins, L. Bennett and T. Mooi-Ho), EDTNA/ ERCA, Luzern, pp. 59–72.
Murphy, F. (2012) Sexual concerns: living with end-stage renal disease. *Journal of Renal Nursing* **4** (1), 12–17.
Murphy, F., Trevitt, R., Chamney, M. and McCann, M. (2011) Patient health and well-being while waiting for renal transplantation: Part 1. *Journal of Renal Care* **37** (4), 224–231.
National Institute for Health and Clinical Excellence (2011) *Clinical Guideline CG125. Peritoneal Dialysis: Peritoneal dialysis in the treatment of stage 5 chronic kidney disease,* http://publications.nice.org.uk/peritoneal-dialysis-cg125/about-this-guideline (accessed 20 May 2013).
National Kidney Foundation (2011) *Sexuality and Chronic Kidney Disease,* www.kidney.org/atoz/content/sexuality.cfm (accessed 20 May 2013).
Navaneethan, S.D., Vecchio, M., Johnson, D.W. *et al.* (2010) Prevalence and correlates of self-reported sexual dysfunction: A meta-analysis of observational studies. *American Journal of Kidney Diseases* **56** (4), 670–685.
Radloff, L.S. (1977) The CES-D Scale: a self-report depression scale for research in the general population. *Applied Psychological Measurement* **1,** 385–401,
Sheils, P. (2003) Sexuality and the older person. *The World of Irish Nursing* **13,** 31–32.
Smart, N.A. and Titus, T.T. (2011) Outcomes of early versus late nephrology referral in chronic kidney disease: a systematic review. *The American Journal of Medicine* **124,** 1073–1080.
Stand, H. and Parker, D. (2012) Effects of multidisciplinary models of care for adult pre-dialysis patients with chronic kidney disease a systematic review. *International Journal of Evidence-Based Healthcare* **10,** 53–59.
Thomas, N. (2009) Education and training in peritoneal dialysis, in *Peritoneal Dialysis. A Guide to Clinical Practice* (ed. A. Riemann and M. Cruz Casal), EDTNA/ ERCA, Luzern, pp. 55–68.
Trevitt, R., Dunsmore, V., Murphy, F. *et al.* (2012) Pre-and post –transplant care: nursing management of the renal transplant recipient: Part 2. *Journal of Renal Care* **38** (2), 107–114.
Wadd K., Bennett, P. and Grant, J. (2011) Being a parent on dialysis: a literature review. *Journal of Renal Care* **37** (4), 208–215.
Whittaker, C., Dunsmore, V., Murphy, F. *et al.* (2012) Long-term care and nursing management of a patient who is the recipient of a renal transplant. *Journal of Renal Care* **38** (4), 233–240.
Wiederhold, D., Langer, G. and Landenberger, M. (2011) Ambivalent lived experiences and instruction need of patients in the early period after kidney transplantation: a phenomenological study. *Nephrology Nursing Journal* **38** (5), 417–423.
Wilkinson, A. (2010) The 'first quarter'. The first three months after transplantation, in *Handbook of Kidney Transplantation.* (ed. G.M. Danovitch, 5th edn, Wolters Kluwer/ Lippincott Williams & Wilkins, Philadelphia, PA, pp. 198–216.
Wilkinson, A. and Kasiske, B.L. (2010) Long- term post-transplantation management and complications, in *Handbook of Kidney Transplantation.* (ed. G. Danovitch), 5th edn, Wolters Kluwer/ Lippincott Williams & Wilkins, Philadelphia, PA, pp. 217–250.
Yeh, S.C.J., Huang, C.H., Chou, H.C. and Wan, T.T.H. (2009) Gender differences in stress and coping among elderly patients on haemodialysis. *Sex Roles* **60,** 44–56.

CHAPTER 5

Acute Kidney Injury

Annette Davies
University of Surrey, UK

Learning Outcomes

- To understand the different types and causes of acute kidney injury (AKI).
- To help and support the patient and family during an episode of AKI.
- To describe the signs and symptoms of AKI.
- To analyse the management of those with AKI.
- To evaluate the various treatment options for AKI.

Introduction

The kidney has multiple functions and the management of the patient with AKI has been likened to 'juggling' as the nurse has to be aware of many different aspects of care at one time (Davies 2009). Approximately one in five people who are admitted to hospital as an emergency will suffer some degree of acute kidney injury(AKI) (O'Donoghue and Matthews 2011). Despite the availability of various dialysis treatments and different drug therapies, the mortality from acute kidney injury is in the range of 30–60%, depending on the patient group (Abraham *et al.* 2012).

Acute kidney injury is viewed as a spectrum of injury, which may result in organ failure and the need for renal replacement therapy (RRT). Clinically AKI is characterised by a rapid reduction in kidney function resulting in a failure to maintain fluid, electrolyte and acid-base homoeostasis (Lewington and Kanagasundaram 2011). Depending on its severity and duration, AKI is often transient in nature and, with careful nursing care, the patient can regain normal renal function. However, without appropriate specialised treatment, the patient may be denied the opportunity to make a full recovery and a precipitation of further impairment may lead to chronic kidney disease (CKD) and established renal failure (ERF).

The aim of this chapter is to emphasise the vital role the nurse plays in the delivery of care for the patient in AKI. The nurse is vital to the wellbeing of the patient as the nurse monitors the patient for complications, participates in renal replacement therapy, assesses the patient's progress and response to treatment, and provides physical and emotional support. In this central role the nurse can maintain close links with the patient's family, which

Renal Nursing, Fourth Edition. Edited by Nicola Thomas. Published 2014 by John Wiley & Sons, Ltd.

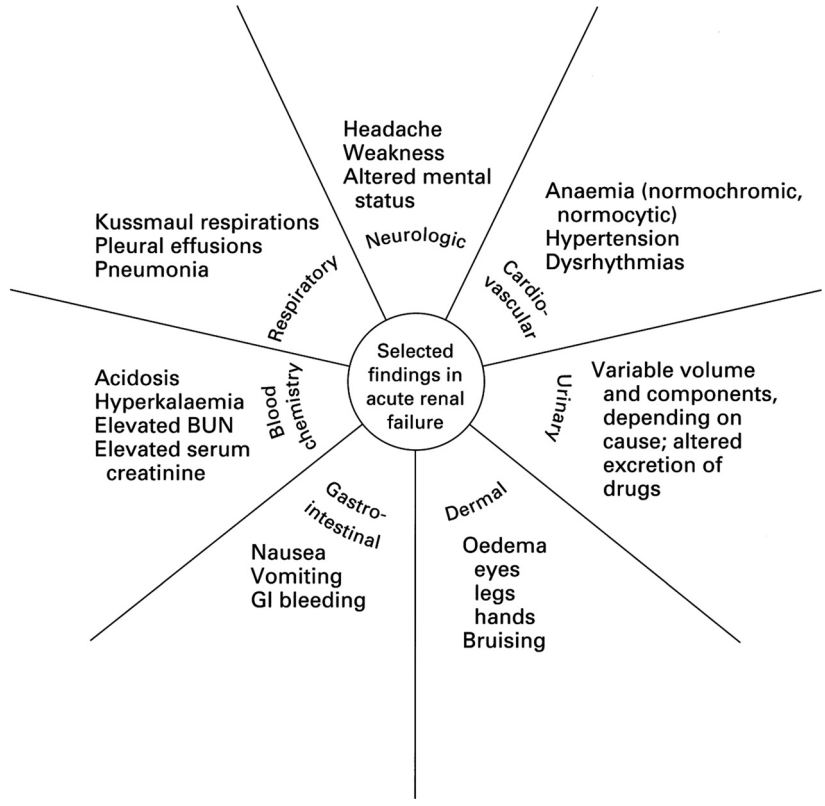


Figure 5.1 Signs and symptoms of acute kidney injury. BUN, blood urea nitrogen; GI, gastrointestinal. (From Brundage D. Renal disorders. Mosby 1992 with permission from Mosby.)

can be instrumental to a family-centred approach to the patient's treatment. The alliance between the patient, the family and the nurse is paramount in keeping the family informed of the patient's condition, assisting them to understand treatments and providing psychological support. Figure 5.1 gives an overview of the signs and symptoms of AKI.

However, in recent years, the intensive care nurse has taken over from the renal nurse in caring for those requiring continuous renal replacement therapy (CRRT). Specific nursing activities for CRRT are therefore beyond the scope of this book, but further reading can be found at the end of this chapter regarding the options available for renal replacement therapy (RRT).

Mortality

There are a number of patient groups for which AKI has a particularly high mortality rate. For example, AKI occurs in up to 65% of patients with septic shock and is independently associated with an increased risk of death in patients with sepsis (Bagshaw *et al.* 2009). The need for rapid identification of the cause of AKI and those patients at highest risk is essential so that the correct course of treatment can be adopted (DuBose *et al.* 1997). Therefore it is vital for the nurse to play a major role in assisting physicians in the treatment options available for this fragile group of patients. The development of new biochemical markers may enable a diagnosis to be made before changes are seen in either serum creatinine or the urine output.

It is important for nurses and carers to be able to understand that AKI is a serious condition that should never be underestimated. Constant improvements in dialysis technology, combined with a growing chronic kidney disease population and limited funds, have put clinicians under pressure to try and predict the outcomes of treatment. Acute kidney injury is costly to the NHS. Marion Kerr, an economist for NHS Kidney Care, estimated the cost of AKI care to be between £434 million and £620 million per annum. This is greater than the costs of lung and skin cancer combined (Laing 2012), although Kolhe *et al.* (2008) have suggested that a perfect mortality prediction model is still missing.

The National Confidential Enquiry into Patient Outcome and Death (NCEPOD) is a government-funded agency whose remit is to maintain and where necessary improve standards of medical and surgical care through confidential surveys, which aim to maintain and improve the quality of patient care. The NCEPOD undertook a study (National Confidential Enquiry into Patient Outcome and Death 2009) that examined the management of AKI. Their findings demonstrated that only 50% of patients dying with AKI received good care. It was identified that the recognition of acute illness, hypovolaemia and sepsis in patients with AKI was generally poor. Following on from the publication of this NCEPOD enquiry many initiatives have been introduced aiming to improve care and reduce the mortality. Examples include the London Acute Kidney Network (LAKIN) care bundles available at www.londonaki.net/ (accessed 20 May 2013) and the Yorkshire AKI Networks Acute Kidney Injury Patient Pathway (AKIPP) available at www.aki.org.uk/(accessed 20 May 2013).

Classification

AKI may be divided into three major categories, in which each category has a physiological location of the insult (Table 5.1):

- prerenal – relates to the ineffective perfusion of the kidneys, which are structurally normal
- renal (intrinsic) – damage to the renal parenchyma, sometimes secondary to prerenal problems
- postrenal – disordered urinary drainage of both kidneys or of a single functioning kidney.

An acute impairment may also present in the patient with existing chronic kidney disease, which may lead to further structural damage; this presentation is often referred to as acute-on-chronic renal failure and evidence would indicate that this is an increasing group (Hsu *et al.* 2008).

Prerenal renal failure

Prerenal causes of AKI are directly related to hypoperfusion states or a decline in the blood supply to the kidneys. The structure of the kidneys is normal. However, when the renal blood supply is restricted, glomerular filtration is reduced, causing decreased perfusion of the kidneys. The net effect is a decreased blood flow to the glomeruli, which therefore leads to ineffective filtration because of inadequate blood flow. Without an effective renal plasma flow rate the glomeruli are unable to filter waste from the blood but the structure of the renal tubules remains intact (Figure 5.2).

In this prerenal state, urine osmolarity is high and sodium low, which is consistent with renal hypoperfusion and well-preserved renal function. If, at this stage, renal blood flow can be restored, then normal renal function will return. However, if the prerenal

Table 5.1 Acute kidney injury: major causes and aetiology.

Stage	Major causes	Aetiology
Prerenal	Cardiovascular	Congestive cardiac failure
		Myocardial infarction
		Cardiogenic shock
		Cardiac tamponade
		Pulmonary embolism
	Vasodilation	Sepsis
		Anaphylaxis
	Hypovolaemia	Haemorrhage, including blood loss due to surgery
		Burns
		Gastrointestinal loss
		Renal loss
Renal (intrinsic)	Glomerulonephritis	Poststreptococcal infection
		Systemic lupus erythematosus
		Haemolytic-uraemic syndrome
		Wegener's granulomatosis
		Goodpasture's syndrome
	Vascular	Vasculitis
		Hypertension
		Eclampsia of pregnancy
		Renal artery stenosis
		Renal vein thrombosis
	Intratubular	
	Pigment	Myoglobin (see rhabdomyolysis)
	Proteins	Myeloma
	Crystals	Nephrotoxins
Postrenal	Obstruction of lower urinary tract	Prostatic hypertrophy
	Obstruction of upper urinary tract	Ureteric obstruction (clots, extrinsic compression, calculi)

state is prolonged, then this may lead to ischaemic damage due to poor perfusion, which in turn may lead to acute tubular necrosis (Devarajan 2006).

It is estimated that between 20 and 30% of cases of AKI are both predictable and avoidable (O'Donoghue and Matthews 2011). Early recognition, diagnosis and treatment are vital in prerenal failure, in order to prevent the condition progressing to renal failure with a degree of parenchymal damage. Nurses can play a large role in the recognition and management of this group of patients.

Renal (intrinsic) failure

This cause is sometimes referred to as intrinsic or intrarenal failure and is associated with structural damage to the glomeruli and renal tubules. The difference between

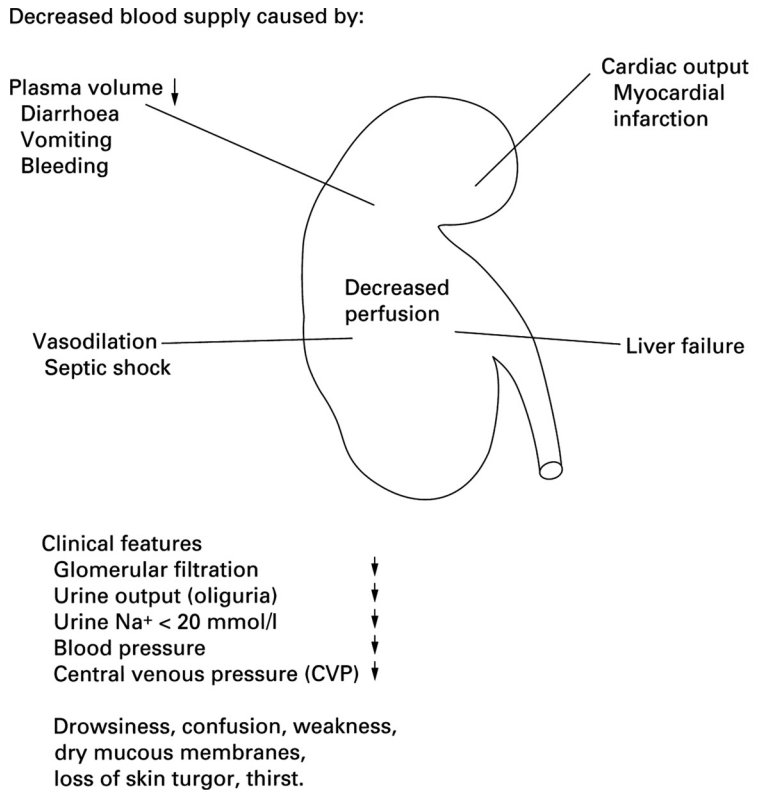


Figure 5.2 Prerenal failure.

pre- and postrenal failure and intrinsic failure is that in intrinsic failure the correction of the aetiology will not guarantee the complete recovery of renal function because of damage to the nephron itself. Here the episode of AKI may have a lengthy duration and can often lead to CKD.

The clinical course of intrinsic renal failure is often complex and, depending upon underlying disorders, the recovery may be prolonged for up to six weeks. As illustrated in Table 5.1, there are a wide variety of causes for intrinsic renal failure, which may involve multisystem disease or originate from a primary renal disorder, but often involve complicating severe illness that causes vasomotor nephropathy. Some specific causes are now discussed.

Acute interstitial nephritis

This condition often follows exposure to drugs in the form of antibiotics, analgesics and nonsteroidal antiinflammatory agents. Infections can cause a very similar clinical and pathological picture and these include *Salmonella*, *Streptococcus*, *Meningococcus*, leptospirosis and many viral disorders.

Other categories of interstitial nephritis are caused by systemic disease, such as systemic lupus erythematosus or sarcoidosis.

Clinical features

Fever, rash, arthralgia, back pain, and eosinophilia are clinical features of acute interstitial nephritis. Acute kidney injury may not develop for some weeks but in some cases renal dysfunction may occur within a few hours after exposure to a causative drug.

Rhabdomyolysis

Rhabdomyolysis is a result of the release of muscle contents, including myoglobin, into the plasma. It is often caused by trauma, for example a crush injury or pressure-induced muscle necrosis. This causes damage to muscle, which allows the pigment myoglobin to be released into the plasma. Myoglobin is an iron- and oxygen-binding protein and is only found in the bloodstream after muscle injury. At high plasma levels it becomes nephrotoxic. If treated early it can be successfully cured with fluid resuscitation (Russell 2005).

Clinical features

The urine is often brown or coffee coloured due to the presence of myoglobin. Patients often present with acute illness, with fever, weakness, pain, nausea and vomiting.

Renal failure and liver disease

AKI is often associated with acute liver injury that may result from:

- paracetamol overdose;
- circulatory shock;
- severe leptospirosis sepsis.

It may also be seen in surgery on the biliary tract.

For the patient with advanced liver disease, the onset of kidney injury is often referred to as hepato-renal syndrome. Septicaemia, fluid and electrolyte imbalance or hypovolaemia from gastrointestinal haemorrhage are common causes of the syndrome. These patients often require intensive care and the appropriate choice of therapy is of utmost importance (Rialp *et al.* 1996).

Cortical necrosis

Cortical necrosis may follow any course of intensive or prolonged ischaemia. The condition is also associated with sepsis, shock, transfusion reactions and burns.

Renal biopsy reveals pathology of patchy necrosis of the glomeruli, tubules and small vessels of the renal cortex. The renal medulla remains intact but the renal cortex becomes infarcted and calcifies, and this may be seen on plain abdominal X-ray.

The return of renal function is often slow but, if cortical necrosis is extensive, recovery is unlikely and the patient may become dialysis dependent.

Acute tubular necrosis

Acute kidney injury due to ischaemic changes or toxic renal injury presents a clinical syndrome that is often referred to as acute tubular necrosis (ATN). It is a very common cause of AKI and has a high mortality rate of around 50%. It causes damage to the tubular portion of the nephron. Unfortunately, despite 35 years of haemodialysis, little progress has been made in altering the outcome for ATN (Ricci *et al.* 2011).

Although the aetiology of ATN can vary, the common factor is that there is a reduction of oxygen and nutrients to the active tubular cells, which results in a lack of cell function and patchy necrosis. The tubular cells will regenerate at the basement membrane level. The aim is to keep the patient alive and well during this regeneration phase. An almost full recovery can be made provided the appropriate and timely treatment is undertaken (Pusnani and Hazra 1997).

Most intrinsic renal failure is caused by ischaemia through exposure to toxic agents, such as drugs or bacterial endotoxins.

Nephrotoxicity

In any patient with AKI, particularly ATN, a potential causative effect could be a therapeutic agent. Therapeutic agents can affect the kidney in any of the three categories listed, as illustrated in Table 5.2 (Perezella 2009). Contrast-induced acute kidney injury (CI-AKI) occurs within 72 hours of the patient receiving the contrast media. Acute kidney injury results from a combination of afferent arteriolar vasoconstriction and direct toxicity of the contrast media to the tubule epithelial cells. Patients with risk factors including the elderly and those with diabetes, have a higher incidence. It is recommended this group of patients receives appropriate fluid expansion before and after procedure (Lewington and Kanagasundaram 2011).

Ischaemic acute tubular necrosis is often associated with inadequate perfusion to the kidney, in that the efferent and afferent arterioles are unable to maintain their autoregulatory function and this leads to a fall in the glomerular filtration rate. This interruption in blood flow to the kidney may be due to surgical intervention, for example aortic repair, and is quite likely to cause ischaemia (Weldon and Monk 2000).

Postrenal failure

Postrenal conditions obstruct the flow of urine, so the obstruction has to be bilateral in order to cause failure. The rapidity of recovery will depend on the duration and completeness of the obstruction.

The urinary tract may be obstructed by three mechanisms:

- obstruction from within (e.g. ureteric stones);
- disease of the wall;
- obstruction from outside (e.g. prostatic hypertrophy).

Table 5.2 Effects of therapeutic agents on the kidney.

Clinical syndrome	Causative agents
Prerenal	Ciclosporin, radiocontrast, amphotericin B, ACE inhibitors, NSAIDs
Intrinsic: acute tubular necrosis	Aminoglycosides, amphotericin B, cephalosporins
Acute interstitial nephritis	Penicillins, cephalosporins, sulphonamides, rifampicin, NSAIDs, interferon, interleukin-2
Postrenal	Aciclovir, analgesic abuse
	Other heavy metals, including gold, lithium, mercury, silver

ACE, angiotensin-converting enzyme; NSAIDs, non steroidal antiinflammatory drugs.

As with all types of kidney injury, it is important to find the cause and start treatment as soon as possible since, in theory, all postrenal failure is reversible (Kellum 2008).

AKI classification systems

The Acute Dialysis Quality Initiative (ADQI), in 2004, proposed the introduction of a diagnostic criterion for AKI using serum creatinine levels and urine output (UO) volumes over standardised periods of time. The system was called RIFLE (Table 5.3) (Ricci 2007). The system provided a uniform standard for diagnosis and classification of AKI in order to optimise the treatment of patients with kidney disease. Many of the ADQI group collaborated at a later date to become the Acute Kidney Injury Network (AKIN), which modified the RIFLE with regards the creatinine measure, due to the clinical significance of relatively small rises in serum creatinine. As a result, the AKIN group modified RIFLE to the new AKI staging system, AKIN (Table 5.4), which reflects these smaller changes, with the AKIN corresponding to the earlier RIFLE stages. Stage 1 relates to risk, while AKIN stage 2 relates to injury and AKIN stage 3 corresponds to failure. The 'loss' and 'end-stage kidney disease' categories were dropped from the staging system but remain outcomes. The AKIN classification also introduced a baseline measure and dropped the use of GFR as this is not an accurate measure of kidney function in AKI.

Lewington and Kanagasundaram (2011) recommend the use of the newest AKI staging system produced by International Kidney Disease: Improving Global Outcomes (KDIGO) staging classification (Table 5.5). All three systems provided guidance and the use of one of these classification systems should promote earlier detection of AKI, leading to appropriate and timely treatment of acute kidney injury.

Table 5.3 RIFLE Classification of AKI.

Category	GFR criteria	Urine output (UO)
Risk	Increase in creatinine ×1.5 or GFR ≥ 25%	UO < 0.5 ml/kg/h × 6 h
Injury	Increase in creatinine ×2 or eGFR ≥ 50%	UO < 0.5 ml/kg/h × 12 h
Failure	Increase in creatinine ×3 or GFR ≥ 75%	UO < 0.3 ml/kg/h × 24 h or anuria × 12 h
Loss	Complete loss of kidney function ≥ 4 weeks	
ESKD	End stage kidney disease (≥ 3 months)	

Table 5.4 AKIN Classification of AKI.

Category	Serum creatinine	Urine output
Stage 1	Serum creatinine ≥ 150–200% from baseline	<0.5 ml/kg/h for > 6 h
Stage 2	Serum creatinine ≥ 200–300% from baseline	<0.5 ml/kg/h for > 12 h
Stage 3	Serum creatinine ≥ 300% from baseline OR serum creatinine ≥ 54 μmol/l with an acute rise of at least 44 μmol/l or commencement RRT	< 0.3 ml/kg/h for > 24 h or anuria for >12 h

Table 5.5 KDIGO classification of AKI.

Category	Serum creatinine (SCr)	Urine output
Stage 1	≥ 1.5 to 1.9 × baseline or increase in SCr ≥0.3 mg/dl (≥26.5 μmol/l)	<0.5 ml/kg/h for 6-12 h
Stage 2	≥ 2–2.9 × baseline	<0.5 ml/kg/h >12 h
Stage 3	3 × baseline or increase in SCr ≥ 4 mg/dl (≥ 353.6 μmol/l) or initiation of RRT	< 0.3 ml/kg/h for ≥ 24 h or anuria for ≥ 12 h

Management of Acute Kidney Injury

Since normal kidney function is essential to homeostasis of the body, particularly with regard to volume, electrolyte balance, acid-base balance and excretion of nitrogenous waste products, loss of these functions can lead to hyperkalaemia, volume overload, acidosis and uraemia.

Prevention is better than a cure, so early detection and treatment of AKI will prevent rapid deterioration. Some people are at a greater risk of AKI – these include patients who have chronic kidney disease, cardiac failure and liver disease, diabetes and those who are over 60 years of age. The clinical management goals for patients with AKI can be divided into three main categories:

- restoration of renal perfusion;
- minimising toxic effects;
- correction of metabolic derangements.

Hyperkalaemia

Hyperkalaemia is often a fatal complication in AKI. The failing kidney is unable to excrete potassium effectively when the patient is oliguric (<400 ml urine day) or, worse, anuric (no urine). It is further complicated by the very complex treatment of an individual who is often septic, hypoxic and requiring blood transfusions and potassium-containing drugs.

Renal replacement therapy is the most efficient treatment for hyperkalaemia but this may take time if vascular access is required. Other alternatives are available:

- The administration of intravenous insulin and dextrose or nebulised salbutamol will help move potassium ions back into the intracellular compartment and away from the extracellular compartment. It is important to monitor the patient's blood sugar as hypo-hyperglycaemia can occur. Also it is important to measure the heart rate, which can increase in response to salbutamol.
- Calcium carbonate is recommended in most cases to reduce the cardiotoxicity and decrease the cardiac membrane excitability
- Oral or rectal potassium exchange agents in the form of calcium resonium (which is a slower acting treatment, often used as maintenance treatment for hyperkalaemia).

Volume overload

Successful volume homeostasis permits maintenance of a constant internal circulatory and extracellular volume despite consumption of varying quantities of water and salt intake and variable invisible losses of water.

The presence of oedema may be seen in the feet, legs and sacral area. This is often pitting in nature. The skin is particularly at risk at this stage and extra care must be taken. Shortness of breath and especially orthopnoea are indicative of pulmonary oedema.

Each patient in AKI should have an individual prescription for fluid and sodium intake. As a generalisation, the fluid intake volume should equal the daily urine output plus 300–500 ml. Patients with a large insensible loss, such as happens with burns, obviously need a larger fluid intake and special care should be taken. It is important that the patient and family are involved in accurate fluid balance.

Metabolic acidosis

The presence of AKI must not lead the nurse to think that it is the only cause of acidosis until other causes have been eliminated, for example ketoacidosis, lactic acidosis.

Acidosis in kidney injury occurs when the renal tubules fail to regenerate bicarbonate and secrete hydrogen ions into the urine, which in turn causes an acid-base imbalance.

As most acid comes from the breakdown of dietary protein, it is possible to reduce the level of acidosis by limiting the level of intake of protein. Another alternative is to infuse sodium bicarbonate but one has to be aware of fluid overload and hypernatraemia. The most efficient way of treating acute acidosis via RRT.

Uraemia

The accumulation of nitrogenous waste products will produce acute uraemia and symptoms of uraemia often include nausea, vomiting, hiccups, increasing bleeding, infection risks, neurological problems, irritability, confusion and twitching. As previously mentioned, it is necessary to begin appropriate dialysis.

Nutrition

Patients with acute kidney injury are often very ill and their metabolisms are often under great stress, resulting in the need for extra calories and extra protein (Kariyawasam 2012). Protein calorie malnutrition is believed to one of the leading factors in the high mortality rate seen in AKI (Murphy and Byrne 2010). Acute kidney injury causes major stress-induced hormonal and metabolic derangements within the body which result in negative nitrogen balance and depletion of body energy reserves (Casaer *et al.* 2008). Nitrogen balance is exceptionally negative in AKI and is often linked to sepsis, surgery and multiorgan dysfunction syndrome and renal factors such as uraemia, acidosis, inadequate protein intake and parathyroid hormone (Murphy and Byrne 2010). Nutritional intake is therefore of particular importance.

Patients require an individualised nutritional assessment and feeding plan, which will require specialist input from a dietitian, taking into consideration their complex metabolic state, fluid balance and current RRT. In the acutely ill patient, enteral nutrition, if tolerated, is considered to be the best treatment option by most experts (Cano *et al.* 2006) as it is cheaper, safer and more physiologically normal. The development of concentrated low-electrolyte feeds has proven invaluable in allowing delivery of optimal protein and calories with the minimum of fluid and electrolytes. However, these special feeds are not normally needed if the patient is receiving continuous renal replacement therapy.

The aims of nutritional support are to:

- prevent protein energy wasting;
- preserve lean body mass/prevent or minimise malnutrition;

- avoid further metabolic arrangements;
- stimulate immunocompetence;
- repair tissue damage;
- preserve organ function;
- maintain biochemistry/fluid balance;
- enhance recovery.

Kidney Disease Improving Global Outcomes (KDIGO) (2012) suggest the goal of any feeding regime should be to provide an energy intake of 20–30 kcal/kg/d. They advise against protein reduction with the aim of preventing or delaying initiation of RRT, recommending the administration of 0.8–1.0 g/kg/d of protein in people who are noncatabolic with AKI, who do not require dialysis. They recommend 1.0–1.5 g/kg/d for people with AKI on RRT, and up to a maximum of 1.7 g/kg/d in patients on continuous renal replacement therapy (CRRT). In patients who are hypercatabolic they recommend a maximum of 1.7 g/kg/day of amino acids if on CRRT (Lewington and Kanagasundaram 2011). Hypokalaemia and hypophosphataemia might be observed once a patient has commenced CRRT and supplementation of these electrolytes needs to be undertaken as required.

Patients with AKI are frequently anuric and hence monitoring of fluid balance and reduction of fluid intake is often necessary. In patients not requiring RRT it is likely that they will require dietary reductions in potassium, magnesium, and phosphate. The development of continuous renal replacement therapy has allowed fluid and electrolytes to be more easily managed without the need for the reduced fluid allowances that previously meant having to limit nutritional support. See Chapter 13.

Infection

Infection is known to contribute to the high mortality of patients with AKI (Hall and Esser 2008). Many patients with AKI are immuno-compromised due to uraemia (Perkins and Kisel 2005). They are therefore at an increased risk of developing infections such as pneumonia, urinary tract infections and sepsis, due to the large numbers of invasive devices they may need *in situ*. To reduce some of these risks it is a priority to remove all unnecessary lines and universal precautions and guidelines for maintaining asepsis should be adhered to at all times.

The Clinical Course of Acute Kidney Injury

The clinical course of AKI can be divided into four stages or phases:

- initiating stage;
- oliguric stage;
- diuretic stage;
- recovery stage.

Types of urine output can be found in Table 5.6.

Table 5.6 Types of urine output

Anuria	No urine output
Oliguria	< 400 ml/day
Nonoliguria	> 400 ml/day
Polyuria	Normal or high urine output

Initiating stage

This occurs when the kidneys are injured and when diagnosis is made and treatment established. It can last anything from hours to days.

Oliguric stage

This can last from 5 days to over 15 days. When AKI persists for weeks, endocrine problems, such as reduced erythropoietin production, are noticed. Functional renal changes occur, such as decreased tubular transport, reduced urine formation and lowered glomerular filtration. Renal healing will begin to occur, with the basement membrane being replaced with fibrous scar tissue and the nephron clogged with inflammatory products. The patient is particularly susceptible to bleeding and infection during this stage.

Diuretic stage

With continued healing the kidney begins to regain most of its lost function, but this depends on the severity of the initial injury. The signs and symptoms of the original condition begin to disappear. Urine output can begin to increase back to normal levels of up to 3 L day.

Recovery stage

The recovery stage can last from several months to over a year. The basement membrane is restored to its previous structure; scar tissue will remain but is not clinically significant. The kidneys respond in a regulatory excretory function to the body's needs.

Futher reading can be found in Lameire *et al.* (2008).

Renal Replacement Therapy (RRT) in Acute Kidney Injury

The purpose of RRT is to prevent morbidity and to support the kidney during its recovery phase. The amount, type and frequency of RRT are dictated by the severity of the patient's condition (Dauguirdas 2000).

Indications for RRT are:

- uraemic symptoms, such as pericarditis;
- volume overload;
- hyperkalaemia;
- metabolic acidosis;
- 'space-making' – for example, nutrition, transfusions;
- AKIN / KDIGO stage 3 or RIFLE failure.

There are a variety of treatment options available for AKI and the choice will depend on physician preference, nurse expertise and availability of the appropriate equipment. The options fall broadly into two categories: intermittent treatments (acute haemodialysis and haemodiafiltration) and continuous renal replacement therapies, of which there are three basic types: continuous haemofiltration, and continuous haemodialysis and continuous haemodiafiltration. Treatments performed continuously over long periods of time allow optimal values to be obtained for urea and fluid exchange control, and electrolyte and acid-base balance.

Acute intermittent haemodialysis

In acute haemodialysis, certain factors need to be considered and these include time on dialysis (possibly only 2 h for the first treatment), frequency (daily dialysis may be required), potassium concentration of dialysate (3 mmol/l dialysate may be necessary), a biocompatible dialyser and good fluid balance control. For those patients who are too haemodynamically unstable for conventional haemodialysis, other forms of renal replacement therapy (RRT) may be appropriate.

Intermittent haemodiafiltration

Intermittent haemodialfiltration can be a therapy option for patients with AKI or established renal failure. It combines the advantages of diffusion (dialysis) with convection (haemofiltration), it is suitable for use in patients with cardiovascular instability, especially those with fluid overload. It has superior small solute clearence over haemofiltration. Blood flow rates are higher than those of continuous HDF and a requires an HDF membrane that is more permeable than a normal haemofilter. However due to the efficiency of small molecule clearence, this would not be a treatment of choice for the patient with severe uraemia at risk of disequilibrium.

Continuous renal replacement therapy

The use of CRRT has developed enormously during recent years and involves either dialysis (solute removal using diffusion) or filtration (solute and water removal using convection) or a combination of treatments. The advantage of continuous therapy is the slower rate of fluid or solute removal, thus making it better tolerated by critically ill patients.

The nurses in the intensive care unit have developed their skills, taking on this responsibility to ensure holistic care. It is recognised that intermittent haemodialysis may be contraindicated in patients with AKI who are critically ill. Complications such as cardiovascular instability, sepsis and multiorgan failure make conventional intermittent treatments difficult.

Continuous haemofiltration (HF)

Continuous haemofiltration provides solute removal by convection. It offers high-volume ultrafiltration using replacement fluid, which can be administered in a variety of concentrations according to the patient's biochemistry. The pump guarantees adequate blood flow to maintain required ultrafiltration rates. This method can be performed using several litres of replacement fluid each hour. This is dependent on the patient prescription, which is usually determined by their weight. The addition of a blood pump to the circuit removes the necessity for arterial access and provides a more reliable and controllable method of delivering treatment (Figure 5.3).

Continuous haemodiafiltration (HDF)

To increase the efficiency of small-molecule clearance, a dialysis solution is continuously pumped through the filter in a countercurrent direction to the blood. Small-molecule (urea) clearance by diffusion is more efficient. It is possible to use a standard blood monitor for the extracorporeal circuit and then use infusion pumps to administer dialysate and replacement fluid (Figure 5.4).

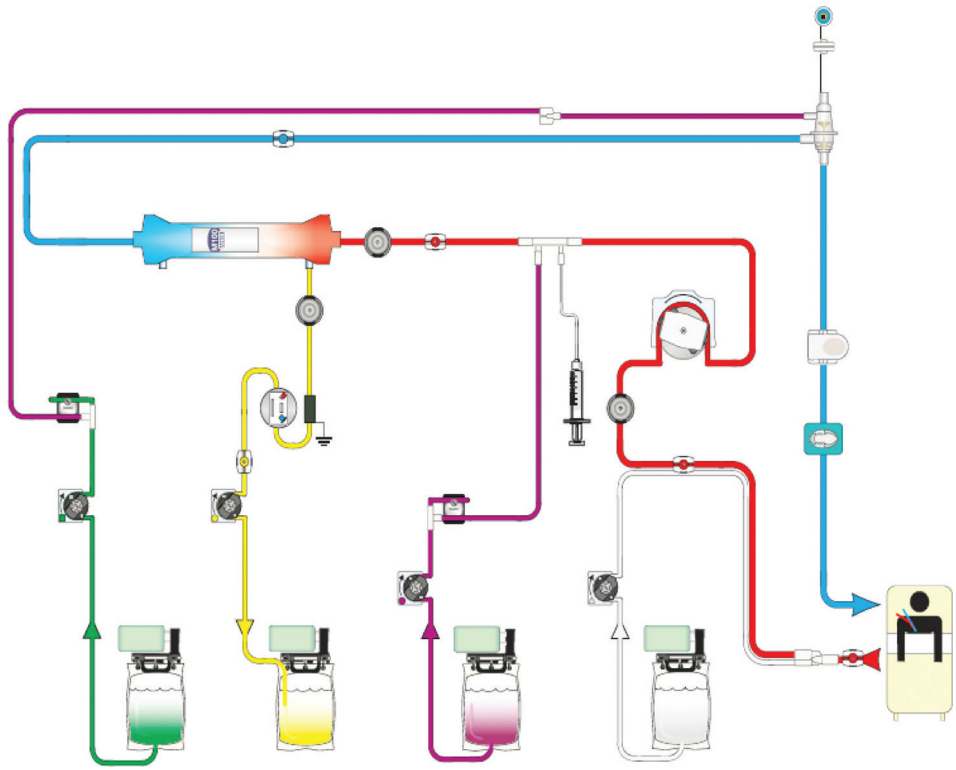


Figure 5.3 Continuous venovenous haemofiltration.
Source: With kind permission from Gambro Lundia AB.

Continuous haemodialysis (HD)

This method incorporates the same principles as intermittent haemodialysis but operates at a greatly reduced rate. From the nursing perspective, the use of fully automated systems provides a reliable and easy method of monitoring the fluid balance of patients who are critically ill.

The machine comprises a basic blood module with blood pump, venous and arterial pressure monitoring and an air detector. The fluid monitor has two integral pumps: one to remove fluid from the filter and the second to pump replacement fluid to the patient. The replacement fluid and the ultra filtrate are suspended on a weigh scale, which calculates and controls a linear patient weight (Figure 5.5).

With such accurate fluid control, the nurse does not need to measure and record fluid loss and replacement constantly as with previous methods. The ultrafiltration rate and physiological solutions are prescribed by the physician based on available clinical data (fluid state, biochemistry). An example of an integrated system used for all the above continuous automated renal replacement therapies is the Prismaflex machine® (Figure 5.6)

Plasma exchange

Therapeutic plasma exchange (TPE) is an extracorporeal blood purification technique, designed for the removal of large molecular-weight substances from the plasma (Seck *et al.* 2011). Most TPE procedures are performed for neurological, immunological or

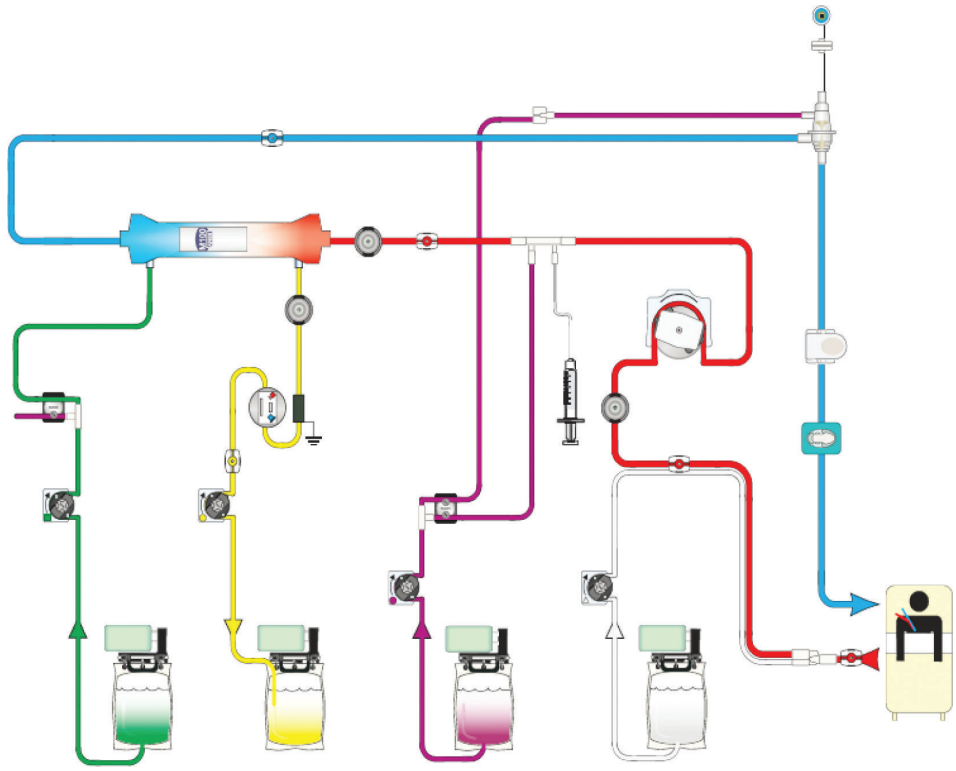


Figure 5.4 Continuous venovenous haemodiafiltration.
Source: With kind permission from Gambro Lundia AB.

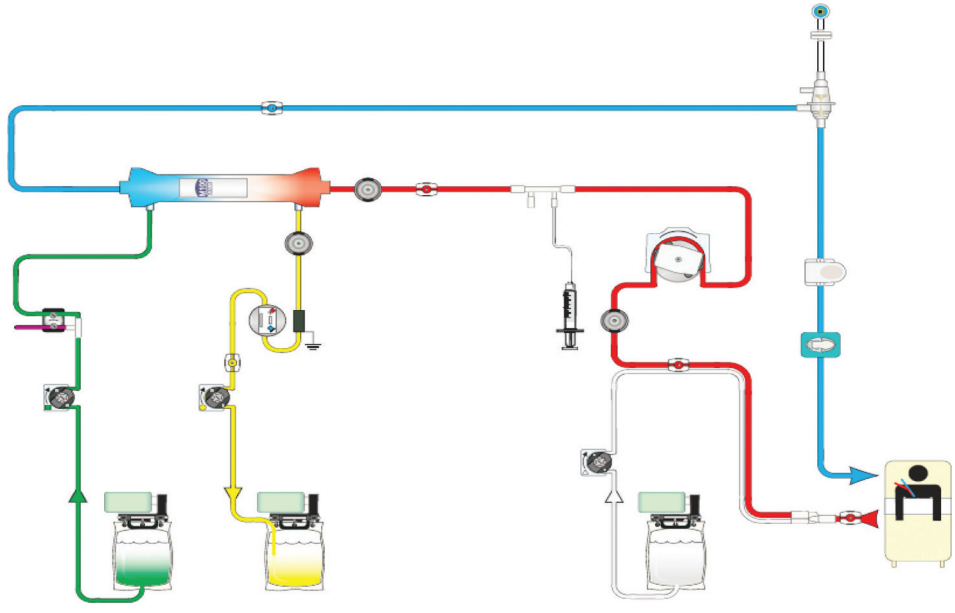


Figure 5.5 Continuous haemodialysis.
Source: With kind permission from Gambro Lundia AB.

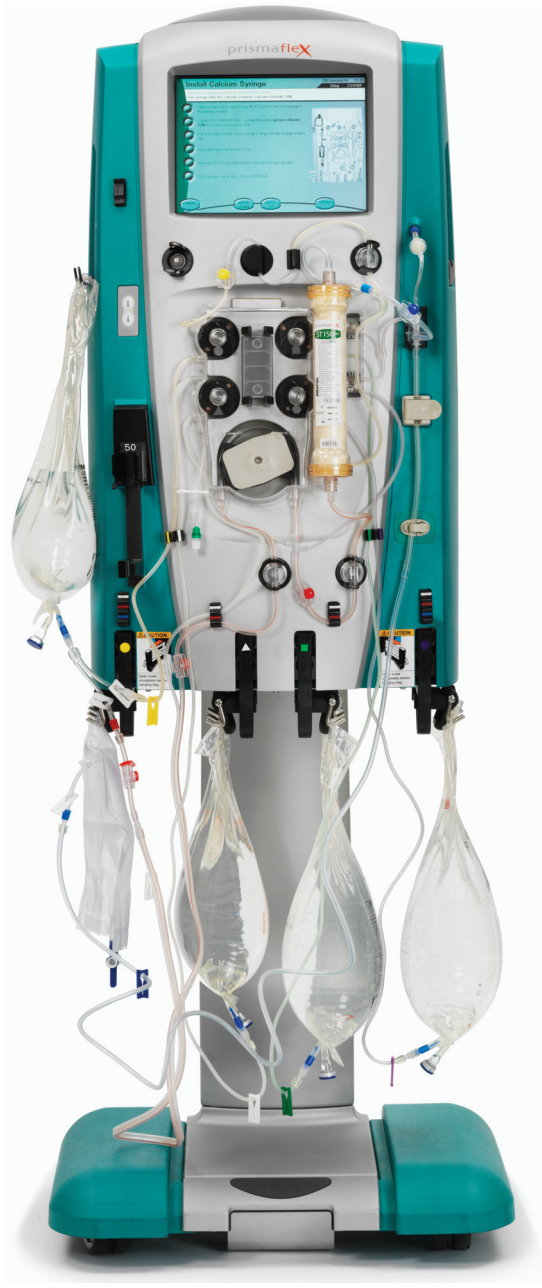


Figure 5.6 Prismaflex® machine.

Source: With kind permission from Gambro Lundia AB.

haematological diseases, including anti-GBM disease, thrombotic thrombocytopenic purpura (TTP), Guillain-Barré syndrome, systemic vasculitis, acute kidney injury secondary to myeloma of the kidney and haemolytic uraemic syndrome (HUS).

Plasma is separated from whole blood and then a replacement fluid is infused in equal volumes to the plasma that has been removed. It is a nonspecific therapy, removing all

circulating substances within the plasma. A plasma filter is used to separate the plasma from all other cellular elements, using a semi-permeable membrane. As TPE removes all circulating substances in the plasma, care should be taken to avoid disturbances with clotting factors, calcium and magnesium levels, and any other substances that may be depleted as a result.

The fluid volume removed by TPE must be replaced to prevent marked volume depletion. Fresh frozen plasma (FFP) is usually given as the sole replacement solution, while albumin can be given alone or in conjunction with normal saline. The optimum choice depends on the disease being treated, for example saline and albumin for hyperviscosity and FFP for TTP.

Albumin

Albumin has the advantage that there is no risk of viral transmission and minimal risk of anaphalaxis.

Albumin-saline combination

When colloid and crystalloid solutions are used in combination, the amount of colloid should not be less than 50% of the total infusion. General recommendations are one-third saline, two-thirds albumin (UK Blood Transfusion and Tissue Transplantation Services 2005).

Fresh frozen plasma (FFP)

Fresh frozen plasma replaces the normal proteins that have been removed, therefore there is no depletion of coagulation factors or immunoglobulins. However, FFP can produce the most complications – including anaphalaxis, muscle cramps and urticaria. Fresh frozen plasma is the fluid of choice for TTP because it may provide a protein that diminishes platelet aggregation. Regimes for plasma exchange vary greatly depending on physician preference and clinical need.

Summary

The impact of AKI on patients and families is often unexpected and, despite new technology, it remains a serious disease with a high mortality rate. Unlike most patients who have had renal disease for some time, the patient with AKI who requires RRT will not have had the opportunity to have had counselling and the chance to evaluate their condition. The key aim of care is to balance humanistic caring skills with the technological and clinical expertise required to optimise the patient's survival and quality of life. All patients with AKI require a high level of nursing management and the nurse therefore needs to understand the complexities of the illness and understand and manage electrolyte disturbances, disordered fluid status and nutritional support to maintain protein stores and to reduce the infection risks. The renal nurse needs to understand the importance of the AKI classification systems. She/he also needs to be able to work with and advise colleagues working in general wards aboutpatients who may have mild AKI (KDIGO stage 1), aiming to reduce the number that progress further along the AKI spectrum. It is imperative that renal nurses keep up-to-date with new technologies and initiatives so they act in a supportive role for their intensive care nurses colleagues.

Acknowlegements

With grateful thanks to Tim Armstrong and Natasha McIntyre who were previous authors of this chapter.

References

Abraham K.A., Thompson, B.B., Bodger, K., Pearson, M. (2012) Inequalities in outcomes of acute kidney injury in England. *Quarterly Journal of Medicine* **105,** 729–740.

Bagshaw, S.M., Lapinsky, S., Dial, S. *et al.* (2009) Acute kidney injury in septic shock: clinical outcomes and impact of duration of hypotension prior to initiation of antimicrobial therapy. *Intensive Care Medicine* **35,** 871–881.

Barrat, J. (2000) Outcome of acute renal failure following surgical repair of ruptured abdominal aortic aneurysms. European Journal of Vascular and Endovascular Surgery **20,** 163–168.

Cano, N., Fiaccadori, E. , Tesinsky, P. *et al.* (2006) ESPEN guidelines on enteral nutrition: adult renal failure. *Clinical Nutrition* **25,** 295–310.

Casaer, M.P., Mesotten, D. and Schetz, M.R. (2008) Bench to bedside review: metabolism and nutrition. *Critical Care* **12,** 222.

Dauguirdas, J.T. (2000) *The Handbook of Dialysis,* 3rd edn, Lippincott Williams & Wilkins, Philadelphia, PA.

Davies, A. (2009) How to manage patients with acute kidney injury. *Journal of Renal Nursing* **1** (3), 119–122.

Devarajan, P. (2006) Update on the mechanisms of ischemic acute kidney injury. *Journal of the American Society of Nephrology* **17,** 1503–1520.

Du Bose, T.D., Warnock, D.G., Mehta, R.L. *et al.* (1997) Acute renal failure in the 21st century: recommendations for management and outcomes assessment. *American Journal of Kidney Disease* **29,** 793–799.

Fiaccadori, E., Lombardi, M., Leonardi, S. *et al.* (1999) Prevalence and clinical outcome associated with preexisting malnutrition in acute renal failure: a prospective cohort study. *Journal of the American Society of Nephrology* **10,** 581–593.

Hall, G. and Esser, E. (2008) Challenges of care for the patient with acute kidney injury. *Journal of Infusion Nursing* **31** (3), 150–156.

Hsu, C.Y., Hordonez, J.D., Chertow, G.M. *et al.* (2008) The risk of acute renal failure in patients with chronic kidney disease. *Kidney International* **74,** 101–107.

Kariyawasam, D. (2012) Nutritional requirements in acute kidney injury. *Journal of Renal Nursing* **4** (5), 231–235.

Kellum, J. A. (2008) Acute kidney injury. *Critical Care Medicine* **36** (4), S141–S145.

Kidney Disease Improving Global Outcomes (KDIGO) (**2012**) Acute kidney injury work group. KDIGO clinical practice guideline for acute kidney injury. *Kidney International* (suppl.) **2,** 1–138.

Kolhe, N.V., Stevens, P.E., Crowe, A.V. *et al.* (2008) Casemix, outcome and activity for patients with severe acute kidney injury during the first 24 hours after admission to an adult general critical care unit: application of predictive models from a secondary analysis of the ICNARC Case Mix Programme Data- base. *Critical Care* **12** (suppl. 1), S2.

Laing, C. (2012) Focus of attention: acute kidney injury. *Journal of Renal Nursing* **4** (3), 116–117.

Lameire, N., Van Biesen, W. and Vanholder, R. (2008) Acute kidney injury. *Lancet* **372** (9653), 1863–1865.

Lewington, A. and Kanagasundaram, S. (2011) *Acute Kidney Injury. Renal Association Guidelines 2011,* www.renal.org/Clinical/GuidelinesSection/AcuteKidneyInjury.aspx (accessed 20 May 2013).

Lieberthal, W. and Nigam, S.K. (2000) Acute renal failure II. Experimental models of acute renal failure: experimental but indispensable. *American Journal of Physiology and Renal Physiology* **278,** F1–F12.

Mehta, R.L. (2005) Continuous renal replacement therapy in the critically ill patient. *Kidney International* **67,** 781

Murphy, F. and Byrne, G. (2010) The role of the nurse in the management of acute kidney injury. *British Journal of Nursing* **19** (3), 146–152.

National Confidential Enquiry into Patient Outcome and Death (**2009**) *Adding Insult to Injury,* http://www.ncepod.org.uk/2009report1/Downloads/AKI_report.pdf (accessed 12 June 2013).

O'Donoghue, D. and Matthews, B. (2011) What are we waiting for? *Health Service Journal,* supplement, 23 June.

Perezella, M.A. (2009) Renal vulnerability to drug toxicity. *Clinical Journal of the American Society of Nephrology* **4,** 1275–1283.

Perkins, C. and Kisiel, M. (2005) Utilizing physiological knowledge to care for acute renal failure. *British Journal of Nursing* **14** (14), 768–773.

Pusnani, M.L. and Hazra, D.K. (1997) Early haemodialysis in acute tubular necrosis. *Journal of the Association of Physicians of India* **45,** 850–852.

Rialp, G., Roglan, A., Betbese, A.J. *et al.* (1996) Prognostic indexes and mortality in critically ill patients with acute renal failure treated with different dialytic techniques. *Renal Failure* **18,** 667–675.

Ricci, Z., Cruz, D. and Ronco, C. (2007) The RIFLE criteria and mortality in acute kidney injury: a systematic review. *Kidney International* **73** (5), 538–546.

Ricci, Z., Polito, A., Polito, A. and Ronco, C. (2011) The implications and management of septic acute kidney injury. *National Review of Nephrology* 7, 218–225.

Russell, T.A. (2005) Acute renal failure related to rhabdomyolosis: pathophysiology, diagnosis, and collaborative management. *Nephrology Nursing Journal* **32** (4), 409.

Seck, S.M., Bertrand, D. and Boucar, D. (2011) Current indication of plasma exchange in nephrology: a systematic review. *Saudi Journal of Kidney Disease and Transplantation* **22** (2), 219–224.

UK Blood Transfusion and Tissue Transplantation Services (2005), *Guidelines for the Blood Transfusion Services in the UK,* www.transfusionguidelines.org.uk/index.aspx?Publication=RB (accessed 24 June 2013).
Venkataraman, R. and Kellum, J.A. (2000) Novel approaches to the treatment of acute renal failure. *Expert Opinion on Investigational Drugs* **9,** 2579–2592.
Weldon, B.C. and Monk, T.G. (2000) The patient at risk for acute renal failure. Recognition, prevention and preoperative optimization. *Anaesthesiology Clinics of North America* **1,** 705–717.

Further reading

Adam, S.K. and Osbourne, S. (2005) *Critical Care Nursing: Science and Practice,* 2nd edn, Oxford University Press, Oxford.
Eaton, D.C. and Pooler, J. (2009) *Vander's Renal Physiology,* 7th edn, McGraw-Hill, New York.
Kellum, J., Bellomo, R. and Ronco, C. (2009) *Continuous Renal Replacement Therapy,* Oxford University Press, Oxford.
Lameire, N., Van Biesen, W. and Vanholder, R. (2008) Acute kidney injury. *Lancet* **372** (9653), 1863–1865.
Levy, J., Morgan, J., Brown, E. and Lawrence, A. (2009) *Oxford Handbook of Dialysis,* 3rd edn, Oxford University Press, Oxford.

Useful web sites

Acute Dialysis Quality Initiative, www.ADQI.net (accessed 20 May 2013).
AKIN, www.akinet.org/ (accessed 20 May 2013).
Hypertension, Dialysis and Clinical Nephrology, www.hdcn.com (accessed 20 May 2013).
KDIGO AKI guidelines, www.kdigo.org/clinical_practice_guidelines/AKI.php (accessed 20 May 2013).
London Acute Kidney Injury Network, www.londonaki.net/(accessed 20 May 2013).
National Kidney Foundation, www.kidney.org/(accessed 20 May 2013).
Renal Association, www.renal.org/(accessed 20 May 2013).
Renal Registry, www.renalreg.com (accessed 20 May 2013).
Renal Web, www.renalweb.com/ (accessed 20 May 2013).
US Renal Data System, www.usrds.org/(accessed 20 May 2013).
Yorkshire AKI network, www.aki.org.uk/(accessed 20 May 2013).

CHAPTER 6

Chronic Kidney Disease

Nicola Thomas
London South Bank University, London, UK

Learning Outcomes

- To understand the classification of chronic kidney disease (CKD).
- To debate the scope of practice of primary care practitioners in managing CKD.
- To review the care and management of patients with mild to moderate CKD.
- To evaluate emerging research into management of CKD.
- To evaluate best practice guidelines and strategies for predialysis care.

Introduction

This chapter will investigate care and management of those with mild to moderate kidney disease before renal replacement therapy (RRT) is required. Renal nurses are often involved with the technical, monitoring and evaluative aspects of RRT for those with established renal failure (ERF). However, many people may experience reduced renal function for years before needing RRT. This chapter will describe the care and management of people who have mild to moderate kidney disease and will discuss the published practice guidelines and strategies to guide care for this group. New healthcare roles are developing in this area of care, and so the potential for renal nurses to expand their scope of practice will be discussed.

Chronic Kidney Disease (CKD)

Chronic kidney disease (CKD) is now recognised as a major worldwide health problem (Davis *et al.* 2008). It is estimated that the prevalence of stage 3–5 chronic kidney disease in the United Kingdom is currently around 6–8% (Stevens *et al.* 2007; de Lusignan *et al.* 2009), although only a very small minority may eventually require dialysis or a renal transplant. Diabetes mellitus has become the most common cause of CKD, not only within the developed world but also increasingly within the emerging world, mainly due to the rise in the incidence of type 2 diabetes (Atkins and Zimmet 2010).

Renal Nursing, Fourth Edition. Edited by Nicola Thomas. Published 2014 by John Wiley & Sons, Ltd.

The National Service Framework and mild to moderate CKD

The National Service Framework (NSF) for Renal Services (Part Two) was published in February **2005**. It identified four quality requirements covering chronic kidney disease, acute renal failure and end-of-life care. The two quality requirements of the NSF (Part Two) which relate to CKD are:

> Quality requirement one: Prevention and early detection of chronic kidney disease
> *People at increased risk of developing or having undiagnosed chronic kidney disease, especially people with diabetes or hypertension, are identified, assessed and their condition managed to preserve their kidney function.*
>
> Quality requirement two: Minimising the progression and consequences of chronic kidney disease
> *People with a diagnosis of chronic kidney disease receive timely, appropriate and effective investigation, treatment and follow-up to reduce the risk of progression and complications.*

One of the specific recommendations within the NSF made a huge change to the way in which kidney function was measured and this change in practice will now be explained.

Kidney function and estimated glomerular filtration rate (eGFR)

Traditionally, kidney function has been assessed by measurement of serum creatinine. Serum creatinine is determined by the rate of production of creatinine, which is dependent on muscle mass, as well as the rate at which the kidney excretes it. Because of wide variation in patients' body size, weight and muscle mass, serum creatinine is an inaccurate measure of kidney function. It is now recommended that kidney function in those with mild to moderate CKD (not including acute kidney injury) should be assessed by an estimation of glomerular filtration rate (eGFR).

The NSF for Renal Services recommended the use of the four-variable Modification of Diet in Renal Disease (MDRD) formula to estimate GFR. Clinical laboratories work out the eGFR based on the results of the serum creatinine, plus the gender and age of the patient. Once the eGFR is reported back to the primary care or renal clinic, an adjustment is made if the patient is African-Caribbean (not mixed race). If the patient is African-Caribbean then the eGFR result must be multiplied by 1.21. Assumption of Caucasian ethnicity can be made when using MDRD if ethnicity is unknown. It was recommended in 2006 that hospital laboratories should report eGFR alongside serum creatinine.

The use of eGFR enables health care professionals to evaluate kidney function within the accepted staging of CKD. It is important to note that an eGFR of 60–89 ml/min is only indicative of CKD in the presence of other laboratory or clinical indicators. This reduces the possibility of inappropriately labelling people as having CKD.

However there are some cautionary notes to interpreting eGFR results. The following cautions are adapted from Renal Association guidance (www.renal.org/eGFR/about.html, accessed 20 May 2013).

- **eGFR is only an estimate:** a significant error is possible. eGFR is most likely to be inaccurate in people at extremes of body type, for example people who are malnourished. It is not valid in pregnant women or in children. 90% of patients will have a measured GFR within 30% of their estimated GFR.
- **Race:** Some racial groups may not fit the MDRD equation well, as it was originally validated for white and black patients in the US. For Afro Caribbean black patients, eGFR was 21% higher for any given creatinine in the MDRD study, so the correction factor (see section above) should be used. In the UK white population, and probably in South Asians living in the UK, the equation seems to work quite well.

- **Not so good near normal:** The MDRD equation tends to underestimate normal or near-normal function, so slightly low values should not be over-interpreted. Furthermore, laboratory differences in creatinine estimations may make significant differences. *Routine reporting of eGFR values >90 is not recommended.*
- **Creatinine level must be stable:** eGFR calculations assume that the level of creatinine in the blood is stable over days or longer. They are not valid if it is changing.
- **Different equations:** from April 2006 in the UK, most local laboratories calculate eGFR on all samples sent for creatinine measurement. The equation they use will take into account local variations in accuracy of creatinine assays, so *eGFR values obtained in this way should be a little more accurate* than those generated by any of the online calculators.

In summary, a normal range for serum creatinine should no longer be given in isolation when assessing people with mild to moderate CKD and the patient's management needs to be based on at least two eGFR results. The widespread use of eGFR has recently contributed to improved recognition of, and appropriate care of, individuals with CKD, including the reduction in late referral rates (now down to around 20%) from primary to secondary care (Renal Registry 2011).

However, since 2010 there has been increasing interest in the use of the CKD Epidemiology Collaboration (CKD-EPI) equation. The CKD-EPI equation was developed as a more accurate determination of the GFR (Levey *et al.* 2009) and one retrospective cohort study which compared the two equations found that the MDRD equation underestimated the prevalence of CKD among blacks and overestimated the prevalence of CKD among whites, compared with the CKD-EPI equation (Arora *et al.* 2012).

Staging of CKD

There is now worldwide acceptance of numerical stages of CKD, based on the Kidney Disease Quality Outcomes Initiative (K/DOQI) classification (Kidney Disease Outcome Quality Initiative 2005). In general terms, stages 1–2 do not require specific interventions; stages 3a and 3b are managed in primary care; people with stage 4 may require referral to renal teams (this is the predialysis phase) and people with stage 5 usually require some form of renal replacement therapy (dialysis or transplantation) or conservative management.

In 2012 the international classification was amended (Kidney DIsease: Improving Global Outcomes 2012) and the biggest change is that, although the glomerular filtration rate (GFR) classification scheme has remained with stages 1–5 (stage 3 is now split into 3A and 3B), there are now also albuminuria stages A1, A2, and A3. In addition, this new guideline recommends eliminating the term 'microalbuminuria'; instead the guideline uses stages A1, A2, and A3 for the degree of albuminuria. Table 6.1 shows the Kidney DIsease: Improving Global Outcomes (2012) stages of chronic kidney disease.

Clinical systems and key messages for managing mild to moderate kidney disease

Understanding the prevalence of CKD means that strategies for identification, assessment and management need to be developed to help reduce the health burden that CKD poses in the United Kingdom. Around 6–8% of the population may have CKD stages 3–5, but not all patients with CKD need to be referred to or managed by nephrologists, although input from renal specialist nurses may be appropriate (Thomas 2011). These patients are at high risk of cardiovascular disease and should be managed appropriately, irrespective of referral to a nephrologist. The development of local guidelines enables progressive CKD and associated complications, such as cardiovascular risk and

Table 6.1 Kidney DIsease: Improving Global Outcomes (2012) stages of CKD.

Assign GFR categories as follows:

GFR categories in CKD

GFR category	GFR (ml/min/1.73 m^2)	Terms
G1	≥90	Normal or high
G2	60–89	Mildly decreased*
G3a	45–59	Mildly to moderately decreased
G3b	30–44	Moderately to severely decreased
G4	15–29	Severely decreased
G5	<15	Kidney failure

Abbreviations: CKD, chronic kidney disease; GFR, glomerular filtration rate.
*Relative to young adult level
In the absence of evidence of kidney damage, neither GFR category G1 nor G2 fulfill the criteria for CKD.

Assign albuminuria* categories as follows:

Albuminuria categories in CKD

Category	AER (mg/24 hours)	ACR (approximate equivalent) (mg/mmol)	ACR (approximate equivalent) (mg/g)	Terms
A1	<30	<3	<30	Normal to mildly increased
A2	30–300	3–30	30–300	Moderately increased*
A3	>300	>30	>300	Severely increased**

Abbreviations: AER, albumin excretion rate; ACR, albumin-to-creatinine ratio; CKD, chronic kidney disease.
*Relative to young adult level.
**Including nephrotic syndrome (albumin excretion usually >2200 mg/24 hours [ACR >2220 mg/g; >220 mg/mmol]).

Source: With kind permission from KDIGO.

anaemia, to be managed in the community or general medical clinics and aims to ensure appropriate referrals to renal services. Referral of all patients with CKD stages 3–5 would overwhelm renal services and is not necessary. Anecdotal evidence suggested that referral rates to renal teams from primary care at least doubled following the introduction of eGFR reporting and a variety of methods to manage the increased numbers are being evaluated. Examples include employment of specialist renal nurses, or computerised systems to identify patients most at risk.

One such computerised system is the System for Early Identification of Kidney Disease (SEIK). This system, in east Kent, provides GPs with computerised decision support for the management of patients who have kidney disease. It offers patient specific advice on appropriate referral for kidney disease by using data extracted from primary care computer systems. The aim is to prevent or delay progression of kidney disease to end stage renal failure and reduce cardiovascular risk.

In general terms, it appears that local and national initiatives have together contributed to the improved understanding and management of CKD in primary care in the United Kingdom and as Stevens *et al.* (2012) have suggested, are showing signs of

BOX 6.1

Key Messages for Primary Care Teams in Managing CKD

- Chronic kidney disease increases in prevalence exponentially with age.
- The most common identifiable causes of CKD are diabetes and vascular disease.
- Chronic kidney disease is more common in some ethnic groups.
- Late referral of patients with CKD requiring renal replacement therapy to specialist renal services is associated with significant extra cost and poor clinical outcomes.
- The majority of patients with early CKD do not progress to ERF but do have increased risks of cardiovascular disease (the risk of death outweighs the risk of progression).
- Progression of CKD is associated with proteinuria and uncontrolled hypertension.

(Adapted from Renal Association www.renal.org/whatwedo/InformationResources/CKDeGUIDE/AbouteGFR.aspx, accessed 20 May 2013.)

having made significant health gains. Box 6.1 shows the key messages that renal nurses can communicate to primary care teams.

The Renal Association and Royal College of GPs' comprehensive guidance for CKD was published in 2005 and was followed in 2011 by clinical practice guidelines for detection, monitoring and care of CKD from the Renal Association. However, for GPs and nonspecialist healthcare providers to engage effectively with these guidelines, consideration must be made of the context of primary care and the current political and financial influences that affect care management. For example, information technology (IT) issues still need to be resolved to enable interface between biochemistry laboratories and GP surgeries, and to ensure adequate support for the GPs.

General Medical Services (GMS) Contract

A new contract for General Practitioners (GPs) in 2004 enabled GPs to be awarded points (related to income) if their surgery achieved specific indictors within a Quality and Outcomes Framework (QOF). With the advent of the Coronary Heart Disease (CHD), Diabetes and Renal NSFs and this new General Medical Services (nGMS) contract, it was important that work undertaken to improve the outcomes for patients with CKD was carried out in conjunction with primary and secondary care. Many of the QOF points concerning early detection and prevention of CKD are common to all three NSFs and the nGMS contract; these include protection strategies for blood pressure, urine testing for microalbuminuria, glycaemia and lipid control; not therefore adding dramatically to work already being undertaken.

The implementation of the nGMS contract in 2004 coincided with the drive to implement measures in primary and secondary care for early detection and prevention of the progression of CKD. The inclusion of tests in the Diabetes QOF, such as measurement of microalbuminuria and annual testing of creatinine for people with diabetes, has increased the quality of screening and documentation, potentially allowing easier identification for those people with varying stages of CKD caused by diabetes (Roland *et al.* 2012).

The QOF for CKD was introduced in April 2006, and was updated in 2012 to comprise five indicators as shown in Table 6.2. Points are attached to each indicator and determine the sum paid to each practice.

Table 6.2 The CKD QOF in the nGMS contract (2013–2014).

Indicator	Points	Achievement thresholds
Records CKD001. The contractor establishes and maintains a register of patients aged 18 or over with CKD (US National Kidney Foundation: Stage 3 to 5 CKD)	6	
Ongoing management CKD002. The percentage of patients on the CKD register in whom the last blood pressure reading (measured in the preceding 12 months) is 140/85 mmHg or less	11	41–81%
CKD003. The percentage of patients on the CKD register with hypertension and proteinuria who are currently treated with an ACE-I or ARB	9	45–80%
CKD004. The percentage of patients on the CKD register whose notes have a record of a urine albumin:creatinine ratio (or protein:creatinine ratio) test in the preceding 12 months	6	45–80%

Source: The indicators detailed in this section have been extracted from the 2013–2014 QOF guidance with the agreement of NHS Employers and the General Practitioners Committee of the BMA. Please note that QOF indicators are subject to change in subsequent years. The current, complete version of the guidance is available to download from the QOF section of the BMA website. These pages also outline the process by which changes are made to the QOF.

The indicators detailed in this section have been extracted from the 2013–2014 QOF guidance with the agreement of NHS Employers and the General Practitioners Committee of the BMA. Please note that QOF indicators are subject to change in subsequent years. The current, complete version of the guidance is available to download from the QOF section of the BMA web site. These pages also outline the process by which changes are made to the QOF http://bma.org.uk/practical-support-at-work/contracts/independent-contractors/qof-guidance (accessed 31 May 2013).

Although recent years have seen an overall improvement in practices achieving blood-pressure and proteinuria targets, there is a large variation in GP practices recording the prevalence of CKD. On average 4.1% of the population were recorded as having CKD in 2010 (NHS Information Centre 2011) and this may mean up to 30% of people with CKD are not known to primary care clinicians.

The impact of clinical guidelines for managing CKD in primary care

Since the publication of the first guidelines for managing CKD in primary care there remains scepticism about the impact and significance of diagnosing a patient with CKD, particularly as the concept of CKD is relatively new and patients with early disease are often asymptomatic (Brady and O'Donoghue 2010). One qualitative study (Crinson *et al.* 2010) found that primary care practitioners varied in their views of CKD. Some sought to implement the full clinical guidance, others only the pay-for-performance (QOF) targets. Nearly all practitioners had reservations as to whether CKD was really a disease and debated whether the diagnosis of CKD based on eGFR alone was appropriate. They also questioned whether CKD in older people was part of natural ageing

and had experienced difficulty in explaining the condition to patients without frightening them. These findings were supported by Greer *et al.* (2012) who found that practitioners in the United States reported several patient, provider and system-level barriers that contributed to poor education about CKD in primary care. A study in the United Kingdom in 2012 found that there was still anxiety about the disclosure of early-stage CKD with patients. The tensions experienced in this study related to identifying and discussing CKD in older people and patients with stage 3A, embedding early-stage CKD within vascular care, and the distribution of work within the practice team (Blakeman *et al.* 2012).

Care and Management of Mild to Moderate Kidney Disease (Stages 3a–3b)

This section provides a general overview of the care and management of people with stages 3a–b CKD, followed by a specific section on care and management of those with diabetes and CKD. The chance of developing CKD increases with age. People of African-Caribbean or south-Asian ethnic groups are also more likely to develop kidney disease. Chronic kidney disease appears to progress more rapidly in patients from lower socio-economic groups. A family history of CKD is also a risk factor. Patients can be directed to the NHS Choices Kidney Disease checker to see if they might be at risk of CKD www.nhs.uk/tools/pages/kidneydisease.aspx (accessed 20 May 2013).

Monitoring of CKD

Everyone at high risk should have an annual eGFR, to ensure that people with kidney disease are identified when the disease is still at an early stage. This is important because treatment of mild to moderate kidney disease with appropriate medicine management and changes in lifestyle can slow down kidney damage. Also early detection and treatment of CKD lessens the chance of it leading to CVD. An overview of tests for CKD management can be found at www.bjpcn-cardiovascular.com/download/3329 (accessed 20 May 2013).

How to explain the diagnosis of CKD

It is unfortunate that age-related decline in eGFR can be common, so it is important to note that an eGFR in the range 45–59, if stable over time and without any other evidence of kidney damage, is unlikely to progress or develop CKD-related complications.

Words used to explain this need to be chosen carefully. For example, it may be helpful to use the terms 'kidney damage' or 'reduced kidney function' rather than CKD, and to explain that kidney damage can be part of the normal ageing process. However, it is also important to explain that people with stage 3 CKD do need to be monitored and this will be carried out through an annual blood (eGFR) and urine (proteinuria) test. People with CKD stage 3A should have their names placed on the CKD Register and should be informed as such. Further information on how to explain CKD to patients can be found here www.bjpcn-cardiovascular.co.uk/download/3680 (accessed 20 May 2013).

Cardio-vascular disease (CVD) risk management

Cardio-vascular risk management is the main aim of care for people with stage 3 CKD, as both CKD and proteinuria are independent risk factors for CVD. A study by

Debella *et al.* (2011) found that CKD is associated with a risk of death similar to that of established coronary artery disease and higher than that of diabetes mellitus. The authors also suggested that CKD is associated with a risk of myocardial infarction (MI) that is at least as much as that from diabetes mellitus.

In summary the following actions should be undertaken to reduce CV risk:

- Blood pressure control. The goal is to keep blood pressure below 140/90 mmHg or 130/80 mmHg (for those with diabetes and/or proteinuria) (see section on diabetes mellitus below). If the blood pressure target is not met on more than two occasions, it is recommended to prescribe a low dose of ACEI/ARB (e.g. ramipril 1.25 mg/day) and then monitor renal function and serum K^+ after 5–10 days. Treatment can be increased progressively with monitoring. It is important to monitor renal function in case of renal function decline. This can happen when glomerular filtration pressure is dependent on angiotensin II –driven efferent arteriole tone (as in volume depletion or renal artery stenosis) (Steddon *et al.* 2006). However there may be up to 30 000 people with CKD who could benefit from ACE/ARBs and are not currently receiving them. As care for a patient on dialysis costs the NHS around £27 000 a year, and the cost of slowing down kidney deterioration is estimated to be £235 a year, timely prescription of antihypertensive therapy is crucial (Kerr 2012).
- Glycaemic control should be optimised according to individual targets.
- Salt intake should be assessed and reduced to 4–6 g/day
- Aspirin should be considered for secondary prevention in patients who have proven cardiovascular disease (National Institute for Health and Clinical Excellence 2008b). It is not contraindicated in renal impairment but there is a significantly increased risk of bleeding complications for patients on multiple antithrombotic agents.
- Weight reduction (aim for BMI < 30) and regular exercise (> 30 minutes/day) is also recommended.

Medicines review

A medicines review should be undertaken in any newly identified patient with CKD. Patients with CKD should be asked about over-the-counter and herbal medicines, to ensure medications are indicated and safe for the individual to take. It is important to emphasise that some medications can affect the kidneys – for example, nonsteroidal anti-inflammatory drugs (NSAIDs) such as ibuprofen – so it is best to check with a pharmacist before purchasing any over-the counter tablets. Metformin is excreted by the kidneys and has the potential to cause lactic acidosis. Many clinicians use metformin until eGFR is < 30 ml/min/1.73 m^2, when it should be stopped altogether, whilst the dose might be reduced when eGFR 30–45 ml/min/1.73 m^2. Special caution should be used when starting metformin in patients who are already on antihypertensive or diuretic therapy, or NSAIDs.

Referral

It is crucial to refer patients to a renal unit if eGFR < 30 or if there is rapidly decreasing kidney function. Renal units require at least one year to prepare people for dialysis, and once people with diabetes and CKD have an eGFR < 30 there may be a rapid decline in kidney function, especially if blood pressure and/or blood glucose are not well controlled.

The National Institute for Health and Clinical Excellence (2008a) guideline gives further details on referral to secondary care and a summary of indicators for referral is shown in Box 6.2.

BOX 6.2

Indicators for referral to secondary care

Referral is indicated in the following situations:

- Acute Kidney Injury (AKI); the discovery of an abnormal eGFR should prompt a review of historical eGFR and where eGFR is not available creatinine measurements.
- All those with Stage 4 and 5 disease should have their care plan formally discussed with a specialist. It may be possible in some cases for assessment and follow up to take place at the GP practice.
- Higher levels of proteinuria (ACR ≥ 70 mg/mmol or PCR ≥ 100 mg/mmol) unless known to be due to diabetes and already appropriately treated.
- Persistent invisible (microscopic) haematuria and proteinuria (ACR ≥ 30 mg/mmol or PCR ≥ 50 mg/mmol).
- Progressive CKD. The National Institute for Health and Clinical Excellence (2008a) has defined progressive CKD by a fall in eGFR of ≥ 5 ml/min/1.73 m^2 within one year (based on at least three readings) or a fall of ≥ 10 ml/min/1.73 m^2 within five years.
- Hypertension that remains poorly controlled despite the use of at least four antihypertensive drugs at therapeutic doses.
- Patients who present with a rare or genetic cause of renal disease (e.g. adult polycystic kidney disease (APKD).
- Suspected renal artery stenosis.

Self-management

One of the best ways to effectively manage mild to moderate kidney disease is to empower patients with knowledge of their condition and likely outcomes. Most people with CKD spend the majority of time managing their own condition, supported by health care professionals for only a few hours each year. Both primary and secondary care nurses are well placed to facilitate opportunities for self-management such as

- Urine test: a reminder to come for urine tests (ACR) as required which will help identify if at risk of progressive CKD.
- Blood test: a reminder to come for blood tests to monitor kidney function as required.
- Blood-pressure control: to explain the importance of BP tablets not only for blood pressure control but also to delay progression of CKD. Explain the need to report side-effects, as high blood pressure is a key factor in the progression of CKD.
- Blood-pressure monitoring: to monitor their blood pressure at home but they will need advice on which machine to buy and training on how to do this.
- Smoking cessation.
- Diet: avoid processed, high-salt and high-fat foods.
- Medicine management:
  - give advice on buying tablets over the counter (particularly anti-inflammatory drugs);
  - patients should tell the pharmacist that they have chronic kidney disease.
- Lifestyle modification: taking exercise and keeping to ideal weight.

One quality-improvement project (Thomas and Loud 2012) aimed to reduce inconsistencies in CKD care and improve self-management opportunities for patients. At the end of the project a 'Package of Innovation (POI) for Managing Kidney Disease in Primary Care' was developed. This package was developed by a team of practitioners and people with experiences of kidney disease and other chronic conditions and aims to

improve the quality of care of people with kidney disease in the community by helping the primary healthcare team to:

- identify people who have kidney disease in their practice;
- improve their knowledge and management of kidney disease;
- educate people about kidney disease;
- facilitate self-management in people who have kidney disease.

The package includes:

- details about how to validate a CKD register used in primary care;
- training packages for healthcare professionals on CKD management, quality improvement techniques and self-management facilitation;
- a training package that can be delivered by patients or healthcare professionals to people in a group education session to educate about kidney disease and encourage both self-management and collaboratively working with healthcare professionals;
- an information booklet and a DVD to help patients to look after their kidneys.

All materials can be used as per the step-by-step guide detailed in the package, although each is also a stand-alone item. The majority of the resources are freely available to download from https://support.kidneyresearchuk.org/packageofinnovation (accessed 31 May 2013).

Diabetes Mellitus

Good blood glucose control in individuals with type-1 diabetes mellitus has been shown some years ago to prevent or slow down the progression of renal disease (DCCT Research Group 1993). This landmark study demonstrated that a reduction in HbA1c (glycated haemoglobin) from 9.0% to 7.0% was associated with a 39% reduction in the occurrence of microalbuminuria and a 54% reduction in the occurrence of proteinuria over 6.5 years in patients with type-1 diabetes (DCCT Research Group 1993).

More recent research in type-2 diabetes mellitus indicated that tight blood pressure control was also crucial (United Kingdom Prospective Diabetes Study Group 1998). More recent studies reflect these findings: chronic kidney disease progression can be slowed by strict blood pressure (de Galan *et al.* 2009) and blood glucose control (Bilous 2008) prescription of medicines that modify the renin-angiotensin system (Araki *et al.* 2008) and lifestyle changes such as smoking cessation (Egede 2003). The National Institute for Health and Clinical Excellence (2008a) recommends annual monitoring of eGFR or more frequently if the eGFR is falling by $> 5\,\text{ml/min/1.73}\,\text{m}^2$ per year. A summary of CKD management in people with diabetes is shown in Box 6.3 and is based on National Institute for Health and Clinical Excellence (National Institute for Health and Clinical Excellence 2008a) guidance.

National Institute for Health and Clinical Excellence guidance (2008a) recommends annual screening for microalbuminuria (using ACR) and prescription of angiotensin converting enzyme inhibitor (ACEI) or angiotensin receptor blocker (ARB) (if ACEI not tolerated) if the ACR is abnormal (even if normotensive). Systolic blood pressure should be maintained below 130 mmHg (target range 120–129 mmHg) and diastolic blood pressure maintained below 80 mmHg.

BOX 6.3

Management of mild to moderate kidney disease in people with diabetes

- Education and promotion of self-management
- Annual monitoring of eGFR
- Annual monitoring of microalbuminuria (ACR) (early morning urine sample recommended). An ACR > 2.5 mg/mmol in men and an ACR > 3.5 mg/mmol in women is clinically significant.
- Systolic blood pressure control to < 130 (target range 120–129 mmHg).
- Diastolic blood pressure control to < 80 mmHg.
- Blood glucose control. A target HbA1c of <48 mmol/mol (6.5%) is often given although individualised targets are recommended. (Changes in the reporting of HbA1c values were introduced in the UK in 2009 and from June 2011 HbA1c is reported in mmol/mol, often alongside HbA1c%.)
- Prescription of ACE inhibitors and ARBs once microalbuminuria is present.
- Lifestyle changes (especially smoking cessation).
- Referral if eGFR < 30 especially if there is progressive CKD.
- Immunisation for influenza and pneumococcus advised.

Care and Management of Moderate to Severely Decreased Kidney Function (Stage 4)

The care and management of people with stage 4 CKD should be the same as in stage 3a/b but other considerations should also be taken into account. Once the eGFR drops to below 20 ml/min/1.72 m^2, the focus should start to be on preparation for RRT.

Optimal nutritional management

Management of nutrition especially the controversial issue of reducing protein intake in CKD is discussed in Chapter 13. All patients at CKD stage 4 should receive a dietary assessment and be screened for malnutrition.

Control of serum bicarbonate within normal levels

As an individual becomes more uraemic, the pH balance in the internal environment starts to become more acidic. The body's natural response to this is to produce bicarbonate, metabolised from the liver and activated by the kidney, which acts as a buffer to return the pH to more neutral levels. However, if the kidney is defective, this process is thwarted and supplementary bicarbonate may be administered. The nurse must be aware that administering bicarbonate may result in plasma volume expansion and hypertension, which should be reported. The safest way to control bicarbonate balance is with dialysis. Hence, if this condition is not adequately controlled then commencement of dialysis may be indicated (see below for further discussion of acid–base balance).

Management of bone disease

Renal disease causes an abnormality of vitamin D metabolism, causing deficient calcium levels, skeletal damage and bone pain. Refer to Chapter 2 for further information on the underlying physiological processes. The aim of care is to keep calcium and phosphate levels within normal ranges, preventing hyperparathyroidism. After correcting

the acidosis, plasma phosphate and calcium levels can be controlled with oral phosphate binders, calcium supplements and dietary changes. See Chapter 12.

Control of anaemia

Anaemia in chronic kidney disease is usually normocytic and normochromic and due to primary causes such as reduced production of erythropoietin production, uraemic toxins inhibiting erythropoiesis and haemolysis due to uraemic changes to the red cell membrane.

The individual will become more anaemic as renal disease progresses, as three types of cells in the blood are affected:

- erythrocytes – causing anaemia;
- leukocytes – causing immunosuppression;
- platelets – causing bleeding tendencies.

National Institute for Health and Clinical Excellence guidance (2011) recommends investigating and managing anaemia in people with CKD if their Hb level falls to 11 g/dl or less or if they develop symptoms attributable to anaemia (such as tiredness, shortness of breath, lethargy and palpitations).

The correction to *normal* levels of Hb with ESAs is not usually recommended in people with anaemia of CKD. The aspirational Hb range should be maintained between 10 and 12 g/dl for adults, young people and children aged 2 years and older, and between 9.5 and 11.5 g/dl for children younger than 2 years of age, reflecting the lower normal range in that age group.

In order to keep the Hb level within the aspirational range, it is important not to wait until Hb levels are outside the aspirational range before adjusting treatment (for example, take action when Hb levels are within 0.5 g/dl of the range's limits). Age alone should not be a determinant for treatment of anaemia of CKD.

People receiving ESA maintenance therapy should be given iron supplements to keep their serum ferritin levels between **200** and **500** µg/l in both patients on haemodialysis and not on haemodialysis, *and either* transferrin saturation level above **20**% (unless ferritin is greater than **800** µg/l) *or* percentage hypochromic red cells (%HRC) less than **6**% (unless ferritin is greater than **800** µg/l). In practice it is likely this will require intravenous iron. See National Institute for Health and Clinical Excellence guidance (2011) for further information.

Control of gastrointestinal disorders

These disorders are common in CKD, especially as the individual approaches the need for dialysis. The person may experience anorexia, nausea and vomiting, hiccups, a metallic taste in the mouth and, for those with diabetes, exacerbation of gut complications presenting as episodes of diarrhoea. Urea is excreted in the gut, and broken down, releasing ammonia which acts as an irritant. Some medications may give unpleasant side-effects, e.g. heartburn with phosphate binders and oral iron supplementation. Constipation can be common in established renal disease as fluid intake is reduced. Generally, the person with renal disease is less physically active due to the effects of a chronic illness causing lethargy and tiredness.

Treatment of dermatological disorders

Generalised uraemic pruritus (itching) is a distressing symptom in persons with CKD, with often little relief from drugs. Deposits of calcium and phosphorus in the skin and

sweat glands excreting urea are thought to be the causative factors of pruritus, but dry skin and drug allergies must not be overlooked as causes. Platelet defects and capillary permeability, both complications of renal failure, can cause bleeding and bruising of the skin, especially if there is continued scratching. Many persons with advanced kidney disease have a yellow tinge to their skin that is a combined result of hypermelanosis and the deposition of pigments in the skin (urochrome and carotene) that are usually excreted by the kidneys. Although medications may be of some help (Rayner *et al.* 2013), commencement of dialysis may be the only long-term relief.

Control of volume disorders

During the progression of kidney disease some nephrons remain intact whilst others continue to be destroyed. The remaining undamaged nephrons hypertrophy and produce an increased volume of filtrate with increased tubular reabsorption, even though there is a reduction in the glomerular filtration rate. This process allows the kidney to continue to function until three-quarters of the nephrons are destroyed. In persons with CKD with blood urea levels above 40 mmol/l, the solute load becomes greater than can be reabsorbed, producing an osmotic diuresis accompanied by polyuria of up to 3 L in a 24 h period. The urine is dilute as the kidney's concentration ability is lost and the person will have nocturia. As more nephrons are destroyed, oliguria with the retention of waste products is evident. The individual develops a wide range of biochemical, haematological and endocrine disorders and the clinical features of fluid overload.

Changes in fluid allowance may be required in association with diuretics. Loop diuretics such as furosemide will increase sodium excretion from the kidney and so prevent sodium retention. During episodes of polyuria, volume replacement should be administered to prevent further reduction in renal perfusion and worsening of kidney function. When volume overload is unresponsive to treatment the commencement of dialysis is indicated.

Control of potassium disorders

Excess potassium is normally removed by renal excretion, but as CKD progresses, excretion of urinary potassium decreases because of a reduced glomerular filtration rate caused by tubular defects in diseases such as diabetes mellitus, ultimately resulting in hyperkalaemia. Hyperkalaemia (indicated as a potassium of above 6.0 mmol/l) can occur in CKD following episodes of acute illness, infection or nonadherence to dietary restrictions. Chronic metabolic acidosis also causes potassium to shift out of the cells and into the extracelluar fluid, giving rise to hyperkaleamia.

If metabolic acidosis is present this should be corrected first, and this will then help to reduce the serum potassium to within safe limits. If chronic hyperkalaemia is present, dietary advice may be indicated, so high potassium foods are avoided (see Chapter 12).

Potassium-sparing diuretics should usually be discontinued as these drugs block the distal potassium transfer so that potassium is retained. If hyperkalaemia persists, this should be monitored very closely and managed in one of two ways – either conservatively or with dialysis. Conservative management of hyperkalaemia may involve the use of exchange resins (e.g. calcium resonium). Oral resins are not absorbed but exchange potassium for calcium or sodium from the gastrointestinal tract. The choice of calcium or sodium depends on the level of hypercalcaemia or fluid overload in the individual.

Control of acid–base balance

In normal health, acid–base balance is maintained by the excretion into the renal tubules of excess acid (hydrogen or H+ ions) where the following processes then take place:

- Filtered bicarbonate is reabsorbed.
- There is increased production of ammonia that combines with H^+ ions and is then excreted in the form of ammonium salts.
- A titratable acid is formed.
- Tubular fluid pH is reduced.

In CKD, a mild metabolic acidosis may be present as normal renal tissue is not sufficient to perform the above functions efficiently. Metabolic acidosis may also be worse in persons who have renal tubular acidosis.

The individual will present with:

- a blood pH of less than 7.35;
- hyperkalaemia, as metabolic acidosis shifts potassium from the cells into the extracellular fluid;
- signs of renal bone disease, as metabolic acidosis reduces the bone carbonate buffers, allowing calcium to be lost from the bones: calcium is more soluble in an acid environment;
- gasping for breath caused by acidosis as the person attempts to breathe off the excess acid through expired carbon dioxide.

Intravenous sodium bicarbonate may correct acidosis but the sodium may cause hypernatraemia, leading to fluid retention and hypertension. Essentially, metabolic acidosis indicates kidney failure and the most efficient and safest way to treat it is with dialysis.

Disorders of the central nervous system

In CKD, nervous system dysfunction can cause numerous mental disabilities such as poor memory function, loss of concentration and slower mental ability. Physical disabilities result in peripheral neuropathies affecting the legs and feet and may result in 'restless legs' and paraesthesia. More serious neurological problems are rarely seen these days, where there is fluid overload and hypertension in advanced kidney disease, in the form of convulsions and cerebral oedema. A 'uraemic flap' may be seen in very toxic patients, where the hands involuntarily flap from the wrists. Other electrolyte disorders (such as hyper-/hypocalcaemia), also cause shaking or an involuntary reflex when nerve points are stimulated. All these symptoms and complications can be avoided with the introduction of early dialysis.

Sexual function

In women, the loss of sexual function may take the form of infertility due to amenorrhoea and other menstrual abnormalities. Loss of libido may be present: if pregnancy does occur there is a high risk of miscarriage due to the effects of uraemia (Levy *et al.* 1998). There is also risk to the mother's health as it is possible that renal failure will accelerate because of the extra workload on damaged kidneys.

In men, the incidence of infertility and impotence increases with age and the advancement of CKD. There are multiple causes of impotence, which include poor nutrition,

anxiety, side-effects of antihypertensive drugs and reduced plasma testosterone. The individual and partner should be given ample opportunity to express fears and talk about symptoms that are causes for concern.

With the wider use of erythropoietin to correct anaemia, fewer women with decreased renal function are experiencing loss of fertility and amenorrhoea. Successful pregnancy for couples where at least one partner has a degree of kidney disease is becoming more common although requires careful planning and monitoring for a successful outcome (Davison and Lindheimer 2011). Pregnancy complications for women with CKD remain high (Bramham *et al.* 2011).

Summary

Patients with an eGFR <30 ml/min/1.72 m^2 should undergo clinical review at least every 3 months and this review should include measures of eGFR, Hb, calcium, phosphate, potassium, bicarbonate and PTH.

Education in the Predialysis Phase

The need for good education and preparation of the individual and the family at all stages of CKD, potentially heading towards ERF, cannot be underestimated (Harwood and Clarke 2011). The psychological aspects of dealing with this chronic illness have been dealt with in Chapter 4, but it is worth reiterating the importance of education and information as part of the preparation process. It is essential that the person and renal staff work in collaboration, not only to ensure the best care possible for the person, but also for the renal team to understand the patient and family perspective. For some, it is very important to be able to continue in their present employment, and so education about RRT modalities must include consideration of how that dialysis is to be performed. For example, peritoneal dialysis that persons can perform for themselves, or some form of home dialysis programme, is key to maintaining employment status.

Shared decision making during the predialysis stage is crucial and this involves not just clear, understandable information about the condition and the treatment or support options but also prompts to help them think about what the different options might mean for them (Coulter and Collins 2011). These prompts are called decision aids and are being designed to help clinicians to actively engage patients in the decision making process. Decision aids include several components with relevant information that helps patients to remember facts and make deliberate choices between two or more treatment options. Decision aids for people with kidney disease can be found at http://sdm.rightcare.nhs.uk/pda/established-kidney-failure-dialysis/ (accessed 31 May 2013).

For some, the thought of attempting to understand any aspect of the RRT process is daunting and overwhelming. This may be due to the immediacy of the circumstances in which they commenced RRT, or indeed their sense of control and unique personal characteristics, which mean the understanding healthcare professionals should take the lead in directing care. This in no way means that the individual absolves responsibility or plays no part in any of the decision-making processes about care and treatment.

For predialysis preparation to be effective, influences on learning such as cultural and religious beliefs about the context of CKD have to be taken into consideration. Indeed misunderstanding and misinterpretation by the individual and their family may have more to do with the way information is presented (e.g. jargon used) by healthcare professionals. For many patients the cultural and religious contexts of health are crucial in shaping how far health care advice is accepted. The renal unit is a confusing place

where the individual has to make sense of their symptoms and proposed treatment plan. Patients also have to work through the stages of grief of losing an old life, and also have to realign the new (renal) life with personal ideology and life goals.

The ultimate skill that any renal healthcare professional can hope to achieve in the care of those approaching RRT is to be able to gain an understanding of each individual. That person is unique as regards personal hopes and aspirations for the future, the ability to understand the care and treatment strategies that lie ahead, and how the individual wishes to be involved in that care delivery. All too often, renal professionals of all kinds can be very focused on the pathological and technical aspects that dominate their understanding of their role as a renal practitioner. For the individual approaching RRT, the priorities may be quite different, so it is important to start providing information very early on, at least one year before dialysis is required. There may also be those for whom initiation of dialysis may not be feasible. The option of not commencing dialysis at all is discussed in detail in Chapter 10.

Pre-dialysis education programmes

There are many benefits to running a structured predialysis education programme (PDEP). Many units run group education sessions for patients, and content of the programmes may include introductions to HD, PD and transplantation plus other issues such as nutrition and social/psychological support available. PDEPs should enable patients to make informed choices about dialysis and indeed Goovaerts *et al.* (**2005**) found that a high percentage of patients exposed to a structured PDEP often choose a self-care modality such as home haemodialysis.

All the current clinical practice guidelines, including the European Best Practice Guidelines and the Caring for Australians with Renal Impairment (CARI) guidelines, recommend the importance of educational programmes to enable patients to make informed choices of treatment options. See Chapter 4. Box 6.4 shows a summary of Renal Association recommendations (http://www.renal.org/Clinical/GuidelinesSection/Guidelines.aspx, accessed 12 June 2013) for educational interventions during predialysis care.

A good overview of how to set up and implement education programmes for CKD can be found in Chapter 1 of the EDTNA/ERCA Handbook Chronic Kidney Disease: Stages 4–5 (Cox *et al.* 2008). A summary of the recommendations for implementing pre-dialysis educational programmes identified in this handbook is shown in Box 6.5

BOX 6.4

Renal Association guidelines for predialysis education programmes

- All patients with severe CKD (stage 5 and progressive stage 4) together with their families and carers, should be offered an appropriate education programme aimed at improving their knowledge and understanding of their condition, and of the options for treatment.
- All patients should be encouraged to perform home dialysis therapy where possible, as part of an integrated approach to renal replacement therapy.
- All medically suitable patients should be informed about the advantages of pre-emptive living kidney transplantation and efforts made to identify potential donor to allow pre-emptive transplantation before the need for renal replacement therapy.
- Patients needing RRT within 3 months access an accelerated care pathway to deliver education, information and prepare for RRT.

BOX 6.5

How to set up and implement education programmes.

- ASSESS. Assess learning style (activist, reflector, theorist, pragmatist). Further information on these learning styles can be found at www.peterhoney.com (accessed 20 May 2013). Assess barriers to learning.
- PLAN. Develop a learning plan in partnership with the patient, e.g. aim of learning; how much information is wanted; how to learn the information.
- IMPLEMENT. Implement either one-to-one or group education session individualised to level of literacy; language, age, stage of disease. Consider different learning resources tailored to individual preference and learning style (face-to-face; books, DVD; Internet; talking with other patients)
- EVALUATE. Evaluate how far the aims of the educational session/programme were achieved. Evaluate the nurse's expertise in facilitation of learning (peer review).

Source: adapted from Cox *et al*. (2008).

BOX 6.6

Suggested content of a predialysis education programme

- Information on CKD – cause, progression and the future.
- Information on how disease may affect the patient, recognition of symptoms and what to expect.
- Information about different treatment options.
- Information about practicalities of starting or changing treatment options and preparation for treatment chosen (e.g. fistula).
- Information about complications or side effects of treatment chosen or medication.
- Information about managing or influencing patient's own condition.
- Information on effects of CKD on daily life, work, finance and social activities.
- Information from other patients regarding living with CKD and various treatment options.
- Information on adjusting and coping with CKD and where to find support.

The content of any education programme or session should always be individualised for each patient and their family but Box 6.6 summarises the information priorities that were identified by and important to patients with CKD (modified from Ormandy *et al*. (2007).

When Should Dialysis Commence?

The optimal time at which the individual concerned can benefit most from commencing RRT continues to be controversial. It is important to bear in mind that pre-emptive transplantation is the gold standard, where possible. What is not disputed is that timely referral to the renal team is beneficial as late referral often results in poorer outcome in terms of mortality and morbidity rates and quality of life experienced during this period (Jungers *et al*. 2000). There is also evidence that early referral may result in the rate of decreasing renal function being slowed and the prevalence of cardiovascular disease can be twice as high in persons who were referred less than 6 months before starting RRT

than in those who benefit from effective nephrological care for more than 3 years in the predialysis period.

Although, in principle, early referral appears beneficial, this is not always easy to achieve in practice, especially as many people with stage 4 CKD will not progress to dialysis and also predicting rate of progression can sometimes be challenging (Taal and Brenner 2006).

How early is early? National guidance from the Renal Association (http://www.renal.org/Clinical/GuidelinesSection/Guidelines.aspx, accessed 12 June 2013) suggests that patients known to the nephrology services for three months or more, should start RRT in a planned way without the need for hospital admission and using established vascular access (AV fistula or graft or PD catheter) or by pre-emptive transplantation. It is recommended that the decision to start RRT in patients with CKD stage 5 (eGFR $<$ 15 ml/min/1.73 m^2) should be based on a careful discussion with the patient of the risks and benefits of RRT taking into account the patient's symptoms and signs of renal failure, nutritional status, co-morbidity, functional status, and the physical, psychological and social consequences of starting dialysis in that individual. In addition it is recommended that serious consideration should be given to starting renal replacement therapy in patients with an eGFR $<$ 6 ml/min/1.73 m^2, even if the patient is asymptomatic.

Conclusion

Having reviewed the guidelines and strategies for supporting the individual with CKD it can be seen there has been an evolution in this area of care, especially concerning patient decision making.

Primary care practitioners and nonspecialist healthcare professionals are now increasingly expected and encouraged to be involved in CKD care delivery. There have been developments in the management of eGFR, anaemia, nutrition and patient education and new clinical guidelines for managing CKD are still evolving.

Future development of approaches to CKD need to include cultural and religious considerations when these areas of a person's life clearly impact on the presenting biomedical symptoms, as well as psychological adaptation and coping strategies. Nurses in particular have many professional skills that could be harnessed within guidelines to address these issues.

References

Araki, S., Haneda, M., Koya, D. *et al.* (2008) Clinical impact of reducing microalbuminuria in patients with type 2 diabetes mellitus. *Diabetes Research and Clinical Practice* **82** (suppl. 1), S54–58.

Arora, P., Rajagopalan, S., Patel, N. *et al.* (2012) The MDRD equation underestimates the prevalence of CKD among blacks and overestimates the prevalence of CKD among whites compared to the CKD-EPI equation: a retrospective cohort study. *BMC Nephrology* **13** (1), 4.

Atkins, R.C. and Zimmet, P. (2010) Diabetic kidney disease: act now or pay later. *Nephrology Dialysis Transplantation,* **25** (2), 331–333.

Bilous R (2008) Microvascular disease: what does the UKPDS tell us about diabetic nephropathy? *Diabetic Medicine* **25** (suppl.) 2, 25–29.

Blakeman, T., Protheroe, J., Chew-Graham, C. *et al.* (2012) Understanding the management of early-stage chronic kidney disease in primary care: a qualitative study. *British Journal of General Practice* **62** (597), e233–e242.

Brady, M. and O'Donoghue, D. (2010) The role of primary care in managing chronic kidney disease. *The British Journal of General Practice* **60** (575), 396.

Bramham, K., Briley, A.L., Seed, P.T. *et al.* (2011) Pregnancy outcome in women with chronic kidney disease: a prospective cohort study. *Reproductive Sciences* **18** (7), 623–630.

Coulter, A. and Collins, A. (2011) *Making Shared Decision-Making A Reality; No Decision about Me, Without Me,* Kings Fund, London.

Cox, S., Thomas, N. and Liossatou, A. (2008) Giving choice through timely education: how to set up and implement education programmes for CKD, in *Chronic Kidney Disease: Stages 4–5* (ed. EDTNA/ERCA), EDTNA/ERCA , Luzern, Switzerland.

Crinson, I., Gallagher, H., Thomas, N. and de Lusignan, S. (2010) How ready is general practice to improve quality in chronic kidney disease? A diagnostic analysis. *The British Journal of General Practice* **60** (575), 403.

Davis, C.L., Harmon, W.E., Himmelfarb, J. *et al.* (2008) World Kidney Day 2008: think globally, speak locally. *Journal of the American Society of Nephrology,* **19** (3), 413–416.

Davison, J.M., and Lindheimer, M.D. (2011) Pregnancy and chronic kidney disease. *Seminars in Nephrology* **31** (1), 86–99.

DCCT Research Group (1993) Diabetes Control and Complications trial (DCCT): the effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin dependent diabetes mellitus. *New England Journal of Medicine* **329** (14), 977–986.

Debella, Y.T., Giduma, H.D., Light, R.P. and Agarwal, R. (2011) Chronic kidney disease as a coronary disease equivalent – a comparison with diabetes over a cecade. *Clinical Journal of the American Society of Nephrology* **6**.(6), 1385–1392.

de Galan, B.E., Perkovic, V., Ninomiya, T. *et al.* (2009) Lowering blood pressure reduces renal events in type 2 diabetes. *Journal of the American Society of Nephrology* **20** (4), 883–892.

de Lusignan, S., Chan, T., Gallagher, H. *et al.* (2009) Chronic kidney disease (CKD) management in southeast England: a preliminary crosssectional report from the QICKD – Quality Improvement in Chronic Kidney Disease study. *Primary Care Cardiovascular Journal* **2** (Special issue CKD), 33–39.

Department of Health (2004) *The Quality and Outcomes Framework (QOF), General Medical Services Contract for General Practices,* www.nhsemployers.org/PayAndContracts/GeneralMedicalServicesContract/QOF/Pages/QualityOutcomesFramework.aspx (accessed 12 June 2013).

Department of Health (2005*) National Service Framework for Renal Services: Chronic kidney disease, acute renal failure and end of life care (Part Two),* HMSO, London.

Diabetes Control and Complications Trial Research Group (1993) The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. *New England Journal of Medicine* **329,** 977–986.

Egede, L. (2003) Lifestyle modification to improve blood pressure control in individuals with diabetes: is physician advice effective? *Diabetes Care* **26,** 602–607.

Goovaerts, T., Jadoul, M. and Goffin, E. (2005) Influence of a pre-dialysis education programme (PDEP) on the mode of renal replacement therapy. *Nephrology Dialysis Transplantation* **20** (9), 1842–1847.

Greer, R.C., Crews, D.C. and Boulware, L. (2012) Challenges perceived by primary care providers to educating patients about chronic kidney disease. *Journal of Renal Care* **38** (4), 174–181.

Harwood, L. and Clarke, A.M. (2011) Understanding health decisions using critical realism: home-dialysis decision-making during chronic kidney disease. *Nursing Inquiry* **19** (1), 29-38.

Jungers, P., Chokroun, G. and Robino, C. *et al.* (2000) Epidemiology of established renal disease in the Ile-de-France area: a prospective study in 1998. *Nephrology Dialysis Transplantation* **12,** 2000–2006.

Kerr, M. (2012) *Chronic Kidney Disease in England: The Human and Financial Cost,* NHS Kidney Care, London.

Kidney Disease Outcome Quality Initiative (K/DOQI) (2005) K/DOQI Clinical Practice Guidelines for Chronic Kidney Disease: Evaluation, Classification, and Stratification. *American Journal of Kidney Diseases* **39,** S1–266 (suppl. 1).

Levey, A.S., Stevens, L.A., Schmid, C.H. *et al.* (2009) A new equation to estimate glomerular filtration rate. *Annals of Internal Medicine* **150** (9), 604–612.

National Institute for Health and Clinical Excellence (2008a) *Early Identification and Management of Chronic Kidney Disease in Adults in Primary and Secondary Care.* NICE clinical guideline 73, NICE, London.

National Institute for Health and Clinical Excellence (2008b) Management of Type 2 Diabetes: Renal Disease – Prevention and Early Management, NICE, London

National Institute for Health and Clinical Excellence (2011) Anaemia Management in People with Chronic Kidney Disease (CKD). NICE clinical guideline CG114, NICE, London.

NHS Information Centre (2011) QOF Prevalence Data Tables 2010/2011. http://data.gov.uk/dataset/the-quality-and-outcomes-framework-2010-11 (accessed 12 June 2013).

Ormandy, P., Hulme, C., Caress, A.-L. *et al.* (2007) *Identifying Chronic Kidney Disease Patients' Priorities and Preferences for Information Topics,* Institute for Health and Social Care Research, University of Salford, Salford.

Rayner, H., Baharani, J., Smith, S., Suresh, V., & Dasgupta, I. (2013). Uraemic pruritus: Relief of itching by gabapentin and pregabalin. *Nephron Clinical Practice* **122** (3–4), 75–79.

Renal Association (2002) *Treatment of Adults and Children with Renal Failure. Standards and Audit Measures,* Royal College of Physicians, London.

Renal Registry (2011) *The Fourteenth Annual Report of the UK Renal Registry, Bristol,* www.renalreg.com/Reports/2011.htm (accessed 20 May 2013).

Roland, M., Guthrie, B. and Thomé, D.C. (2012) Primary Medical Care in the United Kingdom. *Journal of the American Board of Family Medicine* **25** (suppl. 1), S6–S11.
Steddon, S., Ashman, N., Cunningham, J. *et al.* (2006) *Oxford Handbook of Nephrology and Hypertension*, Oxford University Press, Oxford.
Stevens, P., de Lusignan, S., Farmer, C.K.T. and Tomson, C.R.V. (2012) Engaging primary care in CKD initiatives: the UK experience. *Nephrology Dialysis Transplantation* **27**(suppl. 3), iii5–iii11.
Stevens, P., O'Donoghue, D., de Lusignan, S. *et al.* (2007) Chronic kidney disease management in the United Kingdom: NEOERICA project results. *Kidney International* **72**, 92–99.
Taal, M.W. and Brenner, B.M. (2006) Predicting initiation and progression of chronic kidney disease: developing renal risk scores. *Kidney International* **70,** 1694–1705.
Thomas, N. (2011). The management of chronic kidney disease. *Nurse Prescribing* **9** (2), 76–81.
Thomas, N. and Loud, F. (2012) Managing chronic kidney disease in primary care: a quality improvement study. *Renal Society of Australasia Journal* **8** (3), 152–157.
United Kingdom Prospective Diabetes Study Group (UKPDS) (1998) Tight blood pressure control and risk of macrovasular and microvascular complications in type 2 diabetes: UKPDS 38. *British Medical Journal* **317,** 703–713.

Resources

CKD Online, www.ckdonline.org (accessed 20 May 2013).
CKD Strategy Group (a working group of the British Renal Society), www.britishrenal.org/CKD-Forum.aspx (accessed 20 May 2013).
Information sheet to give to patients: *Kidney Damage and What it Means to You*, **www.bjpcn-cardiovascular.com/download/3337** (accessed 20 May 2013).
Kidney Research UK / British Renal Society DVDs: *Living with Kidney Disease,* **www.kidneyresearchuk.org/health/living-with-kidney-disease-dvd.php** (accessed 20 May 2013).
NHS Choices web page on CKD, www.nhs.uk/conditions/Kidney-disease-chronic/Pages/Introduction.aspx (accessed 20 May 2013).

CHAPTER 7

Investigations in Kidney Disease

Althea Mahon
Denali Medical Services, Western Australia

Learning Outcomes

- To explain the procedures commonly undertaken in the diagnosis of acute kidney injury and chronic kidney disease.
- To evaluate the nurse's role in postprocedure care.
- To gain knowledge and understanding of the investigations required in the diagnosis of renal impairment.
- To provide a rationale for the use of these investigations and procedures.

Introduction

Patients referred to a nephrologist are subjected to a bewildering array of diagnostic tests and procedures. Nurses working in this area should familiarise themselves with these investigations in order to be able to completely explain them to the patient; consent will then be truly 'informed'. The tests covered in this chapter include those involving blood and urine, radiological tests, invasive investigations and methods of evaluating glomerular filtration rate. Investigations that are carried out prior to initiating anaemia treatments, such as erythropoeitin stimulating agents (ESAs), are discussed, as well as those used in cases of diminished or nonresponse to ESAs.

Some patients who have progressive kidney disease show no specific signs or symptoms and do not feel unwell until the disease is advanced. Abnormal results of blood and urine tests carried out at routine medical examinations, whether they be pre-employment, pre-life insurance or preoperative, or during visits to a general practitioner for other reasons, may warrant referral. Patients with acute kidney injury (AKI) from whatever cause also come under the remit of a nephrologist, and urgent diagnosis and treatment in this potentially life-threatening situation are vital (see Chapter 5). Sometimes only a large number of investigations will help make the diagnosis.

Nurses are responsible for correctly undertaking many of the investigations, so an understanding of the nature of these tests is vital, as is the ability to recognise abnormal results.

An individual with end-stage kidney disease (ESKD) is subjected to constant investigations to monitor the effectiveness of renal replacement therapy (RRT), with the

Renal Nursing, Fourth Edition. Edited by Nicola Thomas. © 2014 John Wiley & Sons, Ltd. Published 2014 by John Wiley & Sons, Ltd.

objective of giving the patient maximum benefit from treatment with the minimum of side effects, in order to maintain a reasonable quality of life.

Phlebotomy

The World Health Organization (2010) published guidelines on best phlebotomy practice, recommending standards for quality care that include laboratory sampling and the maintainence of quality control. Nurses who can demonstrate competence working within their scope of practice can undertake venepuncture (Nursing and Midwifery Council 1992). Prior to embarking on the collection of blood samples there are several factors that should be considered:

- the safety of healthcare personnel;
- the safety and comfort of the patient;
- planning ahead, for example the correct collection system and appropriate location.

Safety of health care personnel

European Council Directive 2010/32/EU, the sharps directive, is a framework aimed at the prevention of sharps-related injuries in the health sector. Preventative measures include the use of protective equipment such as disposable gloves (also aprons and eye shields in some situations), attention being paid to proper handwashing before and after procedures and the use of safety devices such as closed blood-collection systems, shielded and retractable needles, safety lancets, blunt needles and needle free systems. Of the approximately 1 million sharps injuries that occur in Europe each year, more than 100 000 are in the United Kingdom; the use of safety devices is associated with a 75% reduction in percutaneous injuries (Health and Safety Executive 2010). Hepatitis B, C and human immunodeficiency virus (HIV) are among the dangerous blood-borne pathogens that can be transmitted via contaminated needles. Local protocol may demand that samples from patients known to be infected with human immunodeficiency virus (HIV) or hepatitis B or C and other contagious organisms should be identified with internationally recognised yellow biohazard labels and be processed at the end of a laboratory run.

The Health and Safety Executive (Sharps Instruments in Healthcare) Regulations 2013 for effective safe management of sharps advise:

- Avoid the unnecessary use of sharps where it is reasonably practical.
- Use of safer sharps (incorporating a protection mechanism) – safety devices – for example, closed systems to avoid the need to transfer blood from syringe to laboratory sample tube, as the blood collection device fulfils both functions. Not decanting blood from syringe to blood tube unless absolutely necessary.
- Prevent the recapping of needles – the correct disposal of sharps – on completion of the procedure, no attempt should be made to resheathe the needle.
- Sharps should immediately be discarded at the point of use in a suitable secure sharps container.

(Health and Safety Executive (HSE). Health and Safety (Sharps Instruments in Healthcare) Regulations 2013.

Choice of vein in those with CKD

When carrying out venepuncture great care must be taken as to preserve veins that may be needed in the future for fistula formation for haemodialysis. In stages 4 and 5 CKD the forearm and upper arm veins should be avoided as they may be suitable sites for future vascular

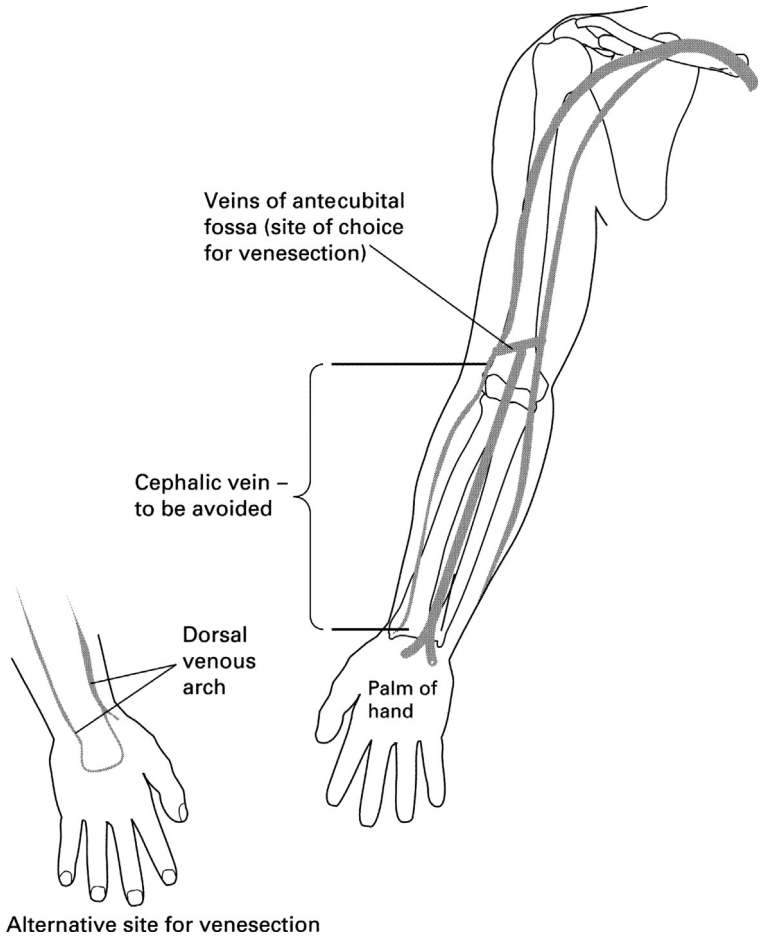


Figure 7.1 Veins of the arm.

access. The dorsal veins in the hands are sometimes preferable, however this can be painful (Figure 7.1). If the arm veins need to be used, the sites should be rotated (NationaI Kidney Foundation 2006) and the antecubital fossa preferred. It also is important to avoid unnecessary venepunctures and the upper limb. Patients should be provided with education on access preservation (Fluck and Kumwenda 2011). Arteriovenous fistulae sites should not be cannulated except for dialysis purposes, to avoid the risk of infection or haematoma which may render the fistula unsuitable for dialysis in either the short or long term.

The correct collection procedure

Before attempting venepuncture, the correct method of collection according to local policy should be ascertained and all necessary equipment assembled. There are many designated tubes available; if blood is sent to the laboratory in the wrong tube it cannot be processed, time and money are wasted and unnecessary discomfort is caused to the patient in repeating the procedure. Check unfamiliar tests with the laboratory before commencing.

If difficulties arise in collecting a blood sample from a patient it is advisable that only two attempts should be made before calling for assistance from a more experienced member of staff. Factors that can cause difficulties locating a vein include dehydration, hypotension, obesity and fragile veins.

Points for consideration

If difficulty is encountered in locating a suitable vein:

- Gently tap the chosen site and then redisinfect the site to prevent contamination.
- Ask the patient to open and close their fist several times.
- Inflate a sphygmomanometer cuff to a pressure between the patient's systolic and diastolic blood pressure proximal to the venepuncture site.
- Hang the arm down towards the floor for a few minutes.
- In cold weather, keep clothing intact until the last moment, or apply a heat pack to the site to encourage peripheral circulation.

Haematoma formation can be prevented by applying adequate pressure to the puncture site until clotting occurs. A haemolysed sample may occur if the incorrect size of needle for the vein is used; the skin disinfectant is not allowed to dry; blood is sampled from an IV cannula or central venous catheter; the blood sample tube is underfilled; too much force is used drawing back or to mix the sample; overnight storage such as an electrolyte sample (WHO 2010).

Blood samples from dialysis access needles or lines must be free of saline and anticoagulants (for example, heparin), be free of clotted material, be blood taken directly from the patient and not the machine and must not be recirculated blood. Blood for any clotting tests should be taken predialysis from another site such as the dorsal of the hand or antecubital fossa, as any heparin contamination will falsify the result. Haemodialysis samples should all have 'pre-, mid- or post-dialysis sample' clearly marked on the request form to avoid confusion.

Key points

- Check the tourniquet is clean prior to use as they are a potential meticillin resistant *Staphylococcus aureus* (MRSA) source.
- Always check that the correct collection tube and request form are to hand.
- Know whether the sample has to be delivered immediately to the laboratory, or can be stored at room temperature, in a fridge or on ice.
- Check whether the patient should be fasting.
- Use minimum pressure with a tourniquet to avoid haemolysis, and also to minimise bruising.
- Ensure the sample is correctly labelled.
- Use biohazard labels for known contaminated samples (as per local protocol). However, all samples should be treated as potentially hazardous.

Biochemical, Blood Tests

Normal values are listed in Table 7.1. These may vary locally and may be expressed in alternative units of measurement. Paediatric normal values should always be checked (see Chapter 12).

Monitoring the blood biochemistry of patients with CKD is central to their diagnosis and ongoing care, as this reflects the kidneys' function in excreting the waste products of metabolism. Serum or heparinised plasma samples are suitable for most biochemistry investigations.

Blood to be separated for serum samples is collected in a plain clotting tube (no additives) or in a tube containing beads treated with a clotting activator.

Blood to be separated for plasma samples is collected in a tube containing lithium heparin or beads treated with lithium heparin. The beads form a layer between the

Table 7.1 Analysis of a normal blood sample.

Urea (blood urea nitrogen)	Adult 2.5–6.4 mmol/l Child 1.1–6.4 mmol/l
Creatinine	Adult 70–120 µmol/l Child (increasing with age) 27–88 µmol/l
Sodium	135–147 mmol/l
Potassium	3.5–5 mmol/l
Calcium	2.2–2.65 mmol/l
Phosphate	0.8–1.5 mmol/l
Bicarbonate	22–30 mmol/l
Cholesterol	3.5–5.7 mmol/l
Total protein	60–80 g/l
Albumin	35–55 g/l
Glucose (fasting)	3.6–5.8 mmol/l

blood clot and serum or plasma after centrifugation, which allows serum to be withdrawn by pipette for the appropriate analysis. Some tubes contain a gel for the same purpose to act as a barrier between cells and plasma or serum.

Renal profile

The following tests (urea, creatinine, sodium, potassium, corrected calcium, phosphate, bicarbonate and albumin) are often requested together. The result is generated from one 5 ml blood sample in a plain or lithium heparin tube. Some centres may include other tests under this profile.

Urea

Urea (normal range 2.5–6.4 mmol/l) is one of the principal end-products of protein metabolism. Urea is formed in the liver, carried by the blood and excreted by the kidneys in the urine. Raised blood urea indicates failure of the kidneys and usually increases in tandem with serum creatinine levels in CKD and ESKD. However, serum urea levels may remain within normal limits whilst serum creatinine levels increase.

Urea can rise dramatically in previously healthy individuals who experience overwhelming infection or major crush injuries and are admitted to hospital with acute kidney injury (AKI). A slight rise in urea may be seen if a very high protein diet is consumed, and in low-protein diets a lower level of blood urea may be observed. Certain drugs, such as corticosteroids and tetracycline, can cause a sudden rise in blood urea, especially if the patient already has CKD.

Nonrenal causes of increased urea levels

- High-protein diet
- Chronic malnutrition – increased protein metabolism.
- Gastrointestinal bleeds – increased protein absorption.
- Dehydration – increased urea reabsorption.

A normal or low urea level is not necessarily indicative of adequate dialysis if a patient is malnourished with a low protein intake.

Creatinine

Creatinine (normal range 70–120 µmol/l) is produced by the breakdown of creatine phosphate in muscle by catabolism and is excreted by the kidney. Creatinine levels may not show a significant increase until there is a 50% loss of kidney function. Therefore, serum creatinine is not a sensitive test for early kidney disease. Estimated glomerular filtration rate (eGFR) is now recommended (see Chapter 6). However, elevated creatinine levels can reliably be used as a specific indicator of kidney dysfunction as it is fairly constant from day-to-day and rises steadily with progressive renal impairment. A higher level of serum creatinine may be expected with large muscle mass, in males, and in those of African-Caribbean ethnicity. A lower level may be seen in those with a low muscle mass (for example, the elderly or those with an amputation), those who are malnourished and/or with the use of some drugs such as trimethoprim and amiloride.

In advanced kidney disease, creatinine levels may eventually rise to a level where it is considered expedient to commence dialysis. This may be in the region of 500–1000 µmo/l but varies with the individual, the symptoms experienced, and the policy of the nephrology service. Those with diabetes are usually commenced on dialysis earlier, sometimes with serum creatinine levels of 350–500 µmol/l. Creatinine levels can be plotted on a log graph at regular intervals over a period of time, and used as a predictor of the time when RRT is likely to be necessary (http://renux.dmed.ed.ac.uk/edren/Handbookbits/HDBKgfrest.html, accessed 20 May 2013).

The NICE CKD guidance (National Institute for Health and Clinical Excellence 2008) recommends the use of eGFR, alongside serum creatinine to measure kidney function. Further discussion about the limitations of reporting serum creatinine alone and ways in which eGFR can be calculated can be found later in this chapter and also in Chapter 6. The NICE guidance (2008) recommends that patients should not eat cooked meat for at least 12 hours prior to a serum creatinine test.

Sodium

Sodium, Na^+ (normal range 135–147 mmol/l) is the principal electrolyte of the extracellular fluid of the blood, maintaining osmotic pressure, and is involved in acid–base balance and the transmission of nerve impulses. Sodium is taken into the body with the diet and is conserved or excreted by the kidneys. Hyponatraemia (<135 mmol/l) can be an indication of excess body fluid, and is also often present in burns, diarrhoea, vomiting, nephritis, neoplasms and diabetic acidosis.

Hypernatraemia (>148 mmol/l) can be an indication of dehydration and insufficient water intake, multiple myeloma, diabetes insipidus, metabolic acidosis or excessive intravenous isotonic fluids in advanced kidney disease. Patients may be proportionally hypernatraemic or hyponatraemic without an altered fluid state.

Potassium

Potassium, K^+ (normal range 3.5–5 mmol/l) is the principal electrolyte of the intracellular fluid, with only low concentrations (2%) circulating in the extracellular fluid. Potassium is provided by the diet and excreted mainly by the kidneys, where regulation of the body potassium content occurs - a small amount is also lost in the faeces. Potassium is necessary to maintain nerve conduction and plays a major role in control of cardiac output. Potassium levels usually remain normal if a urine output in excess of 1500 ml day can be maintained. Hypokalaemia (<3.5 mmol/l) may be found in cases of diarrhoea, vomiting, renal tubular acidosis, diuretic usage,

intravenous fluid administration without added potassium, and when excess insulin causes an increase in the cellular uptake of potassium. Hypokalaemia can cause cardiac arrhythmias.

Hyperkalaemia (>5.5 mmol/l but sometimes defined as >6.0 mmol/l for those on haemodialysis) may be seen in advanced kidney disease, burns, insulin deficiency, post-traumatic conditions (including surgery), disseminated intravascular coagulation or when potassium-sparing diuretics are used with Slow-K, and in any condition where cell damage has occurred causing leakage of intracellular potassium into the extracellular fluid. In CKD a potassium level >6.5 mmol/l may be a medical emergency requiring immediate instigation of dialysis or other treatments. If left untreated, it may result in cardiac arrest caused by the arrhythmic effect of potassium buildup. Blood samples for accurate potassium analysis should be delivered swiftly to the laboratory or, if this is impossible, separated and stored, to prevent leaching of intracellular potassium into the serum, which results in a falsely raised level.

Calcium

Calcium, Ca^{2+} (normal range total Ca^{2+} 2.2–2.6 mmol/l) is provided by the diet, and is excreted by the kidneys. Most body calcium is found in the skeleton but a small proportion is circulated in the blood. About 50% of serum calcium is protein-bound and 50% is ionized. Ionised serum calcium is responsible for muscle contraction, cardiac function and blood clotting. Corrected calcium estimates the total concentration of calcium as if the albumin concentration was normal, i.e estimates the free calcium, and is calculated as follows:

Corrected calcium (mmol/l) = Ca^{2+} + (40 – albumin (g/l)) × 0.02. It is the corrected calcium value that is reported by the laboratory.

In the healthy individual, calcium homeostasis is controlled by parathyroid hormone, vitamin D and the hormone calcitonin. Hypocalcaemia is found in CKD where phosphate retention is present (see Chapter 13). Chronic hypocalcaemia causes an excess of parathyroid hormone to be excreted into the blood stream which in turn releases calcium from the bone, resulting in the mineral bone disease often seen with vitamin D deficiency in CKD. In nephrotic syndrome low levels of calcium will be found due to albumin leaking into the urine, taking bound calcium with it. In the patient with nephrotic syndrome, the ratio of protein-bound and ionised calcium will remain the same. The acidosis of CKD is an added cause of loss of bone calcium. Hypercalcaemia may be an indication of hyperparathyroidism, sarcoidosis or malignancy. High levels of calcium can cause kidney stones and renal tubular disease.

Phosphate

Phosphorus, is found in the diet. Phosphate, $PO4^{3-}$ (normal range 0.8–1.5 mmol/l) is mainly combined with calcium in the skeletal bone. It is controlled, with calcium, by parathyroid hormone and apart from its skeletal function has a part in the metabolism of glucose and lipids. Phosphates are excreted by the kidney. When phosphate is increased, calcium is lowered and vice versa.

Hypophosphataemia may be found in the patient with renal tubular disease who loses phosphate, possibly leading to osteomalacia. Hyperphosphataemia will often be found in conjunction with hypocalcaemia.

Parathyroid hormone

Normal values of parathyroid hormone (PTH) vary according to the local assay method being used. Parathyroid hormone is a hormone produced in the parathyroid gland and is involved with the regulation of extracellular calcium. This test is useful in establishing whether hypercalcaemia is due to an overactive parathyroid. Increased parathyroid hormone is common in stage 3 CKD, vitamin D deficiency and osteomalacia. Hyperparathyroidism has been implicated in reduced response to anaemia treatments and possibly due to the effect on endogenous eryhtropoeitin synthesis, bone marrow progenitors, red cell survival or as a result of indirectly causing bone marrow fibrosis (National Institute for Health and Clinical Excellence 2011). Blood for parathyroid hormone analysis should be delivered immediately to the laboratory for analysis or, if this is impossible, kept on ice for a maximum of 30 mins.

Other biochemical blood tests

Uric acid

Uric acid (normal range female 200–350 µmol/l male 260–500 µmol/l) is an end-product of purine metabolism and is excreted mainly by the kidney, but in part by the bowel. In gout, excess uric acid crystallises in joints. In CKD there is an impaired ability to excrete uric acid and a high serum level may be found in association with raised urea and creatinine. Increased serum uric acid is also found in pre-eclampsia of pregnancy, leukaemia, multiple myeloma, various cancers and in acute shock.

Bicarbonate

The normal range of $HCO3^-$ is 22–30 mmol/l . Low plasma $HCO3^-$ indicates metabolic acidosis caused by CKD with an inability to excrete hydrogen ions adequately.

Glucose

The normal range of fasting serum glucose is 3.6–5.8 mmol/l . Blood glucose levels are maintained by the liver, which absorbs and stores glucose as glycogen and releases it into the circulation in response to the demands of the body. Glucose is regulated by insulin which is synthesised by the beta cells in the islets of Langerhans in the pancreas.

Glycosylated haemoglobin

Glycosylated haemoglobin, more commonly known as HbA1c indicates the amount of glucose carried by red blood cells in the body and is a more accuarte measure of long-term glucose control in people with diabetes. The target HbA1c is <48 mmol/mol (6.5%), or a higher target if the person is at risk of hypoglycaemia (<58 mmol/mol (7.5%)). HbA1c provides an average blood glucose level over a 8–12 week period (the average life of a red blood cell), however it may underestimate blood glucose control in advanced kidney disease or conditions where the red blood cell lifespan is reduced, for example sickle-cell disease, with the use of ESAs, or produce a higher results in uraemia.

Serum protein electropheresis

Serum protein electrophoresis uses an electrical field to separate out the proteins in the serum and helps to diagnose certain diseases such as multiple myeloma.

Lipids

Cardiovascular disease is a major cause of morbidity and mortality in patients with kidney disease (Jun *et al.* 2011) and one of the main risk factors for this is dyslipidaemia. It

is recommended by the National Institute for Health and Clinical Excellence (2010) to perform both total cholesterol and LDL cholesterol to best calculate cardiovascular risk. Hyperlipidaemia is often found in those with CKD, especially those with nephrotic syndrome and in transplant recipients. The patient should be advised to fast 10–12 h prior to the test. The normal targets are: total cholesterol ≤ 5 mmol/l and for those at high risk of cardio-vascular disease (CVD) ≤ 4 mmol/l ; LDL cholesterol ≤ 3 mmol/l (those at high risk ≤ 2 mmol/l); HDL cholesterol ≥ 1 mmol/l and triglycerides < 2.0 mmol/l.

Liver function tests (LFTs)

This is a collection of tests that include serum albumin levels, total plasma protein, alkaline phosphatase (ALP), alanine aminotransferase (ALT), aspartate aminotransferase (AST), gamma glutamyl-transpeptidase (GGT), bilirubin levels and clotting to assess liver function.

Albumin

The normal range of albumin is 35–55 g/l. Albumin levels can be elevated in patients with dehydration. Low albumin levels are common in CKD due to protein loss through peritoneal dialysate, poor dietary intake and nephrotic syndrome. Other causes of low albumin levels are decreased absorption in liver disease and increased breakdown in malignancy.

Plasma total protein

The normal range of plasma total proteins is 60–80 g/l . Hypoproteinaemia associated with low albumin (normal value 35–55 g/l) levels may be found in the many conditions associated with nephrotic syndrome where protein leakage occurs from the kidney into the urine. Also, decreased total protein in conjunction with low albumin may be found in liver disease, burns and haemorrhage. Hyperproteinaemia (increase of total plasma protein) with a normal albumin/globulin ratio may occur in dehydration. If total protein increases with a falling albumin/globulin ratio (i.e. a raised globulin), this may indicate autoimmune disease such as systemic lupus erythematosus, shock, chronic infection or myeloma.

Alkaline phosphatase is a protein involved in cellular metabolism which is mainly produced in the bones, and bile ducts of the liver though some is produced in the kidneys and intestines. An elevated ALP is seen in mineral bone disease, liver damage and pregnancy.

Alanine aminotransferase and AST are enzymes found in high concentrations in the heart, liver and skeletal muscle. Increased levels most commonly indicate liver diease, for example hepatitis.

Gamma glutamyl-transpeptidase is an hepatic enzyme, elevated levels may be seen with liver disease, heart failure and with alcohol use and with some medications.

Bilirubin (normal range 3–17 µmol/l) is a bile pigment produced by the breakdown of haem and reduction of biliverdin. Unconjugated bilirubin is insoluble in plasma unless bound to protein, mainly albumin. Salicylates, sulphonamides, nonesterified fatty acids and reduced pH levels result in decreased protein-binding of unconjugated bilirubin. Normally, 95% of the circulating bilirubin is unconjugated. Raised levels occur with increased production, for example in haemolysis or in hepatobiliary disease or obstruction. Jaundice or icterus describes the yellow staining of the tissues due to an excess of bilirubin - unconjugated or conjugated. Jaundice becomes clinically detectable at levels > 40 µmol/l.

Serology

Serological tests are frequently required as renal impairment is often a manifestation of a systemic disease. Many kidney disorders arise from immune dysfunction and serology will often, therefore, provide an exact diagnosis. A positive antineutrophil cytoplasmic antibody (ANCA) test is found in diseases such as systemic and renal vasculitis. Antiglomerular basement membrane (anti-GBM) is detected in Goodpasture's syndrome. The presence of other immunoglobulins may indicate other autoimmune diseases e.g. antinuclear antibodies may be found in Systemic Lupus Erythematosus (SLE).

Complement

The most common complement studies performed are for C3 and C4. These levels rise during an acute inflammatory state. However, there are many other specialised complement studies that can be undertaken in order to diagnose a particular disease process.

Creatine kinase

An enzyme present in heart and skeletal muscle which is elevated in myocardial infaction and rhabdomyolysis.

Immunoglobulins

Immunoglobulins (five groups – IgD, IgE, IgG, IgM and IgA) are proteins present in both circulating blood and in the cells which function as antibodies defending the body against infection. Elevated levels may be seen in autoimmune disease, cancers and allergic reactions, for example IgA nephropathy and multiple myeloma. Cryoglobulins are abnormal immunoglobulins that are found in diseases such as multiple myeloma, autoimmune disease, such as systemic lupus nephritis, and infections such as hepatitis.

Viral serolgy

Screening for hepatitis B, C and HIV is required for at risk groups and those requiring RRT. HIV and Hepatitis B and C can also be a primary cause of kidney disease.

Haematology

Haematological tests give information about anaemia, haematological malignancies and clotting disorders. Infections, inflammatory disease and other conditions can be indicated by changes in total and differential white cell counts. Normal values are shown in Table 7.2 (there may be slight local variations, especially in the paediatric normal range).

Table 7.2 Normal values – haematological tests.

Haemoglobin	Male 13.5–18 g d/l Female 11.5–16.5 g d/l
Haematocrit	Male 40–55% Female 35–45%
Platelets	150–350 $\times$ 10^9/l
Leukocytes (white bloodcells)	4.5–10 g/l

Full blood count (FBC)

This test includes haemoglobin, heamatocrit, red blood cell count, white blood-cell count and differential, platelet count and blood film, which often provide evidence of renal anaemia in CKD. It may be appropriate to investigate further those values falling outside normal parameters.

Haemoglobin

Haemoglobin (Hb) should be checked to ensure that anaemia is not present. Haemoglobin varies with age, gender and ethnicity. The level at which it is considered that an ESA should be initiated varies from one centre to another, but current NICE guidance (2011) recommends an aspirational haemoglobin range of 10–12 g/dl for adults, young people and children (2 years and older) and investigations for anaemia should be undertaken if Hb $<$ 11 g/dl (National Institute for Health and Clinical Excellence 2011). Normocytic erythrocytes are typical in the patient with renal anaemia. However, in the case of iron-deficiency anaemia, microcytic and hypochromic red blood cells will be seen.

Haematocrit

Haematocrit (HCT) is the percentage of red blood cells in the whole blood volume, which will be low in the patient with renal anaemia, running in parallel with the low level of haemoglobin. When the patient responds to the effect of erythropoeitin, a rise in haematocrit will be seen in conjunction with a rise in haemoglobin and red blood cells.

Red cell count

Red cell count (RCC) and mean corpuscular volume (MCV) reflect the size, and mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) reflect the haemoglobin concentration, of individual cells (normal ranges: MCV 76-96 fL; MCH 27–32 pg/cell (1.68 – 1.92 fmol/cell); and MCHC, 30-36g/dl). These red blood cell indices are useful in the diagnosis of types of anaemia.

Anaemias are classified on the basis of cell size (MCV) as microcytic, normocytic or macrocytic, and on the basis of the amount of haemoglobin (MCH) as hypochromic, normochromic or hyperchromic. They can therefore be classified as follows:

- Normocytic/normochromic anaemia - from acute blood loss, prosthetic heart valves, sepsis, tumour, or aplastic anaemia.
- Microcytic/hypochromic anaemia - from chronic blood loss, iron deficiency, lead poisoning, or thalassaemia.
- Microcytic/normochromic anaemia - erythropoietin deficiency in CKD.
- Macrocytic/normochromic anaemia - from chemotherapy, folate deficiency, or vitamin B-12 deficiency.

White blood cell count and differential

White blood cells are the cells in the body that fight against infections and allergies. There are five types of white blood cells, which can be split into two groups – granulocytes and agranulocytes. The granulocytes include neutrophils, eosinophils, and basophils and have granules in their cell cytoplasm, they also have a multilobed nucleus. Agranuloctye white blood cells, lymphocytes and monocytes, do not have granules and have nonlobular nuclei. They are sometimes referred to as mononuclear leukocytes.

The normal range for total white blood cell is 4–11 $\times$ 10^9/l. A low white cell count is referred to as leukopenia and a high white cell count as leukocytosis. Leukocytosis is usually due to an increase in one of the five types of white blood cells and is given the

name of the cell that shows the primary increase (i.e., neutrophilia, eosinophilia, basophilia, lymphocytosis and monocytosis). Leucocytosis may be indicative of an infection, inflammation or a haemotolgic malignancy and leukopenia may be due to bone suppression or replacement, hypersplenism or deficiencies of cobalamin or folate.

Differential (or relative value)

This is a count of the five different types of white blood cells and is often expressed as a percentage of the total white cell count (rather than their absolute value).

- Neutrophils: **50–70**% relative value. An increase may indicate infection and is called neutrophilia. A decrease is called neutropenia and may be due to chemotherapy.
- Eosinophils: **1–3**% relative value. An increase may indicate infections or allergies.
- Basophils: **0.4**%**–1**% relative value. Basophilia is an uncommon cause of leukocytosis but can be caused by infections or inflammatory conditions such as inflammatory bowel disease, chronic airway inflammation.
- Lymphocytes: **25–35**% relative value. Absolute lymphocytosis may be caused by acute infections (cytomegalovirus infection, Epstein–Barr virus infection, pertussis, hepatitis, toxoplasmosis); or chronic infections (tuberculosis, brucellosis); or lymphoid malignancies (chronic lymphocytic leukaemia). Relative lymphocytosis is seen in the acute phase of several viral illnesses, in connective tissue diseases, thyrotoxicosis, Addison's disease and splenomegaly with splenic sequestration.
- Moncocytes: **4–6**% relative value. Monocytosis may be due to either chronic infection, chronic inflammatory disorders such as Crohn's Disease or carcinoma. However a transient monocytosis can be seen with the resolution of an infection. A monocytosis may also be seen in the myelodysplastic conditions.

Coagulation

In circulating blood a series of factors are present that provide the means for clot formation as appropriate when damage to a vessel occurs. Prior to many kidney procedures, such as kidney biopsy, it is standard practice to ascertain that the patient has normal clotting function to avoid the ris k of haemorrhage. Those with uraemia are more prone to bleeding as urea affects the clotting cascade.

Included in this group of tests are platelets (normally, 150–400 $\times$ 10^9/l included in the FBC). Platelets adhere to each other and initiate the clotting cascade when damaged endothelium is encountered. Platelet deficiency (thrombocytopenia) is a common cause of prolonged bleeding.

Other coagulation studies likely to be encountered in kidney investigations include the bleeding time (normal $<$10 min); partial thromboplastin time (PTT); activated partial thromboplastin time (APTT); fibrinogen and international normalised ratio (INR). Most methods in current use require a very precise amount of blood in coagulation tests; the blood sample should exactly reach the marked line. Blood for coagulation studies during or immediately post-haemodialysis or from heparinised lines (for example, temporary or permanent dialysis catheters) should not be taken from a central line as the result will be inaccurate – it is recommended to use a vein instead.

Further investigations for renal anaemia

Anaemia is a major complication of CKD and a contributory factor to cardiovascular disease in patients needing dialysis. The major cause is the lack of production of the hormone erythropoeitin which is produced by the kidney. There are clinical benefits associated with correcting renal anaemia, including improved cardiac function, quality of life of dialysis patients and reducing the decline in kidney function in the early stages of CKD (Locatelli *et al.* 2007). Anaemia treatments are discussed further in Chapter 6.

Symptoms of anaemia

These include lethargy, dyspnoea, headache, dizziness, palpitations and pallor, decline in exercise tolerance and sexual function and cognitive function.

Prior to the commencement of treatment, some basic investigations must be completed in order to correct any deficiencies which may prevent an adequate response to this very expensive therapy. It is also important to exclude or treat (if possible) underlying causes such as:

- iron deficiency
- blood loss;
- infection or inflammatory disease;
- hyperparathyroidism;
- aluminium toxicity;
- vitamin B_{12} and folate deficiency;
- haemolysis;
- haemoglobinopathies.

Other anaemia investigations

Having ascertained that the patient has renal anaemia, the next step is to carry out certain investigations to check that there is no condition present which may prevent or reduce the effect of ESAs. These tests should be repeated if diminished or nonresponse to ESAs occurs at a later date.

Haematinics

In order to maintain the haem component of the healthy red blood cell, an adequate amount of available and stored iron must be present. There are several tests which can be carried out to determine this very important factor – the main cause of nonresponse to ESAs has been found to be low available iron. Iron-deficiency anaemia is either absolute or functional.

Ferritin

The normal range in health is 30–200 µg/l. Iron deficiency anaemia in CKD is indicated if less than 100 µg/l and should be maintained greater than 200 µg/l. Ferritin is the main form of stored iron found in all tissues, but especially in the liver, spleen and bone marrow. Ferritin found in the serum relates to the amount of stored iron, but is not necessarily an accurate assessment of available iron. Unless ferritin levels are at least 100 µg/l before commencing treatment with ESAs therapy, the response will be short lived. Ferritin levels should be kept in excess of this by infusing intravenous iron to allow adequate erythropoiesis, as oral iron supplementation is inadequate. A false high level can be seen in infection and inflammatory states, indicated by an elevated CRP (see the following section on 'Other Tests').

Transferrin saturation rate

Iron is transported by the specific plasma protein transferrin (or siderophilin). A useful test of available iron for red cell production is the transferrin saturation rate. Transferrin saturation indicates how much iron is circulating in the plasma relative to total iron-binding capacity. Less than 20% is indicative of iron deficiency anaemia, however it is not a reliable test and requires seqential readings to determine an average.

Serum iron

Serum iron (standard reference range varies between laboratories) in those with CKD is of no great significance (except in iron overload) but is necessary for calculating transferrin saturation rate.

Red-cell folate

Folic acid is a water-soluble vitamin in the B-complex group that is absorbed from the duodenum and jejunum. Folic acid works along with vitamin B_{12} and vitamin C to help the body digest and utilise proteins and to synthesise new proteins when they are needed. It is necessary for the production of red blood cells and for the normal DNA synthesis and affects erythrocyte precursors. Folic acid also helps with tissue growth and cell function. Low levels can cause macrocytic anaemia. Stores of this vitamin last only a few months.

Vitamin B_{12}

Vitamin B_{12} (normal range 150–1000 ng/l) is a water-soluble vitamin that is part of the vitamin B complex. It is absorbed in the ileum. The uptake is dependent on the production of acid and intrinsic factor in the stomach, adequate oral intake and production of transcobalamin (transport protein). Vitamin B_{12}, like the other B vitamins, is important for metabolism, and helps in the formation of red blood cells and in the maintenance of the central nervous system. Although the body stores can last several years without oral intake, low levels (e.g. in pernicious anaemia) can cause a macrocytic anaemia.

As folic acid and vitamin B_{12} are water soluble they are both lost during haemodialysis which can lead to dialysis-induced deficiency.

Other tests

C-Reactive Protein (CRP)

C-reactive protein (CRP) is a globulin that is synthesised by the liver and is present in small amounts in a normal individual. An elevated CRP indicative of infection, inflammation or malignancy. The most important role of CRP is its interaction with the complement system, which is one of the body's immunologic defense mechanisms. It is normally present in the plasma at a concentration of less than 5 mg/l.

C-reactive protein increases in virtually all conditions associated with tissue damage and may double its concentration every 6 h. It is better than ESR for monitoring fast changes as it does not depend on fibrinogen or immunoglobulin levels, and is not affected by red blood cell numbers and shape.

Haptoglobins

Haptoglobin is an acute-phase protein, rising in concentration during acute inflammation. Classically, a low haptoglobin concentration is indicative of intravascular haemolysis. It may also occur in extravascular haemolysis - some free haemoglobin leaks from the phagocytic cells of the spleen, chronic liver disease, metastatic malignancy and sepsis.

Coombs' test

The Coombs' test is used in the investigation of haemolytic anaemia. A positive Coombs' test is found in cases of autoimmune haemolysis due to the presence of immunoglobulin G (IgG), complement or both, on the surface of the red cells. A positive result may be found in a haemolytic transfusion reaction or autoimmune haemolysis, including drug-induced haemolysis.

Lactate dehydrogenase (LDH)

This is an enzyme that is found throughout the body in the tissues with low levels found in the circulating blood. Elevated levels occur when there is damage to the tissue as they enzyme is released from body tissue in to the bloodstream. It is used to assess acute and chronic liver damage, monitor progressive diseases, for example liver, kidney, malignancy and to diagnose haemolytic anaemia.

Occult blood

A faecal occult blood test (FOBT) is a noninvasive test that detects the presence of hidden (occult) blood in the stool. Such blood may arise from anywhere along the digestive tract. Hidden blood in stool is often the first, and in many cases the only, warning sign that a person has colorectal disease, including colon cancer. A positive test result requires further investigation of the gastrointestinal tract, usually with a colonoscopy in the first instance.

Reticulocytes

Reticulocytes (normal range in men 0.5–1.5%, in women 0.5–2.5%) are immature red blood cells that have been newly released from the bone marrow, and can be recognised as such for about 48 h before reaching a mature state. Patients with renal anaemia have a depressed reticulocyte count before ESA therapy and a rise should be seen when stimulation of erythrocyte production occurs as a response to ESAs. If no response occurs, further investigation should be considered.

The percentage of hypochromic red blood cells will assess how much iron is being incorporated into the red blood cell. This level should be <6%, greater levels indicate iron-deficiency anaemia.

Poor response to ESA therapy

Low or nonresponse to ESA therapy other than reduced haematinic levels requires investigation to assess adherence to treatment regimen and to exclude other causes such as iron deficiency anaemia, infection or inflammation, nonadherence to anaemia treatment, occult malignancy, bone marrow disorders, hyperparathyroidism, inadequate dialysis, ACEI and immunosuppressive drugs, aluminium toxicity, carnitine deficiency, chloramine toxicity in haemodialysis patients only and chronic blood loss (for example, haemorrhoids, menorrhagia, gastrointestinal bleeding), pure red cell aplasia (PRCA).

Urine investigations

Urinalysis plays an important part in the assessment of kidney disease, as kidney damage may allow increased concentrations of various chemicals through to the urine together with other signs of disease such as haematuria or proteinuria. The quantity of urine passed during the day together with its specific gravity also gives an indication of kidney function. Table 7.3 lists the normal volumes of urine passed per day.

Urine is composed of about 95% water and 5% solids, mainly urea and sodium chloride, it is slightly acidic (pH 6.0) and it has a specific gravity of 1.010–1.030 (specific gravity of water = 1.000).

Table 7.3 Normal volumes of urine

Healthy adult	1–1.5 l/day
Newborn baby	50–300 ml/day
Infant	350–550 ml/day
Child	500–1000 ml/day
Adolescent	700–1400 ml/day

Urinalysis

Measurement of specific gravity can be unreliable in the presence of water and electrolyte imbalance, low-protein diets, chronic liver disease and pregnancy.

Appearance

Urine can vary in colour from pale straw to dark amber:

- Pale urine is dilute because of:
  - heavy fluid intake;
  - polyuria due to kidney disease where the tubules fail to reabsorb water;
  - diabetes insipidus or diabetes mellitus.
- Dark urine may indicate:
  - concentration due to fluid depletion
  - presence of bile.
- Haematuria can vary in appearance from 'smoky' to 'tea' to red, either bright or dark.
- Coloured urine can be caused by blackberries, beetroot in the diet and other vegetable food dyes, porphyria and some medications, for example, orange-coloured urine is caused by rifampicin or senna.
- Frothy urine indicates heavy proteinuria, however may occur with an old urine sample
- Smoky urine may indicate the presence of bleeding from the kidney.
- Deposits or cloudy/turbid urine, which occurs when the urine sample is left to stand, may be crystals of phosphate, oxalate or urates, or due to pus in the presence of infection.
- Pink to black/brown (coca cola) urine may indicate the presence of myoglobin

Dipstick tests

Dipstick tests can be carried out in the clinic or ward situation as well as in the laboratory. Dipsticks are available that accurately show the presence of a variety of substances which may occur in the urine (for example, protein, glucose, ketones, blood, leuckocytes and nitrites) as well as giving the pH of the urine sample. The stick should be briefly dipped into a fresh sample of urine and read after 1 min or according to the manufacturer's instructions. The results are then compared with those supplied on the instruction sheet.

Caution

These kits are very reliable providing that the container is always kept dry and capped between use, the strips are only briefly dipped into the urine sample and the expiry date is not exceeded.

Osmolality

Osmolality (normal 500–800 mOsmol/kg) measurement indicates the kidney's ability in concentration and dilution and is considered more reliable than measuring the specific gravity and requires collection of an early morning urine sample.

Glucose

The presence of glucose may indicate diabetes mellitus, proximal tubular dysfunction, Fanconi's syndrome, glomerulonephritis or nephrotic syndrome.

Blood

The presence of blood in the urine is either microscopic (only visible under microscope) or macroscopic (visible to the naked eye). Microscopic haematuria is often

an incidental finding and requires further investigation to assess for kidney disease or maligancy if > +1 on two or three separate occasions and significant if > 2 per high powered field (hpf). It is also important to establish the cause is not related to a urinary tract infection, rule out other causes such as menstruation, sexual intercourse, trauma e.g. urinary catheter, too much exercise or an old sample (lysis of red blood cells).

Protein

Although protein is a normal urinary constituent, its level should be no more than a trace (i.e. < 20 mg /24 h, mainly albumin). Proteinuria may however be present at a level of 150 mg in 24 h before a dipstick test shows a positive reading. Causes of transient proteinuria include acute metabolic crisis, intercurrent illness, urinary tract infection and contamination. Persistent proteinuria is a common sign of many forms of kidney disease. In nephrotic syndrome, proteinuria may be as high as 350 mg/ 24 h. It is important to rule out a urinary tract infection or orthostatic hypotension.

The measurement of microalbuminuria/proteinuria can be used for the early detection of kidney disease and if not treated can lead to deterioration of kidney function. It is also a strong predictor of cardiovascular disease and death. NICE CKD guidance (National Institute for Health and Clinical Excellence 2008) recommends the use of albumin:creatinine ratio (ACR). An ACR measures the concentration of albumin and creatinine and has a greater sensitivity in detecting low levels of proteinuria and should be used for diabetes (normal range: ACR < 2.5 mg/mmol in men and <3.5 mg/mmol in women). Protein:creatinine ratio can also be used for monitoring in nondiabetes (it does not detect microalbuminuria, normal range: <15 mg/mmol). These tests ideally should use an early morning urine sample, although a 'spot urine' can be taken, then repeated with an EMU if positive. The urine should be kept refrigerated following the collection period to minimise bacterial growth. Twenty-four hour urine collections are no longer required for quantification of protein, however they may be required for other tests. See page 155.

Microalbuminuria

Microalbuminuria is defined as persistent small amounts of albumin not determined by the usual dipstick test and is of importance as a predictor of renal involvement in diabetes mellitus. The first sign of kidney damage due to diabetes is microalbuminuria, which can then proceed to larger quantities of protein excretion (proteinuria) and, possibly, low serum albumin, oedema, deranged blood chemistry and hypertension. Microalbuminuria is defined as persistent small amounts of albumin not determined by the usual dipstick test and is of importance as a predictor of renal involvement in diabetes mellitus. Whereas a normal sample of urine may contain albumin 2.5–25 mg/24 h, microalbuminuria is in the range 30–300 mg/24 h and macroalbuminuria is defined as greater than 300 mg/24 h (see Chapter 6).

Bence Jones protein

This test consists of a sample of urine from the first specimen of the day. In the laboratory the urine is heated; if this protein is present, it will precipitate on heating and dissolve at 100 °C; on cooling the protein will precipitate again. This test is now performed by electrophoresis and immunoelectrophoresis. It is most commonly (70–80% of positive results) found in multiple myeloma due to the proliferation of paraprotein-producing bone marrow. It is also occasionally seen in amyloidosis, cryoglobulinaemia and hyperparathyroidism.

Myoglobin levels

Myoglobinuria may occur due to conditions such as rhabdomyolysis where there is a breakdown of muscle tissue, causing the release of myoglobin into the blood stream. This may occur due to trauma or crush injury, seizures, immobility or severe exercise. The kidneys filter the blood and excrete the myoglobin in the urine. Myoglobin is nephrotoxic and large amounts of this protein can cause the occlusion of the renal tubules, leading to acute tubular necrosis and acute kidney injury. This can be diagnosed by a sample of urine – usually the first sample of the day.

Urine microscopy and culture

Microscopy will reveal information from the sediment found in urine – casts, crystals, blood cells and bacteria. The site of origin of casts can often be determined, indicating the type and extent of damage to the kidney. It is normal to find red blood cells in urine at approximately < 2 hpf and these normally originate from the renal pelvis, ureter or bladder and are uniform in shape and size. Leukocytes are also present at approximately < 2 hpf but the presence of eosinophils can be indicative of an allergic interstitial nephritis.

Casts

Different types of casts found in the urine may indicate underlying conditions. Hyaline casts, known as Tamm–Horsfall proteins, originate from the renal tubules. They may be present due to the use of diuretics, fever and exercise; however, they may also be present in kidney disease (for example, pyelonephritis). Granular or cellular casts may be seen in renal parenchymal disease. Red cell casts indicate bleeding and white cell casts indicate pyelonephritis or renal parenchymal disease.

If microorganisms are found to be present in the urine specimen – usually determined by the Gram staining method - the laboratory will provide information as to which antibiotic is most appropriate. The presence of multiple organisms may indicate contamination of the sample. It is important that the urine sample is collected before a broad-spectrum antibiotic is taken - this may be given in the interim period before specific sensitivity is ascertained.

A positive microscopy sample shows at least $>10^5$ cfu/ml and organisms 1–10 hpf; below this figure is not considered significant. However, with very dilute urine, a false-negative result may occur despite infection being present.

Kidney Function Tests

In CKD, a regular assessment of kidney function can be useful in monitoring the decline in kidney function and in predicting the time when RRT is likely to be needed. Glomerular filtration rate (GFR) tends to decrease in a linear fashion over time in progressive kidney disease and so, by extrapolation, predictions can be made as to when ESKD may occur. Measuring GFR provides details of the filtration rate of the functioning nephrons.

Knowledge of the amount of nephron damage is useful in assisting in making the choice of suitable drug regime. When there is more than 30% of nephron loss, certain drugs should be avoided or used with caution because of the slow excretion of the drug or its metabolites. GFR often declines with age (as much as 1 ml/min each year), starting at the fourth decade.

- Increased glomerular filtration rate can occur with:
  - increased protein intake;
  - diurnal variation;
  - pregnancy.

- Decreased glomerular filtration rate can occur with:
  - exercise;
  - age;
  - low-protein diet;
  - liver disease.

Many research studies and clinical trials of pharmaceuticals depend on regular glomerular filtration rate calculations to monitor the effect of treatments with regard to kidney function.

Kidney function investigations discussed here include creatinine clearance, the ^{51}chromium ethylenediaminetetraacetic acid glomerular filtration rate, (^{51}Cr EDTA GFR) and estimated glomerular filtration rate (eGFR).

eGFR (estimated glomerular filtration rate)

The eGFR (calculated from serum creatinine results) provides the best overall assessment of the level of kidney function. However creatinine clearance estimation (using 24 urine collection) can be helpful in the following situations:

- Estimation of GFR in individuals with exceptional dietary intake (vegetarian diet, creatine supplements) or decreased muscle mass (amputation, malnutrition, muscle wasting).
- Assessment of diet and nutritional status.

The eGFR can be calculated in adults using equations that take into account the serum creatinine concentration and some or all of the following variables: age, gender, race, and body size:

$$\text{Cockcroft-Gault equation} = (140 - \text{age}) \times \text{weight}/72 \times \text{Creat} \; (\times 0.85 \text{ if female})$$

$$\text{Modification of Diet in Renal Disease (MDRD) (known as the four-variable MDRD)} = 186 \times [\text{serum creatinine (umol/l)} \times 0.011312]^{-1.154} \times \text{age}^{-0.203} \times (1.212 \text{ if African or Caribbean}) \times (0.742 \text{ if female})$$

For adults the preferred equation is the MDRD (which uses creatinine, age, gender and ethnicity in its calculation). eGFR should not be used in AKI, as serum creatinine level may reflect a normal range as a result of delay in the decline in eGFR and the steady state of creatinine. eGFR should not be used in those <18 and >90 years or in pregnancy (National Institute for Health and Clinical Excellence 2011). Prior to measuring eGFR patients should be advised to not eat meat for 12 h before the test and for the most accurate results, the test should be processed within 12 h.

There is a tendency for the MDRD calculation to overestimate CKD stage 1 and 2. A newer method of measuring eGFR is the chronic kidney disease epidemiology collaboration (CKD-EPI) equation which has found in initial studies to be more accurate if GFR > 60 ml/min/1.73m^2 (Matsushita *et al.* 2012).

Results and interpretation of eGFR calculations are discussed in Chapter 6.

Measurement of protein excretion

Twenty-four hour protein estimations are no longer recommended. The total daily protein excretion (in mg) can be estimated simply by multiplying the total protein-creatinine ratio (TPCR) (from a spot urine sample, preferably early morning, measured in mg/mmol) by a factor of ten. For example: Urine protein = 750 mg/l, urine creatinine = 7.5 mmol/l. So, total protein-creatinine ratio (TPCR) = 750/7.5 = 100 mg/mmol.

$$\text{Therefore daily protein excretion} = 100 \times 10 = 1000 \text{ mg, or } 1 \text{ g}$$

Creatinine clearance

Note: this test is not recommended to estimate kidney function however may still be requested by the medical staff. The principle of clearance is that an estimation of a known substance in the plasma is compared with the amount in the urine. This substance must only be excreted in the urine. The calculation by which the clearance of the substance occurs can be measured is thus:

$$\frac{\text{urine concentration of substance (U)} \times \text{volume of urine in 24 h (V)}}{\text{Plasma concentration of substance (P)}}$$

Because creatinine is believed to be manufactured at a fairly constant rate by the muscle mass, is circulating in the blood stream and is filtered by the glomeruli (although a very small amount is excreted by the tubules), this is the usual substance measured. When used in the above example, this is known as creatinine clearance.

About 50% of nephrons will have lost their function before an appreciable alteration occurs in the result of the creatinine clearance test. The normal value of creatinine clearance should be between 70 and 125 ml/min; the function lessens with age. A creatinine clearance result of less than 10 ml/ min is often an indication to start RRT.

Procedure

A 24h urine collection is made which will provide the urinary creatinine content (*U*) and volume (*V*). A blood sample should be taken to indicate the plasma creatinine (*P*).

Patient information for 24-h urine collection

The reason for the test should be explained to patients and they should be told what is expected of them. One (or more) 2l collection bottles containing no additives or preservatives should be given to the patient. While male patients can usually void straight into the bottle, female patients should be provided with a suitable receptacle in which they can catch the urine. The patient must be instructed to discard the first urine of the day (on day 1) into the lavatory and then collect all urine passed for the next 24 h into the bottle provided. On the following morning (day 2), patients should empty their bladders precisely 24h after the initial sample and then the collection is complete. The completed urine collection should be labelled with the date and time of start and completion of the collection as well as the usual details such as name, identity number and date of birth.

The urine collection and the blood sample should be delivered to the laboratory with the request form, which should specify creatinine clearance test. The above formula is then applied and the creatinine clearance calculated.

CKD ^{51}Chromium EDTA GFR

A more accurate method of assessing kidney function than the creatinine clearance test is the ^{51}Cr EDTA GFR. As with the creatinine clearance test, the normal range is a clearance of 70–125 ml/min.

Patient preparation

The patient should be informed of the reason for this test, the fact that a small dose of a radioisotope will be injected, and the necessity of a series of blood samples over a 4 h period, and consent should be sought.

Procedure

The radiolabelled substance is given by intravenous injection. The patient's weight and height must also be recorded to enable the result to be normalised for the individual patient's body surface area.

Over the 4 h following the injection the usual procedure is for four blood samples to be drawn from the opposite arm to the injection of the radioisotope. This is to avoid contamination from any activity still lingering around the injection site, which will falsify the result.

Kidney Biopsy

Patients who are referred to the nephrology outpatient clinic with proteinuria, haematuria or renal impairment with no obvious cause may require a kidney biopsy in order that the nephrologist can make a diagnosis and commence appropriate treatment. Whilst in experienced hands kidney biopsy is a fairly safe procedure, there are risks which should be taken into consideration. Risks of kidney biopsy, which are greater in AKI, are perirenal haematoma, prolonged and severe bleeding necessitating blood transfusion and possible surgery, and rarely irreparable damage to the kidney requiring a nephrectomy.

Kidney biopsy is contraindicated in the following:

- small kidneys
- a single kidney
- cystic kidney or hydronephrosis
- UTI, acute pyelonephritis
- gross obesity
- uncontrolled hypertension
- nonadherent patient
- obvious diagnosis
- severe anaemia
- uncontrolled coagulopathy

Patient preparation

Information regarding the benefits and risks attached to this procedure should be given to the patient, who should be allowed the opportunity to ask questions and time to consider the implications before consenting to the biopsy. Children under 16 years usually need written parental consent.

Patients are usually admitted to the ward on the day planned for biopsy and a further explanation of the exact procedure and what is expected of the patient should be given prior to signature of a consent form. Children are fasted for 4 h before the biopsy as they will be sedated with a preparation such as midazolam following a mild premedication. In order to gain full compliance, whilst still in the ward, it is helpful to ask the patient to practise deep breathing and breath holding. Unless the patient can cooperate with breath holding on demand, the procedure should not be attempted, as the danger of malplacement of the sharp biopsy needle causing laceration or haemorrhage becomes a possibility.

Investigations include baseline urinalysis to exclude the presence of urinary tract infection, haemodynamic observations - the BP should be $< 140/90$ mmHg. Blood samples are required for FBC, group and save and clotting profile (Hb > 10 g/dl, INR > 1.2, bleeding time > 10 mins, platelets $>100 \times 10^9$/l) as the highly vascular kidney can haemorrhage even when clotting times are within normal limits. It is also important to check if the patient is currently on any anticoagulant therapy (e.g. warfarin, heparin,

clopidogrel), which should have been ceased five days prior to the procedure and that they are not taking any nonsteroidal anti-inflammatories or aspirin. Some patients may require DDAVP (a synthetic version of the antidiuretic hormone vasopressin which works as a haemostatic agent) (Mackie 2012) or a blood transfusion in the case of urea $\geq$ 20 mmol/l or creatinine $\geq$ 300 mmol/l or for abnormal clotting times. Check the patient is not allergic to iodine if to be used as antiseptic preparation solution.

Procedure

Patients will be asked to empty their bladders before the procedure. Percutaneous kidney biopsy may be performed on the ward or X-ray department, under local anaesthetic. The patient lies in a prone position, with a pillow under the upper abdomen to isolate the kidney, perhaps supported with sandbags to prevent movement. The kidney (usually left) is identified by real-time ultrasound as to position and depth and the skin is marked as to where the needle should be inserted. After cleaning the ultrasound gel from the skin, using a full aseptic technique, the area is cleaned, the area infiltrated with lidocaine as a local anaesthetic and a needle is inserted into the lumbar muscle layer until the needle is noted to swing with the patient's respirations. The patient should be asked to hold the breath whilst the needle is advanced 5 mm at a time, leaving the needle to swing free when the patient breathes in and out. When the needle has located the kidney, more local anaesthetic should be injected.

The needle is then withdrawn, a small incision is made at the needle exit site and a Tru-cut kidney biopsy needle (or a spring loaded biospy gun) is inserted along the pathway made by the needle in the same manner, making advances as the patient holds the breath. When the kidney is again located, the biopsy is taken with the patient holding a breath. The tru-cut needle is withdrawn and the specimen obtained is immediately placed on a slide and viewed under a dissecting microscope to ascertain that cortex which has been obtained is large enough (about 5 mm length) to divide into three samples. If not enough cortex has been obtained, the tru-cut needle will have to be inserted again until a suitable strip of cortex containing sufficient glomeruli has been identified. Samples are sent to the laboratory for histology (in a 10% formalin pot), for immunofluorescence (in sterile normal saline) and electron microscopy (in specific glutaraldehyde fixative, kept cold). These samples should be delivered immediately (within minutes, not hours) to the laboratory, which must have had advance warning of the biopsy.

Finally, after the tru-cut needle has been withdrawn, a pressure dressing is applied and the patient is asked to remain flat in bed. The patient will need much encouragement and reassurance during the kidney biopsy procedure as it can be painful, despite local anaesthetic. A friendly hand to hold and quiet encouragement to cooperate with breathing requirements from the attending nurse can be very reassuring.

Patient care following kidney biopsy

It is usual practice to keep patients in lying flat for 2–6 h and bed rest will be dependent on unit policy, but it is common to be performed as a day case unless there is any frank haematuria which will require overnight observation. Haemorrhage and haematoma are the main complications following kidney biopsy; the wound site should be frequently checked for surface bleeding and blood pressure and pulse observations should be carried out until stable, for example on the time scale of every 15 min for 2 h, then every 30 min for 2 h, and then hourly for 4 h. The signs and symptoms giving an indication of internal bleeding are a rise or fall in blood pressure and dull aching pain in the abdomen, back or shoulder. The patient should be warned that some degree of haematuria will occur initially, but only persisting or heavy haematuria is of significance (1% require blood transfusions). Small urine samples from each void should be retained

in transparent specimen containers for observation of diminishing haematuria and dipstick testing. The patient should be advised not to do any strenuous activity for 4 weeks, to check the puncture site for signs of swelling, bleeding and redness and contact the renal unit if they have any back pain, fever, dizziness or haematuria post biopsy.

Kidney biopsy in the transplant recipient

Closed percutaneous biopsies of the transplanted kidney are undertaken to support evidence of rejection and also to confirm suspicion of recurrent or primary glomerular disease (see Chapter 10). The procedure is similar to the biopsy of the native kidney but more straightforward due to the superficial position of the transplanted kidney. The patient will be placed in a supine position with a pillow beneath the transplant side to move the intraabdominal contents away from the site. The amount of tissue required in a transplant biopsy will be less than in a native kidney biopsy as fewer tests will be performed. The patient should remain resting in bed for 4–6 h and usually discharged home the same day, though it is important to ensure the patient has passed urine and a dipstick test has been performed to check for blood.

Radiographic Investigations

Investigations using various radiographic methods are often employed to assist diagnosis and to assess progression of kidney disease and its attendant side effects. The most common techniques are discussed here.

Patients should have received adequate explanations before entering the department in order to allay any fears they may have on finding themselves in a department full of strange machinery, hazard warnings and unfamiliar staff. If they are aware of the reasons for the investigation and what will be expected of them, the likelihood of an accurate result of the examination will be enhanced. The patient will be asked to sign a consent form for some invasive tests and early information will be of help for understanding the procedure.

All investigations involving X-rays must be performed according to the safety regulations in using a potentially hazardous substance, and these techniques must not be used unless the risk to the patient is outweighed by the benefit. It is important that women of child-bearing years are asked specifically if there is any possibility of pregnancy prior to carrying out the test. The foetus is most vulnerable to ionising radiation in the first trimester and the woman may not know that she is pregnant, so if there is any possibility it should be discussed with the referring doctor.

Plain abdominal X-ray

Plain abdominal X-rays incorporating the kidneys, ureters and bladder (KUB) indicate the size, shape, position and the presence or absence of one or both kidneys, and may be taken before other more complicated radiological procedures in order to provide an overall background picture. Most calculi may be seen as they are usually composed of radiopaque material. KUB X-rays are usually taken from the anterior aspect. A combination of KUB and ultrasound often forms the basic routine screening in those with kidney disease.

Bone density scan

Also known as dual energy x-ray absorptiometry (DEXA) scan measures the mineral density of bones using a low dose noninvasive x-ray technique. The x-ray beam has

two energy peaks, one aimed at the bones and the other the tissue, then the tissue amount is subtracted providing a bone mineral density amount which indicates the strength of the bones.

Skeletal X-rays

Skeletal X-rays are not commonly peformed as superseded by bone density scans, but may be taken in the patients on dialysis. This is to detect osteodystrophy, which may become apparent in association with impaired glomerular filtration and associated disturbed metabolism of calcium and phosphate. Those bones most likely to show the characteristic abnormalities are the phalanges, skull, pelvis and vertebrae. Pain and deformity will ultimately develop unless imbalances of calcium and phosphate can be corrected and inadequate metabolism of vitamin D can be halted (see Chapter 13).

Intravenous urogram (IVU)

This procedure is also known as the intravenous pyelogram (IVP). This examination indicates the size and position of the kidneys and the anatomy of the calyces and pelvis. The ureters are also outlined by the progression of the dye containing urine to the bladder and the subsequent use of sequential X-rays, enabling any deformities in these organs to be demonstrated. The IVU gives little useful information in advanced CKD and consequently is not the investigation of choice if more than 50% of nephron loss is suspected. If impaired kidney function is known and an IVU is indicated, a greater dose than usual of the radiopaque contrast medium may need to be given – this in itself is nephrotoxic and may exacerbate CKD, at least temporarily.

Patient preparation

The patient should be told that the investigation will take about an hour to complete – longer if there is renal impairment. If the patient is taking metformin it must be stopped 24 h prior to prevent the risk of lactic acidosis. After an explanation of the procedure with adequate time to ask questions, the patient may be asked to sign a consent form and be checked for any allergies to iodine or shellfish. Caution should be observed with asthmatics and others who have allergic conditions, as the contrast medium is iodine based. Therefore, it is standard procedure that injections of adrenaline (epinephrine) 0.5–1 mg (0.5–1 ml of 1:1000 solution = 1 mg/ml) i.m., antihistamine (e.g. chlorphenamine (chlorpheniramine) 10–20 mg i.v.) and hydrocortisone should be immediately available to treat anaphylaxis should it occur. Some patients may require prophylactic corticosteroids if there is a history of atophy or asthma.

Bowel preparation will be dependent on local policy and, if used, should be carried out two days prior to the procedure to clear the bowel to enable a clear view of the urinary system. It may not be used in older patients as there is a risk of dehydration, which could lead to reduced kidney perfusion. Adult patients should fast for 4–6 h, but limited clear fluid is usually allowed until 1 h before the IVU. Emptying the bladder beforehand is important, or the contrast will become overdilute on reaching a full bladder and a poor picture will result. A fluid restriction of 500 ml in 24 h may be requested if the patient has normal kidney function for better images as a result of concentrated contrast media.

Post procedure, kidney function should be checked in known CKD and urinalysis checked for any sign of haematuria. Haemodynamic observations should checked for signs of infection or bleeding and allergic reaction to the contrast agent. Symptoms of mild to moderate allergy include pruritis, urticaria and vomiting, and can be treated with an antihistamine. Symptoms of severe anaphylaxis (a medical emergency) include bronchospasm, hypotension and shock. Any reaction should be noted in the medical file for any further procedures. The patients should be encouraged to drink fluids if not contraindicated, to aid clearance of the contrast media. Nurses should be aware that there is a possibility of acute kidney injury following this investigation, so urinary output should be monitored. Prior to restarting metformin, a check creatinine level is required 48 h post procedure.

Retrograde pyelogram

In this examination, radio–opaque dye is injected directly into the upper urinary tract via a catheter inserted through a cystoscope into the ureter. A series of X-rays are performed on one or both kidneys. This test is useful in outlining stones, calyceal defects and masses in the ureter or renal pelvis and in defining deformities such as hydronephrosis or hydroureter. This investigation is sometimes performed after an IVU or ultrasound (US) has demonstrated a hydronephrosis and more clarification is needed for a diagnosis. After the procedure the urine should be observed for haematuria and patients should be watched for signs and symptoms of infection. Post procedure care is as for IVU. Patients should be encouraged to drink copiously to help avoid infection, unless contraindicated due to reduced fluid allowance (antibiotics may be given as a prophylaxis).

Computed axial tomography or computed tomography (CAT/CT) scan

This investigation is reserved for the patient who needs staging of a renal mass or a diagnosis when other methods of detection have failed to provide a clear picture. Computer tomography is an X-ray technique that uses a computer to reconstruct cross-sectional images of 1 cm slices of the organ targeted. The dose of radiation is about the same as that for an IVU. A clear bowel is necessary so a suitable laxative may be given 2 days before the scan. A light diet should be taken for 2 days before the scan and nothing on the day of examination apart from clear fluids. Patients must be able to follow instructions such as when to hold the breath, to be able to lie motionless and not to talk. Contrast agents may be used to assess the renal cortex better, so check for any allergy to contrast media or history of asthma.

Nuclear magnetic resonance or magnetic resonance imaging (MRI)

This form of scanning involves application of a strong external magnetic field along with a radiofrequency signal that produces a current in a receiving coil proportional to the density of protons in the body organ being scanned. This signal is processed by computer to create a tomographic slice of the organ similar to a CT scan. In renal medicine a clear picture of tumour invasion into blood vessels can be demonstrated as well as differentiation of tissue character.

The advantage of MRI over CT imaging is that no ionising radiation is used. A non-nephrotic contrast agent may be used and many planes can be visualised. Caution is required with the use of gadolinium as it has been associated with nephrogenic systemic fibrosis and kidney function should be checked prior to use. Older patients are more at

risk and high risk gadolinium should not be used in severe kidney disease (European Medicines Agency 2010).

It is important that the patient is not wearing any magnetic metal object, and it must be ascertained that no internal metal objects are present such as aneurysm clips, screws, pacemakers or shrapnel.

Ultrasound

Ultrasound investigations have replaced some x-ray procedures (especially the IVU) to a large degree, and because this procedure does not carry the hazards associated with radiation this method can be used in women without consideration of the possibility of pregnancy. This is a noninvasive procedure where a transducer (sonar probe) is moved in close contact with the skin over the area of investigation and it can be repeated frequently if necessary, unlike X-ray. Ultrasound is especially useful in examinations of the abdominal and pelvic organs. It is widely used to determine the size and shape of the kidney, its presence and position, and the composition of cysts or neoplasms if present, and also in the diagnosis of polycystic kidney disease. However, it is less useful in providing information about the ureters. Ultrasound is also used to guide the operator in procedures such as kidney biopsy.

Patients who are to have kidney US scans are usually asked to fast for 6–8 h (in order to keep pockets of air in the gut to a minimum) except for drinks of clear fluids.

Ultrasound in kidney transplantation

The most important and common cause of early transplant dysfunction is acute rejection, which occurs in 10–20% of all patients. This is accompanied by inflammation, which leads to swelling of the kidney and an increase in pressure inside the organ. Ultrasound can visualise any changes to the kidney and can be undertaken daily and two size increases on consecutive days would be strongly indicative of acute rejection. However, dysfunction attributed to other causes must be excluded. Infection may be associated with an increase in the kidney size, but this is easily diagnosed by routine testing of midstream specimens of urine.

Renal vein thrombosis is a serious complication and will cause a rapid increase in size, possibly resulting in a tear of the kidney substance. If this condition is quickly diagnosed with US, rapid surgical intervention is possible and the graft may be rescued. Renal artery thrombosis may be diagnosed ultrasonically by the observation of lack of vessel pulsation. For greater accuracy, duplex scanning using a combination of imaging and frequency waveform analysis is available.

Early complications following transplantation include urine leaks, usually from the site of the ureteric anastomosis. These are seen ultrasonically as a fluid collection around the graft site. Later complications are obstructive lesions, which are often insidious in onset and lead to deteriorating kidney function. Routine scanning of outpatients is a simple and easy method of detecting dilatation and stenoses of the urinary tract, which are then treated surgically.

Needle core biopsy of the transplanted kidney remains the best method of detecting rejection and determining the degree of interstitial fibrosis and acute inflammation. Using ultrasound guidance of the biopsy needle, a good core of the renal cortex may be safely obtained, carefully avoiding the structures of the renal medulla and damage to the graft. Ultrasound is therefore a valuable tool in the detection and diagnosis of kidney allograft dysfunction, allowing intervention and early treatment of problems.

Renal doppler studies

A noninvasive ultrasound test to assess vascular flow to the kidney, for example renal vein thrombosis, acute tubular necrosis, renal artery stenosis and evaluate transplanted kidneys for urine outflow obstruction and acute rejection.

Renograms

An injection of intravenous radioistope, which is excreted via the kidneys, and a series of x-rays are taken over a 2-4 h period, which enables the assessment of kidney function and tubular secretion and can indicate the position of an obstruction – no radioistope is seen if there is a reduction in blood supply to the kidney or in the obstructed area. This investigation can be used in place of IVU if the patient is allergic to iodine contrast medium, and it is also used in transplanted patients. In renal artery stenosis, a renogram (using either DPTA or MAG 3) may be performed and then repeated, incorporating an injection of captopril as a test dose to outline any response induced – i.e. a reduction in renal blood flow in the presence of an blockage. Check with medical staff if the patient on antihypertensive treatment as he/she may need to stop or adjust dose. Blood pressure should be monitored after the procedure for 2 h.

Renal scans

There are three types of radioisotope scan that can be performed to provide quantitative data on the function of the kidneys.

Firstly, the isotope, ^{99m}technetium-labelled diethylenetriaminepentaacetic acid (^{99m}Tc DTPA), is rapidly excreted by the kidney and shows the blood flow through the kidneys, identifies obstructions, for example renal artery stenosis, and provides valuable information about the function and excretion capacity of the kidney. A diuretic may also be given intravenously and the patient should be well hydrated. The procedure takes about 1 h. It is not as effective if creatinine $> 200\,\mu$mol/l.

The second isotope is ^{99m}Technetium-labelled dimercaptosuccinic acid (^{99m}Tc DMSA) which is retained by the cells in the proximal tubules and parenchyma and enables the identification of areas of cortical scarring, contusions and solid lesions. This will provide quantification of relative kidney function between kidneys and within a kidney.

The third is known as MAG 3, which uses the isotope ^{99m}technetium-labelled benzoylcaptoacetyltriglycerine and is a dynamic imaging scan as the isotope is rapidly excreted by the kidney via glomerular filtration or a combination of filtration and tubular secretion. The test enables visualisation of the aorta and renal perfusion. Quantification of renal blood flow can be calculated and it identifies the overall kidney function and presence of obstruction, thrombus, emboli and stenosis. When patients undergo radioisotopic scans they should empty their bladders immediately before scanning. Patients should be advised that they are radioactive for 24 h and nursing staff should ensure universal precautions when managing waste disposal.

Renal angiogram

This is performed through a catheter inserted via the femoral vein (however the brachial artery may also be used if required) and fed to the renal artery. Radiopaque contrast dye is injected and a series of fluoroscopic x-rays performed. It identifies tumours, emboli, thrombosis, trauma and stenosis of vessels and for transplant donor assessment and identification of bleeding site post kidney biopsy. Caution should be taken with patients

who have some degree of renal insufficiency as the dye is nephrotoxic. If patients are able then they should drink plenty of fluids to flush through the contrast.

The most common complication of a femoral angiogram is bruising, false aneurysm, haemorrhage, infection, reaction to the contrast agent and haematoma. Consent is required.

The patient should fast 4 h for food and 2 h for clear fluids prior to the procedure and must be checked for any allergies to iodine and shellfish. It is important to ensure that hydration is adequate, especially if there is decreased kidney function and low urine output, which may require the use of a nephroprotective agent or IV 0.9% normal saline or 1.26% sodium bicarbonate over a 4 h period prior. Other agents used include N-acetylcysteine (NAC) for low urine output and impaired kidney function. Anticoagulants may be required (if INR < 1.7) and possibly heparin. Metformin should be stopped preprocedure to prevent lactic acidosis. Baseline neurovascular observations should be recorded. Bloods samples should be taken for FBC, U&Es and clotting profile.

After the procedure, the frequency of observations of the puncture site, neurovascular and haemodynamic observations are dependent on the unit policy, but as a guide should be performed every 15 min for 1 h, then half-hourly for 2 h for signs of bleeding whilst the patient is lying flat or at 45 degrees for 1–2 h and bed rest for up to 24 h, which is dependent on unit policy. Increase oral intake where possible to flush contrast media. Kidney function should be checked if known renal impairment and serum creatinine checked 48 h post recommencement of metformin. Anticoagulants should be recommenced, usually the evening postprocedure.

Patients should be advised not to do any strenuous exercise for 48–72 h or have a bath/shower for 24 h. The puncture site should be patted dry and slight pressure placed over the site initially if the patient coughs or sneezes.

Summary

The investigations which have been discussed above are by no means exhaustive. Since those with kidney disease usually have multifactorial disease processes many other specific investigations may be indicated, especially cardiovascular tests such as electrocardiography and echocardiography. The gastrointestinal tract in patient with kidney disease are frequently investigated for bleeding problems using techniques involving endoscopy (e.g. gastroscopy, colonoscopy).

Such is the commercial pressure to exploit the latest technology, it is inevitable that new methods and procedures will enter the renal field in the near future, condemning some present-day tests to redundancy. However, it is hoped that if nurses understand something of the current techniques used in renal investigations, they will be able to inform and reassure their patients reliably.

References

Department of Health. Guidance for Clinical Health Care Workers (1998) *Protection Against Infection with Blood-borne Viruses – Recommendations of the Expert Advisory Group on AIDS and the Advisory Group on Hepatitis*, HMSO, London.

European Medicines Agency (2010) *Questions and Answers on the Review of Gadolinium Containing Contrast Agents,* London, EMA, www.ema.europa.eu/ema/index.jsp?curl=pages/medicines/human/referrals/Gadolinium-containing_contrast_agents/human_referral_000182.jsp&mid=WC0b01ac0580024e9a (accessed 20 May 2013).

Fluck, R and Kumwenda, M. (2011) *Renal Association Clinical Practice Guidelines: Vascular Access for Haemodialysis,* 5th edn, Renal Asssociation, London.

Health and Safety Executive (HSE) (2010*) Consultation on Proposals to Implement the 2010 Sharps in Healthcare Directive.* www.hse.gov.uk/aboutus/meetings/hseboard/2012/270612/pjb1251.pdf (accessed 20 May 2013).

Health and Safety Executive (HSE) (2013). Health and Safety (Sharps Instruments in Healthcare) Regulations 2013: Guidance to Employers and Employees – information sheet, www.hse.gov.uk/pubns/hsis7.htm (accessed 24 May 2013.)
Jun, M., Lv, J., Perkovic, V. and Jardine, M.J. (2011) Managing cardiovascular risk in people with chronic kidney disease: a review of the evidence from randomized controlled trials. *Therapeutic Advances in Chronic Disease* **2** (4), 265–278.
Locatelli, F, Pozzoni, P. and Del Vecchio, L. (2007) Recombinant human epoetin beta in the treatment of renal anaemia. *Therapeutics and Clinical Risk Management* **3** (3), 433-439.
Mackie, S. (2012) An overview of percutaneous renal biopsy. *Journal of Renal Nursing,* **4** (2), 90–95.
Matsushita, K., Mahmoodi, B.K., Woodward, M. *et al.* (2012) Comparison of risk prediction using the CKD-EPI equation and the MDRD study equation for estimated glomerular filtration rate. *Journal of the American Medical Association* **307** (18), 1941–1951.
National Institute for Health and Clinical Excellence (2008) *Clinical Guideline 73. CKD: Early Identification and Management of CKD in Adults in Primary and Secondary Care,* National Institute for Health and Clinical Excellence, London.
National Institute for Health and Clinical Excellence (2010) *Clinical Guideline 67. Lipid Modification: Cardiovascular Risk Assessment and the Modification of Blood Lipids for Primary and Secondary Prevention of Cardiovascular Disease,* National Institute of Health and Clinical Excellence, London.
National Institute for Health and Clinical Excellence (2011) *Clinical Guideline 114: Anaemia Management in Chronic Kidney Disease: National Clinical Guideline for Management in Adults and Children,* Royal College of Physicians, London, www.nice.org.uk/guidance /CG114 (accessed 20 May 2013).
Nursing and Midwifery Council (**1992**) *Perceptions of the Scope of Professional Practice,* UKCC, London.
Williams, J.D. and Phillips, A.D. (2010) Section 21: Disorders of the kidney and urinary tract. In *Oxford Textbook of Medicine* (eds A. Warrell, T. Cox and D. Firth), 5th edn, Oxford University Press, Oxford.
World Health Organization (**WHO**) (2010) *WHO Guidelines on Drawing Blood: Best Practice in Phlebotomy. WHO Safe Injection Global Network (SIGN),* WHO, Geneva.

Useful web sites

BC Renal Agency, *Vascular Access Guideline. Chronic Kidney Disease: Vein Preservation,* **March 2011, revised August 2012, www.bcrenalagency.ca/NR/rdonlyres/AC0BB28B-00A9-41A6-BD76-55F441559B03/59299/VeinPreservationRenalPatientsUpdateAug172013.pdf** (accessed 20 May 2013).
EdrenINFO, **www.edren.org/pages/edreninfo/ckd-chronic-renal-failure-and-its-progression.php** (accessed 20 May 2013).
Lab Tests On-line, **www.labtestsonline.org.uk/** (accessed 20 May 2013).
Royal College of Radiologists, **www.rcr.ac.uk** (accessed 20 May 2013)
The UK Renal Association. *About eGFR,* **www.renal.org/whatwedo/InformationResources/CKDeGUIDE/AbouteGFR.aspx** (accessed 20 May 2013).
UK Renal Association. *Patient Information Leaflets for Kidney Biopsy (Native and Transplanted), Angioplasty and Stent Insertion,* www.renal.org/whatwedo/informationresources/patients.aspx (accessed 20 May 2013).

CHAPTER 8

Haemodialysis

Paul Challinor
B. Braun Avitum, UK

Learning Outcomes

- To describe the physiological processes of dialysis.
- To evaluate the nurse's role in care of vascular access.
- To outline the principles of patient-centred pre- and post-dialysis assessment.
- To recognise and prevent complications of haemodialysis.

Introduction

Haemodialysis is an area of renal nursing that has developed and continues to develop at a very fast rate. Expert practitioners in this field are constantly striving to promote excellence in the application of nursing care and are implementing evidence-based practice.

The principles of haemodialysis depend upon a number of simple phenomena, namely diffusion, osmosis, ultrafiltration and hydrostatic pressure. The term haemodialysis itself is derived from the roots of two words: 'haemo-', meaning blood, and 'dialysis' meaning filtration or cleansing. The process of haemodialysis is the filtration of substances from the blood via a semipermeable membrane (the dialyser), which are then carried away by dialysis fluid. The process primarily employs diffusion for solute removal, and osmosis and ultrafiltration for fluid removal. However, the role of osmosis is limited in haemodialysis.

Despite the relative simplicity of the principles involved in haemodialysis, the principles of nursing patients who are undergoing haemodialysis are complex. The nurse needs to be able to deal with ever-changing technology but at the same time be able to engage with the patient over a prolonged period of time. Helping them to adapt to the changes in lifestyle that a chronic condition and its treatment imposes on the individual is vital.

Principles of Haemodialysis

Terms and definitions

'Haemodialysis' is a term used to describe the removal of solutes and water from the blood across a semipermeable membrane (dialyser). Techniques have become

Renal Nursing, Fourth Edition. Edited by Nicola Thomas. © 2014 John Wiley & Sons, Ltd. Published 2014 by John Wiley & Sons, Ltd.

increasingly sophisticated, resulting in a variety of highly efficient methods of clearing waste products and excess fluid that would normally be removed by the healthy kidney.

The process of dialysis depends on two major physiological concepts that involve solute remove: diffusion (sometimes referred to as conduction) and filtration (convection). Fluid is removed by the process of ultrafiltration. It is essential to have a clear understanding of how these physiological principles relate to dialysis to appreciate fully both the benefits and the limitations of this form of renal replacement therapy (RRT).

Diffusion

'Diffusion' is the term used to describe the movement of molecules from an area of high concentration (of solutes) to a region of low concentration (of solutes) until they are equal. For diffusion to take place, a concentration gradient is essential, and the rate of diffusion is greatest when the concentration gradient is highest. In RRT a physiological solution (dialysate) passes on the opposite side of the semipermeable membrane to the blood. The dialysate contains essential solutes in similar concentrations to normal serum. The dialysate, however, does not contain waste products such as urea and creatinine and so these substances will pass across the membrane from the region of high concentration (the patient's uraemic blood) to the region of low concentration (the dialysate).

The rate of diffusion is dependent upon the differences in concentration of the solute between the dialysate and the blood – the concentration gradient. The higher the concentration difference, the faster the rate of movement.

Diffusion is also proportional to the temperature of the solution (increased temperature increases random molecular movements) and inversely proportional to the viscosity and size of the molecules (small molecules diffuse more quickly).

Convection

Convection involves the transfer of solutes along with the movement of fluid. As fluid is removed during dialysis, solutes are 'dragged' across the dialysis membrane. Convection is the main principle involved in solute movement in haemofiltration, but also plays a part in haemodialysis. Convection, unlike diffusion, is dependent upon fluid movement across the dialyser (see Figure 8.1). The combination of diffusion and convection results in a total solute removal called mass transfer. The effectiveness of haemodialfiltration relies on the principles of solute movement involved in convection.

Ultrafiltration and hydrostatic pressure

As blood is pumped through a dialyser, a positive pressure will be exerted on the membrane. The pressure in the space on the opposite side of the membrane will be lower, whether or not the space is filled with dialysate. As a result, fluid and small solutes will move from the area of greater pressure to the area of lower pressure (see Figure 8.2).

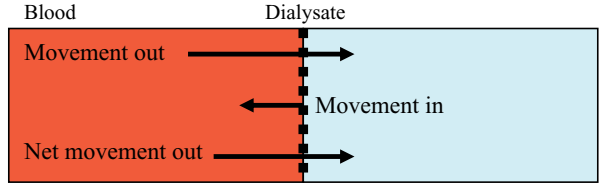


Figure 8.1 Net movement of solutes across the dialyser membrane during dialysis.

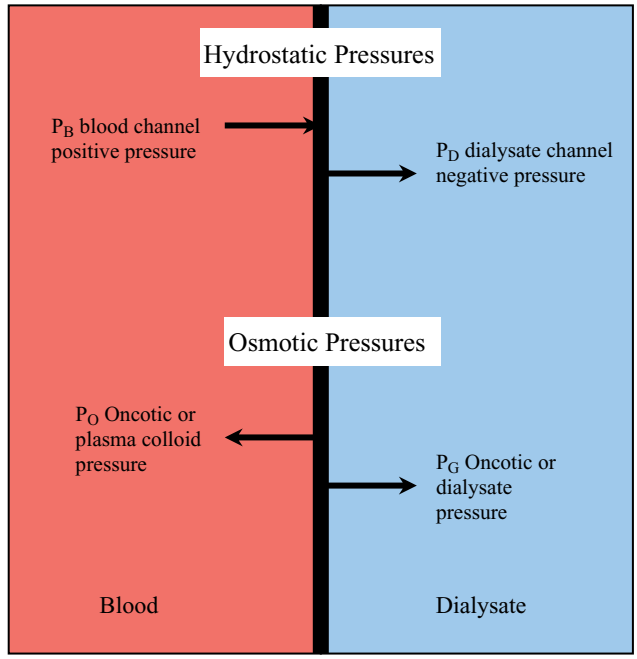


Figure 8.2 Transmembrane pressures. Overall pressure difference over the dialyser membrane = $(P_B + P_D) - (P_O + P_G)$. However, as the osmotic pressures are small in relation to the hydrostatic pressures the transmembrane pressure (TMP) = $(P_B + P_D)$.

Ultrafiltration and convection

As a result of hydrostatic pressure, fluid will move across the semipermeable membrane, and this process is called ultrafiltration. The rate of ultrafiltration depends on the permeability of the membrane and the hydrostatic pressure exerted upon it. The sum of the positive pressure in the blood compartment and the negative pressure in the dialysate compartment equals the transmembrane pressure (TMP).

The removal of fluid by ultrafiltration also results in the removal of solute, or those molecules dissolved in the water; this process is known as convection or solvent drag. Again, the higher the permeability of the membrane, the higher the removed volume of fluid and contained solute will be.

During conventional haemodialysis treatment, fluid will be removed by ultrafiltration, but this is usually a small amount (2–3 L) and will not provide significant removal of waste products by convection. Haemodialysis has traditionally been the standard form of extracorporeal treatment: haemofiltration and haemodiafiltration are becoming more common therapies in the treatment of patients requiring on-going renal replacement therapy. Some centres, however, now routinely use intermittent haemodiafiltration in place of conventional haemodialysis. For the purpose of this chapter the reference is to standard haemodialysis unless otherwise stated.

Molecular weight and solute movement

As well as diffusion and convection there are a number of other influences on the 'clearance' or removal of a solute across the dialyser membrane. The smaller the molecular

size of the solute the easier it will pass across the membrane. Urea, creatinine and electrolytes will dialyse easily. However, toxins with a larger molecular size, such as β2-microglobubin (β2M) will be cleared in smaller volumes. Movement across the dialyser is also dependent upon the permeability of the membrane (called the co-efficient of ultrafiltration (KUf): see below). High flux dialysers will enable greater clearance of middle-sized molecules, such as β2M, in comparison to low-flux dialysers.

Flow through the dialyser

Haemodialysis depends on diffusion for the efficient clearance of waste products. The patient's blood is pumped through the circuit (via blood tubing) on one side of the membrane whilst a physiological dialysis fluid (dialysate) is passed through the circuit (via dialysate tubing) on the opposite side of the membrane. The faster the blood flows through the dialyser, the greater the amount of blood that is 'processed' in a given time. Efficiency of dialysis is also therefore dependent upon optimising the blood flow through the dialyser.

To optimise the concentration gradient, the blood and the dialysate flow in opposite directions (countercurrent flow). This maintains an optimum concentration gradient throughout the dialyser.

Dialysate flows through the dialyser at a rate of 500 ml/min. Lower flow rates are associated with lower clearances. Some units increase the dialysate flow above the standard 500 ml, using the rule of thumb of 1:2 ratio of blood flow to dialysate flow. However, there is conflicting evidence on whether this significantly improves clearance rates. Bhimani *et al.*(2008) found that a high dialysate flow rate increases phosphate clearance, but not urea or β2M.

Principles of Haemodiafiltration

Haemodiafiltration (HDF) continues to gain in popularity as the treatment of choice for many patients. This increase in popularity has been aided by new machine technology allowing the production of sterile replacement fluid at the point of treatment, so there is no longer the need to purchase, store and handle large bags of sterile solution during treatment. Space constraints do not allow more than a simple introduction to HDF within this chapter.

The principles of haemodialysis described above apply to HDF, but the treatment has a greater reliance on the removal of solutes, particularly middle molecules, through convection. Leypolt (2000) argues that HDF is more efficient at removing middle molecules (5–50 kDa in size). In addition, compared with conventional HD, convective therapies such as HDF and HF, reduce intradialytic symptomatic hypotension (ISH) in long-term patients on dialysis (Locatelli *et al.* 2010). One study (858 patients over an 18-year period) found no benefit for HDF over high-flux HD with respect to anaemia management, nutrition, mineral metabolism, and BP control (Vilar *et al.* 2009). However these authors recommended that the mortality benefit associated with HDF that was found in their programme requires confirmation in a large randomised, controlled trial. A more recent trial (Grooteman *et al.* 2012) did not detect a beneficial effect of haemodiafiltration on all-cause mortality and cardiovascular events compared with low-flux haemodialysis. Blankestijn *et al.* (2010) summarises the available clinical evidence on haemodiafiltration.

Diffusion remains the driving force for solute removal in HDF as it does in haemodialysis (HD) (see Figure 8.3). However, solute removal is influenced by the dialyser membrane characteristics, and whereas low-flux membranes whilst having a high diffusive

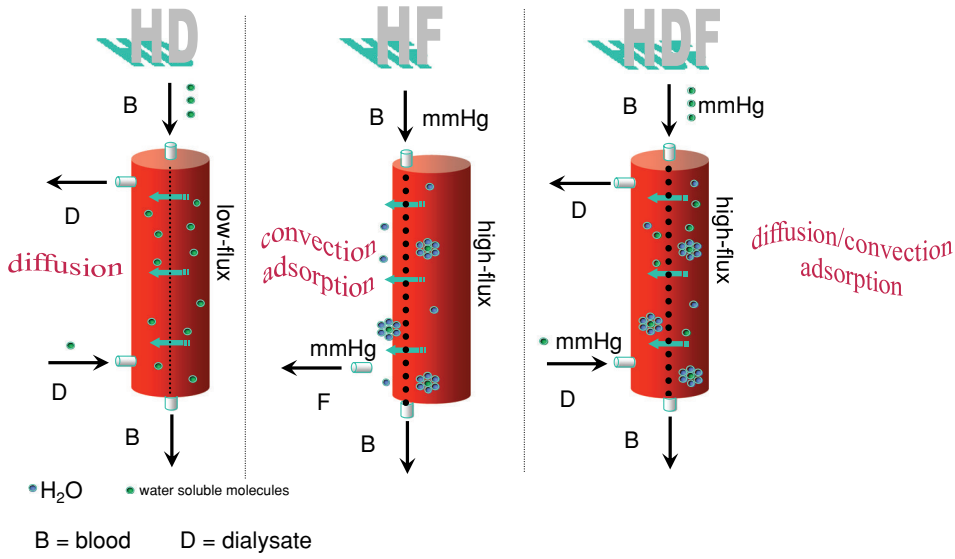


Figure 8.3 Comparison of haemodialysis, haemofiltration and haemodiafiltration (used with kind permission from B.Braun Medical).

permeability, are not as effective as the solute molecular size increases. Haemodiafiltration requires high flux membranes to allow the principles of convection to remove the larger molecules along with (see Figure 8.3) the ultrafiltrate.

Haemofiltration (HF) relies solely on convection to remove solutes. Because of this, high ultrafiltration rates are required to achieve an effective treatment, resulting in high volumes of replacement fluid. Haemodiafiltration uses a combination of diffusion and convection. However, their effects are not additive, because the two processes interfere with each other (Lebedo and Blankestijne 2010). Diffusion reduces concentration of small molecules, leaving less for convective transport. Likewise convection reduces blood flow through the dialyser, and consequently the diffusive force. These conflicts can lead to multiple alarms if the nurse is not experienced and able to adjust the UF rate to achieve an optimal treatment.

High convective volumes have been recommended to maximise middle molecular weight (MMW) solute removal during HDF, in the DOPPS study, high efficiency HDF (arbitrarily defined as infusion volumes 15–24 L per treatment) appeared to be related to improved survival, whereas low-efficiency HDF (infusion volume <15 L per treatment) did not (Canaud *et al.* 2006).

There remains a debate regarding the most effective method of infusing the replacement fluid required during HDF, either predilution or postdilution. Predilution relies on the replacement fluid being infused into the blood lines before the dialyser. This can resolve problems with low ultrafiltration volumes and high TMP values associated with haemoconcentration. However, the blood is diluted when entering the dialyser, which will affect diffusion and convention. Diffusion is reduced due to the dilution effect, and convention is also reduced as the ultrafiltrate contains less solutes.

Postdilution requires infusion of the replacement fluid after the dialyser. This does allow an accurate measure of the HDF dose as the ultrafiltration is equal to the convention volume. However, it may be difficult to achieve high UF volumes due to haemoconcentration of the blood as it passes through the dialyser resulting in high TMP alarms and the possibility of interrupted treatment times.

A number of studies have shown that outcomes associated with HDF are better when compared with outcomes of patients receiving haemodialysis (Jirka *et al.* 2006; Canaud

et al. 2006). However, these studies have mainly compared HDF against low flux dialysis. The CONTRAST study has not found a major benefit for HDF in relation to all-cause mortality and cardiovascular events when compared with low flux haemodialysis (Grootman *et al*. 2012). The authors have suggested that the findings may be explained by a number of factors. The loss of nutrients during HDF may outweigh the beneficial effects of higher toxin clearance. The study period of just over 3 years may be too short to show longer term benefits. Also the effect of HDF may be associated with the use of ultrapure water, which is necessary for this form of treatment. Poor water quality will have an impact on patient treatment. There is no information in any of the studies relating to the water quality of the comparator low flux haemodialysis treatments.

Access for Haemodialysis

The success of haemodialysis therapy depends almost entirely on the adequacy of the blood flow through the dialyser. Optimal clearance of waste products depends on dialysate flow rate, membrane permeability, membrane surface area, duration of dialysis and, most significantly, blood flow rate. Dysfunctional access will therefore adversely affect dialysis adequacy and consequently increase patient mortality and morbidity (KDOQI 2006).

The nurse has a responsibility to ensure that the prescribed blood flow is achieved whenever possible. Poor access should be addressed as a priority. Various types of access can be used for haemodialysis which fall broadly into two categories:

- Arteriovenous fistulae (AVF) and arteriovenous grafts.
- Percutaneous access, including jugular, subclavian and femoral lines, which can be either temporary or permanent.

For those with established renal failure the AVF is preferred, as there is evidence of long-term patency, improved flow rates and fewer complications than other methods (Fluck and Kumwenda 2011). The National Services Framework for Renal Services Part 1 (Department of Health 2004) set down a standard that patients should have vascular access created in a timely manner prior to renal replacement therapy being required. Planning for creation of vascular should be undertaken when the patient is in Stage 4 CKD (Fluck and Kumwenda 2011). However, the creation and maintenance of long-term access still remains one of the most challenging aspects of caring for those with renal disease, particularly patients with vascular disease, older people and those with diabetes mellitus (Konner 2004; Ernandez *et al*. 2005; Vasquez 2009).

There have been a number of initiatives around the world to decrease the reliance on central venous catheters as vascular access for haemodialysis. The Fistula First Campaign has been running in the United States for over a decade with varying success across different regions. In the United Kingdom the Department of Health has included a quality measure within the Renal Tariff to encourage the use of native fistulae as the vascular access of choice. The Renal Association (Fluck and Kumwenda 2011) is championing a quality marker of a minimum of 65% of patients with established renal failure who are on haemodialysis to have a fistula or graft.

The arteriovenous fistula

The AVF is created during a surgical procedure to anastomose an artery and a vein (Figure 8.4). Most commonly the radial artery and the cephalic vein are used in the

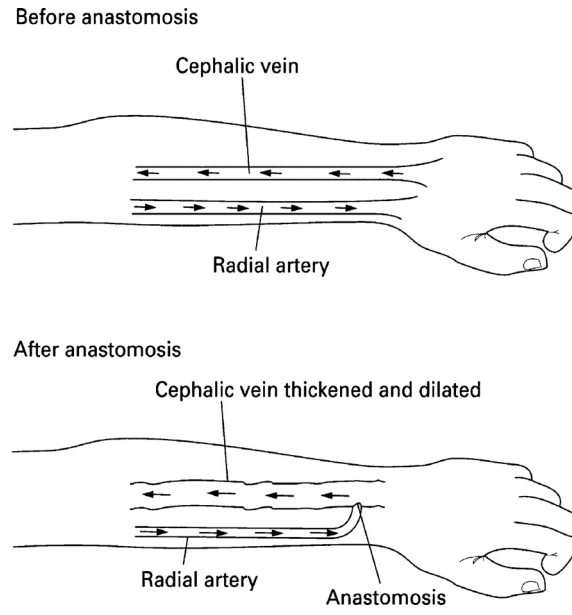


Figure 8.4 Arteriovenous fistula.

patient's nondominant forearm. Other sites include the upper arm: the brachial artery and cephalic vein or brachial artery and basilic vein.

As a result of the anastomosis, blood from the artery is forced into the vein where it flows in a retrograde direction. The increased blood flow and pressure cause the vein to thicken and dilate. Once established, blood flow through the fistula of up to 800–1000 ml/min can be achieved.

Ideally the patient should have the fistula created at least 3–4 months before the need for dialysis arises. This will ensure that the operation is performed when the patient is well and will allow the fistula time to mature, preventing the need for insertion of temporary access and the associated risk of infection. Many renal centres have a policy that medical and nursing staff should avoid phlebotomy or cannulation into the forearms of patients with suspected renal disease. This precaution will help to prevent damage to vessels that may subsequently be required for fistula formation. Repeated use of subclavian central venous catheters prior to fistula formation can also cause swollen arms and dilated chest veins following fistulae formation, so should be avoided (Naroienejad *et al.* 2010).

Formation of the Arteriovenous Fistula

Preoperative care Patients should be given every opportunity to participate in their plan of care and all aspects of treatment should be discussed with them. As part of the patient's predialysis preparation and education a full explanation of the surgical procedure and aftercare should be given to the patient. The patient may wish to visit and speak with someone who has a well-established functioning fistula to find out what it looks and feels like.

Information should include explanation that the fistula will be cannulated each dialysis, often using a different site (see explanation of the rope ladder puncture, below). Also it is helpful if the needles that will routinely be used should be available for the

patient to see and examine. Patients should be well hydrated before surgery, and above their target weight if recently dialysed. This reduces the chance of post-operative hypotension which would adversely affect the blood-flow through the fistula, increasing the chance of thrombosis.

Postoperative care In addition to routine postoperative care the nurse should ensure that the following specific postoperative care is carried out:

- The limb should be kept warm and well supported to help peripheral circulation.
- Blood pressure should be monitored closely and maintained at a minimum of 100 mmHg systolic. If the blood pressure falls below this, peripheral blood flow may be affected, with an increased risk of fistula thrombosis. It may be advisable to avoid antihypertensive therapy in the postoperative period.
- The wound site should be examined regularly for signs of excess bleeding or swelling.
- The blood flow through the fistula should be checked regularly by completing the following observations:
  - Placing a stethoscope lightly over the incision, a 'whooshing' sound should be heard. This is called a 'bruit'. The bruit should be loudest near the incision and it gradually becomes softer as the stethoscope is moved further up the vessel.
  - Placing a hand lightly over the incision site, a buzzing sensation should be felt. This is called the 'thrill'.
- The bruit and thrill should be checked regularly (half-hourly at first) and the patients should be taught how to perform these observations as soon as they are able.
- Before discharge, the patient should be informed how to care for the fistula and advised to avoid using the fistula arm for carrying heavy loads and to avoid tight or restrictive clothing on the arm. Hand exercises (such as clenching and releasing pressure on a squash ball or small bandage) may promote fistula maturation. The patient must also be advised to inform nonrenal doctors and nurses that the arm should never be used for phlebotomy, cannulation or for recording blood pressure, as all of these may result in permanent damage to the fistula.
- Patients should be advised to contact the hospital immediately if they notice bleeding, swelling or absence of bruit or thrill.

Cannulation of the arteriovenous fistula

In the first instance the fistula should be allowed 2–3 months to mature before cannulation is attempted, to allow healing of the anastomosis and some development of the vessels. After this time the fistula can be safely cannulated but the procedure should only be undertaken by experienced practitioners.

New fistulae may be prone to extravasation and clotting, which can be painful and distressing. Therefore, all attempts should be made to minimise trauma during the initial dialysis treatments when the fistula is still new and maturing.

If the patient is anxious, a local anaesthetic may be offered. Common forms of local anaesthetic include lignocaine or topical creams. Topical creams are a sensible choice; the injection of lignocaine can sting and defeat the object of pain-free cannulation. However, the topical cream needs to be applied at least 30 min before cannulation.

Prior to each cannulation a thorough physical examination of the fistula should be undertaken to check that there is no evidence of oedema, infection or bruising and that blood flow through the fistula is evident through the presence of the bruit and thrill.

The unit policy for strict asepsis and cleansing of the arm should be adhered to. Universal precautions should be employed, including wearing gloves, aprons and a face visor, as blood may splash into the face and eyes during cannulation. A tourniquet may

be used prior to cannulation to help engorgement of the vessel but in well-established larger fistulae this is often unnecessary.

Cannulation protocols

Many units are now evaluating the use of planned protocols to insert fistula needles, with the aim of reducing complications and extending the longevity of the fistula. The effect of repeated puncture on fistulae can adversely affect elasticity of the surrounding tissue (Roy-Chaudhury *et al.* 2005). During each cannulation a small area of vessel tissue is displaced. When the needle is removed, this area is filled with a thrombus. Scar tissue is then formed, resulting in increased tissue and subsequent elongation of the vessel wall. Over time this results in a loss of elasticity of the vessel and dilation results in aneurysm formation and adjacent stenosis.

McCann *et al.* (2008) described three methods of cannulation and the effects of each (Figure 8.5).

- Rope ladder puncture: This describes the systematic use of the entire length of the vessel. Each needle is inserted at approximately 2 cm above the last site and back again, resulting in a uniform use of the vessel. This has demonstrated less aneurysm formation as the punctures per area are reduced (KDOQI 2006). However, care must be taken to ensure that an area puncture technique is *not* undertaken in the belief that the nurse is following the rope ladder technique.
- Area puncture: This describes the development and use of one or two areas of the fistula that are regularly used. This may result in increased aneurysm formation related to the number of repeated punctures over a small area causing increased tissue elongation and aneurysm formation. As a consequence of the increased risk of long term damage to the vascular system, area puncture is not advocated (Fluck and Kumwenda 2011).
- Button hole puncture: This describes the repeated puncture of exactly the same site at exactly the same angle into exactly the same hole each dialysis. Over time cylindrical

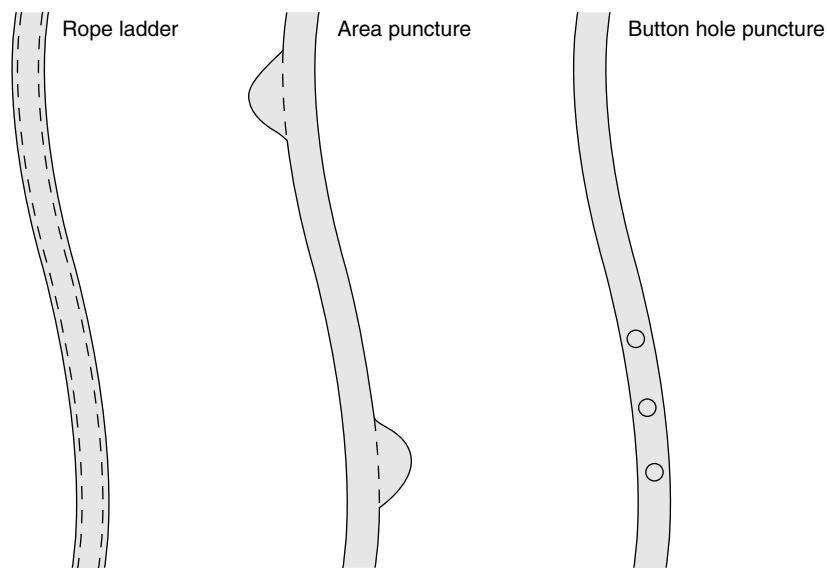


Figure 8.5 Cannulation protocols.
Source: From Kronung (1984).

scar tissue develops, guiding the needle into the right place. It is suggested that the button hole technique results in less aneurysm formation and has been shown to have high survival rates (Shearer *et al.* 2012). Button hole cannulation has also been associated with less pain associated with cannulation, and a reduction in haemostasis post dialysis (Sukthinthai *et al.* 2012).

There are no firm guidelines on whether the arterial needles should be placed antegrade (in direction of blood flow, away from the anastomosis) or retrograde (towards the hand). Brouwer (2005) and English (2005) advocate both positions. However Ozmen (2008) found no difference in the effectiveness of positioning on dialysis outcomes.

Cannulation skills can have an impact on the longevity of the vascular access. Poor cannulation techniques can lead to the increased use of central venous catheters or single needle dialysis (Van Loon 2009).

Whilst the adoption of protocols may be beneficial and ensure high standards of uniform practice, it is acknowledged that additional evaluation is necessary to provide evidence for the long-term effects of any of these protocols on the longevity of fistulae. The implementation of a vascular access monitoring programme can positively influence the longevity of vascular access (Van Loon 2007). Coupled with a cannulation training programme (Van Loon 2009) it can decrease access complications and increase staff competence and can be beneficial in prolonging the life of the vascular access. Both these initiatives are important in ensuring good standards of nephrology nursing practice.

Needle sets

The achievable blood flow for many patients is often underestimated. The careful selection of needles will ensure that optimum flows are obtained. Smaller needles (e.g. 16- and 17-gauge) produce high resistance as the blood pump is increased. This results in a 'sucking' effect on the needles and possible arterial alarms. Larger needles (14 g and 15 g) produce lower resistance and therefore avoid negative pressure as the blood pump speed is increased.

For patients with an AVF, needles should be inserted aseptically at 30–40° to the skin following appropriate skin preparation. Patients with an AVG should be cannulated at an angle of 45° to prevent damage to the material that the graft is made from.

The entire needle shaft should be inserted and the butterfly wing secured with tape. On insertion, a syringe should be attached to the end of the needle tubing and blood withdrawn. Any resistance to withdrawal may indicate that the needle position needs adjusting. Sometimes the needle hole is occluded against the side of the vessel wall. This can be corrected by placing a small piece of sterile gauze under the butterfly, this will lift the needle externally and lower the needle tip internally. If flow still cannot be obtained the presence of a clot may be suspected or there may be complete misplacement of the needle. In this event the needle should be removed. Arterial and venous needles need to be placed at least 5 cm apart to avoid recirculation.

If the needle punctures the wall of the vessel extravasation will occur, resulting in a painful visible swelling around the site. The needle should be removed and firm pressure applied for about 10 min before further insertion is attempted. On no account should the nurse push and pull the needle blindly, hoping that the needle will finally find the vessel. This will result in much pain and discomfort for the patient and will bruise and damage the surrounding tissue, which may in turn cause permanent damage to the fistula.

It is also important that nurses, no matter how experienced, recognise their limitations in relation to cannulation. If a cannulation attempt has failed after more than two or three attempts, assistance should be sought from a colleague, as the increased anxiety

of the nurse and patient may negatively influence further attempts at successfully siting the needle.

Complications of arteriovenous fistulae

Defining a functioning vascular access can be problematic as there are no clearly accepted definitions. In the absence of a clear definition it could be argued that a functioning arteriovenous fistula (AVF) or arteriovenous graft (AVG) allows for repeated cannulation with two needles, allowing an adequate blood flow to deliver the prescribed dialysis dose.

Thrombosis Thrombosis may occur in the immediate postoperative period or at a later date, sometimes following a hypotensive episode on dialysis (Chang *et al.* 2011), but is most commonly associated with stenosis of the AVF (KDOQI 2006). There are a number of different methods available for treating thrombosis, including surgical intervention, angioplasty and antithrombotics, or both. There are varying success rates. Surgical treatment (thrombectomy) may be indicated but salvage is often unsuccessful in the long term (Jain *et al.* 2008). However, if reported promptly, permanent damage may be avoided by the use of thrombolytic agents (KDOQI 2006).

Stenosis Stenosis of the fistula can occur anywhere along its track, but is more common on the venous side of the fistula (Yevzlin, *et al.* 2009). However, irrespective of where it occurs there is an increased chance of the fistula failing. Stenosis at the anastamosis site will reduce blood flow into the fistula, increasing the risk of thrombosis.

A stenosis higher up above the needle site will increase pressure within the fistula, reduce blood flow out and increase the percentage of recirculation. All of which could adversely affect the adequacy of dialysis (KDOQI 2006).

The first choice of treatment for venous outflow stenosis is percutaneous angioplasty, but if the fistula is thrombosed then surgical intervention may be required (Fluck and Kumwenda 2011).

Aneurysm Although unsightly, aneurysm formation in the AVF does not always adversely affect the function or blood flow through the fistula (Almehmi and Wang 2012). However, aneurysms are frequently associated with an increase in post dialysis haemostasis, pain and fistula loss (KDOQI 2006). Aneurysms can be caused by repeated area puncture (Figure 8.5). The skin eventually becomes much thinner as the aneurysms dilate (Almehmi and Wang 2012). Cannulation in the aneurysm should be avoided. Aneurysms are also associated with the development of stenosis of the vein above the needling site.

Steal syndrome The creation of an AVF alters the normal blood flow through the lower part of the affected limb and hand. The creation of the AVF does not give rise to side-effects in the majority of patients, but approximately 5% can develop hand ischaemia in the affected hand (Scheltinga *et al.* 2009). The patient may complain of pain, oedema, coldness or 'pins and needles' as blood is 'stolen' from the hand as a result of the fistula (lower resistance in the arteriovenous anastomosis). Onset of steal syndrome can vary, with a rare acute onset within hours of surgery. Most patients develop symptoms over weeks, months, or even years. Surgical correction to restore blood supply to the hand is usually required, with subsequent loss to the fistula.

Infection Infections of established arteriovenous fistulae are uncommon and are mainly localised to the immediate area, not progressing to bacteraemia. Treatment with antibiotic therapy is usually successful. Buttonhole cannulation has a higher infection rate then rope-ladder technique, therefore care must be taken to ensure that removal of the scab and skin disinfection is carried out carefully to reduce the risk (Birchenough 2010).

Arteriovenous grafts (Figure 8.6)

If the peripheral blood vessels are unsuitable for fistula formation the surgeon may decide to create a graft. Most grafts are created using synthetic materials such as polytetrafluoroethylene (PTFE). Grafts may be cannulated soon after insertion, preferably after 14 days.

The graft may be configured in a straight line or in a loop. Grafts are less compliant than fistulae, resulting in higher pressure through the vessels. Patients should be carefully taught how to care for the graft, especially with regards infection control.

The nurse should perform the same predialysis physical examination prior to cannulation. However, the angle of insertion of the needle is steeper than for an AVF and cannulation should be at an angle of 45°. Thorough skin preparation is vital as there is higher infection risk for grafts compared with fistulae. The arterial needle should be inserted at the arterial end of the graft at least 5 cm from the anastomosis site. The venous needle should be inserted in the venous end with the same considerations. For loop grafts it is important to identify the arterial and venous sides of the graft as incorrect needle placement will result in recirculation. Needles may be rotated through 90° following insertion (bevel of needle downwards), to reduce the risk of graft damage.

Monitoring access patency (surveillance)

Adequacy of dialysis is directly related to the total blood volume that is processed during the dialysis treatment. As such it is important that the access used should be capable of delivering the optimum blood flow. However, stenosis occurring in the anastamosis area will reduce the volume of blood passing through the fistula; while a stenosis above the needling site will likewise decrease blood flow and increase the chance of recirculation. Regular monitoring of the blood flow will provide valuable information and trends on blood flow through the fistula and the percentage of recirculation.

There are a number of methods that can be used to monitor the effectiveness of the vascular access. These can range from low technology, simple observation and assessment of the access each dialysis session through to high technology solutions that measure blood flow via ultrasonic methods.

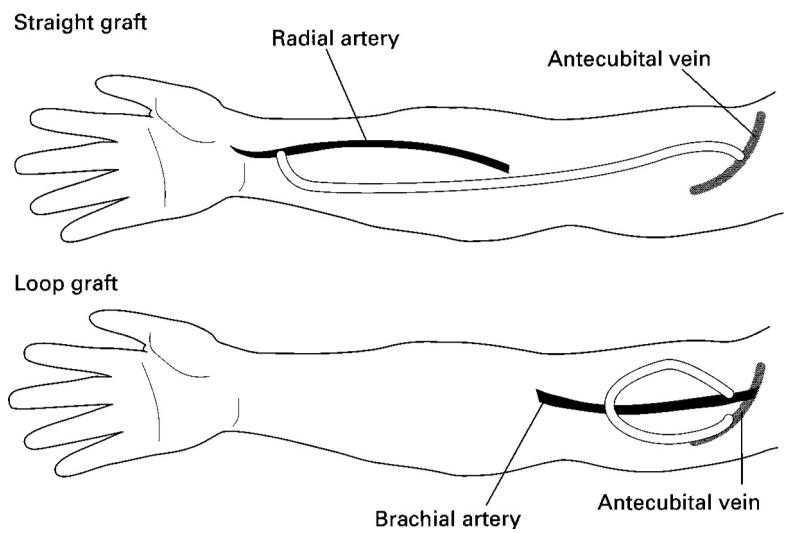


Figure 8.6 Arteriovenous graft.

BOX 8.1

Rule of six for a mature fistula (KDOQI 2006):

- A minimum of 6 mm in diameter with discernible margins when a tourniquet is in place
- Less than 6 mm deep below the surface.
- Have a blood flow greater than 600 ml/minute.
- Have at least 6 cm of straight segment for cannulation.

Physical examination of the vascular access at each dialysis session is a simple and cost effective method of identifying changes over time. The 'rule of six' is a simple method and is summarised in Box 8.1. There are three components to assessment of the vascular access: inspection (look), palpation (feel) and ausculation (listen). The AVF or AVG should not have any indications of infection or inflammation. On palpation the fistula will have a soft continuous thrill along it length and should be easily compressible (Vachharajani 2012). On auscultation the AVF should have a low-pitched continuous bruit.

As well as a physical examination, monitoring changes in venous and arterial pressure during dialysis over time can also provide meaningful information on the state of the vascular access. Increasing venous pressure over a period of weeks or months may indicate a stenosis, especially if associated with prolonged bleeding times post dialysis. A reduction in achievable blood flow over a period of time could be an indication that the blood flow through the vascular access is falling. An unexplained drop in the patient's *Kt/V* can also provide clues to the condition of the vascular access, and may indicate an increase in recirculation.

Surveillance of the blood flow through the fistula is another method of assessing the health of vascular access. Blood flow through the fistula or graft of less than 600 ml/min is an indicator of access failure (KDOQI 2006; Fluck and Kumwenda 2011). There are a number of methods of indirectly measuring the blood flow, however, there is no single technique that has been shown to be superior (Fluck and Kumwenda 2011).

Vascular access standard

The Renal Association (Fluck and Kumwenda 2011) has recommended that 65% of all patients starting HD for the first time should commence with an AV fistula and 85% of all patients on maintenance haemodialysis should have a functioning AV fistula. If this is to be achieved then there will be increasing pressure on nurses to care for AVF proactively and to ensure that only well-trained competent nurses carry out cannulation. Detailed ways in which the multiprofessional team can work together to achieve this aim are beyond the scope of this book, but McCann *et al.* (2008) provide a good review of how to prolong vascular access patency.

Percutaneous access

Percutaneous access is the term used to describe the insertion of a cannula or catheter into a major vein, often termed a central venous catheter (CVC) (Figure 8.7). Catheters may be inserted as a temporary measure, as in acute kidney injury, or for temporary use whilst a fistula matures. Potential sites include the subclavian, femoral and internal jugular veins. The use of the subclavian vein is not recommended in patients with end-stage kidney disease as this may adversely affect the success of the creation of an AVF

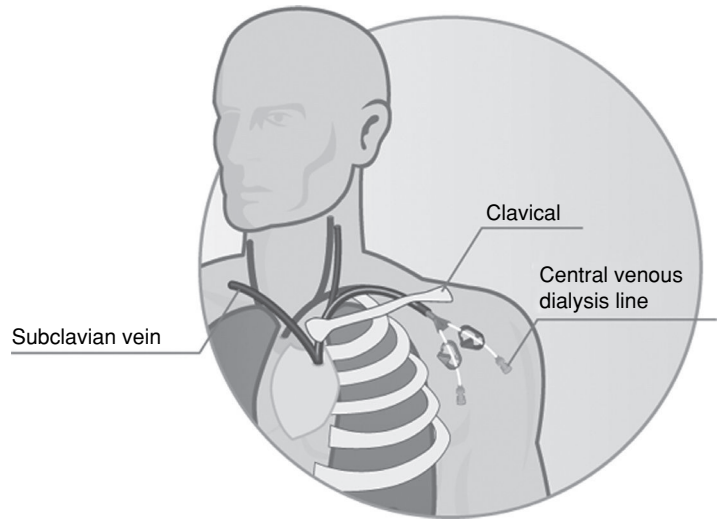


Figure 8.7 Central venous catheter.

due to central venous stenosis. Femoral catheters should only be used in those who are immobile and should be changed every 1–3 days. General knowledge and understanding of central venous catheters (CVCs) as a method of haemodialysis vascular access can be gained by reading McCann *et al.* (2010)

More commonly, percutaneous catheters are being inserted as permanent access for patients whose fistulae have either failed or whose vessels are inadequate to attempt AVF creation in the first place. The permanent catheters are cuffed and inserted through the creation of a subcutaneous tunnel, as this ensures optimal placement of the catheter and helps reduce the rate of infection.

Catheters are invariably double-lumen, but single-lumen catheters are occasionally used. Catheters may be inserted under general or local anaesthetic and nursing care pre- and postoperatively will be the same as for any surgical procedure. After insertion it is essential that the correct placement of the catheter is checked by X-ray prior to dialysis as insertion complications may include pneumothorax and puncture of the adjacent vessels.

The nurse's responsibility includes the maintenance of catheter patency, patient education, prevention of infection and early intervention when infection occurs. Nurses caring for percutaneous access must demonstrate meticulous care, as defined by a strict unit policy. This policy should include the need for strict asepsis during any catheter intervention (Vanholder *et al.* 2010). The exit site should be examined before each dialysis and observed for signs of infection such as soreness, redness or the presence of exudate. Exit sites should be covered with a dressing that will maintain an optimum environment conducive to healing (not too wet and not too dry) and one that will repel *Staphylococcus aureus*.

The Renal Association has recommended an audit benchmark of an annual *Staphylococcus aureus* bacteraemia rate of less than 2.5 episodes per 100 patients on HD and less than 1.0 episode per 100 patients for meticillin resistant *Staphylococcus aureus* (MRSA) over 2 years (Fluck and Kumwenda 2011).

Chlorhexidine aqueous solution or povidone-iodine can be used to clean the exit site and then a nonocclusive dressing is applied (Pratt *et al.* 2007). It is important to note

that manufacturers' guidelines on use of a cleansing agent should be strictly followed, as chlorhexidine alcohol solutions can degrade the materials of which the central line are made. The catheter hubs and portals are common sites of infection and should be cleaned prior to connection and disconnection from dialysis (Pratt *et al.* 2007).

Maintaining patency of the central venous catheter

To maintain patency between dialysis treatments it is common to instil a bolus of heparin (usually 5000 iu/ml) equal to the volume of each catheter lumen. It is important that the exact volume of each respective lumen is ascertained to prevent giving a systemic dose of heparin to the patient. However, other locks such as citrate or a mixture of heparin and gentamycin have been found to be equally effective (Betjes and Van Agteren 2004; McIntyre *et al.* 2004). The use of an antimicrobial lock has the advantage of reducing catheter related infections (Vanholder *et al.* 2010), but can be more expensive to use than heparin. This modest increase in price though can be a cost saving when taking into account treatment costs for blood stream infections.

There has been an increase in the use of trisodium citrate as a catheter lock in recent years, and is this is now considered a safe alternative to heparin, especially as the price differentiation between the two has decreased. The use of trisodium citrate has been shown to have improved outcomes with regards catheter exchange, tissue plasminogen activator (tPA) (thrombolytic) use and access-related hospitalisations compared with heparin locking (Lok *et al.* 2007). Two recent meta-analyses have shown that the use of trisodium citrate has a lower incidence of catheter related blood stream infections when compared with heparin as a lock (Labriola *et al.* 2008; Yahav *et al.* 2008).

Before the next dialysis treatment, the anticoagulant lock must be removed by aspirating the catheter with a syringe and then flushing with 0.9% normal saline before connecting the dialysis lines. Nevertheless, clotting is a common complication, either preventing the use of the catheter, or reducing flows rates adversely, affecting adequacy of the dialysis. Several attempts may be needed to aspirate a clot in the catheter if resistance is felt. It is vital that any clot is removed and no attempt is made to flush a catheter that cannot be aspirated from either lumen. In permanent catheters, the administration of urokinase should dissolve the clot if all other methods have failed, and should be left for at least 30 min before or between dialysis sessions.

In dual-lumen catheters it is important to use the arterial and venous lumens appropriately. Occasionally, flow from the arterial lumen is partially occluded owing to poor positioning of the arterial holes against the side of the vessel wall. The lines may have to be reversed to achieve an acceptable blood flow, however it must be borne in mind that reversal of the lines will result in increased recirculation (McCann *et al.* 2010).

Haemodialysis Equipment

The dialyser

The dialyser is the functional unit of the extracorporeal circuit just as the nephron is the functional unit of the kidney, and some patients and nurses refer to the dialyser as the 'kidney'.

Manufacturers have made significant advances in the development of membranes that provide highly efficient clearance of waste products and which are biocompatible for the patient. There are two types of dialyser design: the hollow fibre (Figure 8.8) and the parallel plate. However, the vast majority of dialysers produced and used today are hollow fibre dialysers.

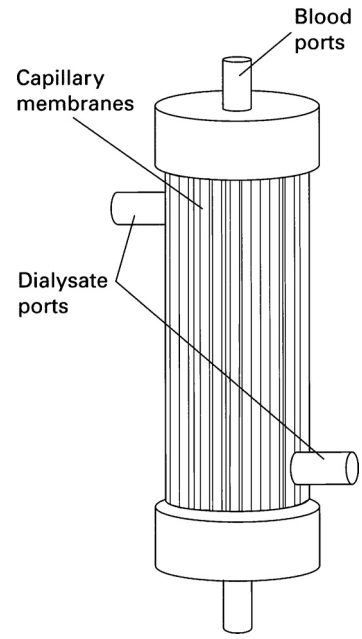


Figure 8.8 Hollow fibre dialyser (used with kind permission from B.Braun Medical).

The hollow fibre dialyser is made up of thousands of hollow fibres or capillaries about the thickness of a human hair. The fibres are secured at each end of the cylindrically shaped dialyser in a polyurethane potting compound. Blood passes through the centre of each fibre like a straw, whilst the dialysate passes on the outside of the fibres in the opposite direction.

The plate dialyser consists of sheets of membranes arranged in layers. Blood passes through the space between one set of layers whilst the dialysate passes through the adjacent layers in the opposite direction. Plates have more compliance (stretch) than hollow fibre dialysers and therefore have higher priming volumes.

The dialyser membrane

The choice of membrane type is becoming increasingly important as part of the patient's individual dialysis prescription. In addition to selecting the membrane which provides the desired clearance and fluid removal, the nurse should also consider the issue of biocompatibility related to the patient's needs.

A large and increasing variety of membrane types are available, but these fall broadly into three categories:

- Cellulose membrane (e.g. Cuprophan): low flux
- Modified cellulose membranes (e.g. cellulose acetate, cellulosynthetic such as Hemophan, cellulose triacetate): mid or high flux
- Synthetic membranes (e.g. polysulfone, polyacrilynitrile (PAN), polymethylmetacrylate (PMMA), polycarbonate (Gambrane) and polyamide): mid- or high flux

The efficiency with which a membrane clears water and solutes is described as its flux properties. Thin membranes with large pores are very permeable to water and large

molecules and are called high-flux membranes as they have the ability to clear solutes with a molecular weight of up to 30 kDa. Low-flux membranes are less permeable to water and solutes but will provide adequate clearance of solutes up to a molecular weight 10 kDa. The membrane's permeability to water is described as its ultrafiltration coefficient (*KUf*), and is measured in ml/h/mmHg (the number of millilitres per hour of fluid that is removed for every one unit of pressure across the membrane). The efficiency of solute clearance is measured by the mass transfer urea coefficient or KoA, indicating the effectiveness of the membrane for allowing solute to pass across its surface.

High-flux membranes have a high *KUf* (>10) and moderate-water-permeability membranes have a *KUf* of between 5 and 10 ml/h/mmHg. Details of the properties of each dialyser can be found on the dialyser specification sheet which is provided with each box of dialysers. The use of high-flux membranes during haemodialysis and haemodialfiltration is now the membrane of choice (Tattersall *et al*. 2010). The routine use of high-flux membranes has been found to have a positive effect on the survival of patients on haemodialysis, especially at risk patients with low serum albumin (Locatelli *et al*. 2009b).

Solute removal by modified cellulose and synthetic membranes is similar, although β_2-microglobulin clearance is greater with synthetic membranes, and this may translate into fewer amyloid dialysis deposits (Schwalbe *et al*. 1997).

Biocompatibility

It is ironic that the very process of haemodialysis, whilst providing an effective treatment for established renal failure, can result in significant side effects due to the interaction of the blood with the various components that make up dialysis equipment. The process of dialysis requires the repeated exposure of the patient's blood to foreign substances including the dialyser membrane, blood lines, dialysate, chemicals, drugs and water. Biocompatibility can be defined as the use of a material that elicits the least amount of inflammatory response during dialysis.

At its simplest, the exposure of blood to the artificial surfaces of the dialysis circuit results in coagulation within the dialyser and dialysis line. Although all membranes elicit an increased incidence of thrombogenesis and fibrinolysis, cellulosic membranes create a more marked increase than synthetic membranes (De Sanctis 1996). However, dialysis may also initiate subtle but long-term effects on immunological responses that include activation of the complement system and release of cytokines involved in the inflammatory process and anaphylactic reactions.

Recent moves to ensure that the products used during dialysis (the dialyser and dialysis lines) are sterilised through gamma irradiation has reduced one serious issue of bio-incompatibility, namely the incidence of 'first use syndrome' associated with sterilisation using ethylene oxide. Although rare, patients can experience a severe reaction to a dialyser membrane (Coentrao *et al*. 2010), therefore when exploring unexplained incidents on dialysis the possibility of a membrane reaction should be considered.

Dialysis-related amyloidosis leading to conditions such as carpal-tunnel syndrome is associated with elevated β-2 microglobulin (β-2M) levels. This was initially thought to be related to exposure of cellulose membranes, however subsequent studies have found no significant evidence that bioincompatible membranes have a marked increase on the production of β-2M. Interestingly, biocompatible high-flux dialyser membranes have been shown to increase the clearance of β-2M, slowing the development of amyloidosis (Traut *et al*. 2005). More focus is now on the use of high-flux dialysis and haemodiafiltration as the treatment of choice for renal replacement therapy.

Other more subtle effects of biocompatibility should not be ignored. It has also been suggested that bioincompatible membranes adversely affect the nutritional parameters of patients in comparison to those dialysed with biocompatible membranes.

Poor water quality can also induce inflammatory reactions. Bacterial and endotoxin contamination resulting from biofilm development have been implicated in increased morbidity of haemodialysis patients (Hoenich and Levin 2003; Lonnemann 2004). Standards aim to define safe levels of chemical and bacteria contaminants, outlining regular monitoring to identify potential quality problems (Mactier *et al*. 2011) although there are calls for international harmonisation (Nystrand 2009).

The importance of water quality cannot be emphasised enough in units using high-flux or haemodialfiltration. The larger pores in the dialysis membrane increase the risk of exposure to bacteria or endotoxin. Therefore the risk of backfiltration during dialysis always exists, and poor water quality will adversely affect the patient.

Water treatment

A patient dialysing 4 h, three times a week is exposed during treatment to approximately 6240 L of water a year. Because of this level of exposure, the water used during dialysis must be well controlled and regularly monitored for impurities and contamination. Raw water coming into the dialysis unit from the mains supply contains many contaminants that pose a potential risk to the patient. The clinical effects on patients caused by various contaminants can be seen in Table 8.1.

In order to avoid these symptoms, raw water is treated to reduce the concentration of contaminants to safe levels. The standards controlling contaminant concentration of processed water used are defined by the Association for the Advancement of Medical Instrumentation (2004) and ISO (2011). A simplified schematic drawing of a typical water-treatment plant can be seen in Figure 8.9.

Water first passes through a sediment filter to remove particulate matter, before passing through the water softener, though in some configuration the carbon filter may be placed before the softener. The water softener is a crucial part of the pretreatment system. Its main purpose is to 'soften' the water by removing calcium (Ca^{++}) and magnesium ions (Mg^{++}), in order to protect the RO membrane from fouling and blocking. Calcium and magnesium ions degrade the RO membrane performance by forming mineral deposits on it. As a consequence, membrane lifetime of the RO is shortened and the risk of hard water getting to the patient (due to high Ca and Mg levels) increases.

Table 8.1 Clinical effects of water contaminants.

Symptom	Related contaminants
Anaemia	Aluminium, chloramine, nitrate, lead, copper, zinc
Bone disease	Aluminium, fluoride,
Hypertension	Calcium, magnesium, sodium
Hypotension	Bacteria, endotoxin, nitrate
Acidosis	Low pH, sulphate
Muscle weakness	Calcium, magnesium
Nausea/vomiting	Bacteria, endotoxin, chloramine, low pH, nitrate, sulphate, calcium, magnesium, copper, zinc
Neurological disturbance	Aluminium, lead, calcium, magnesium

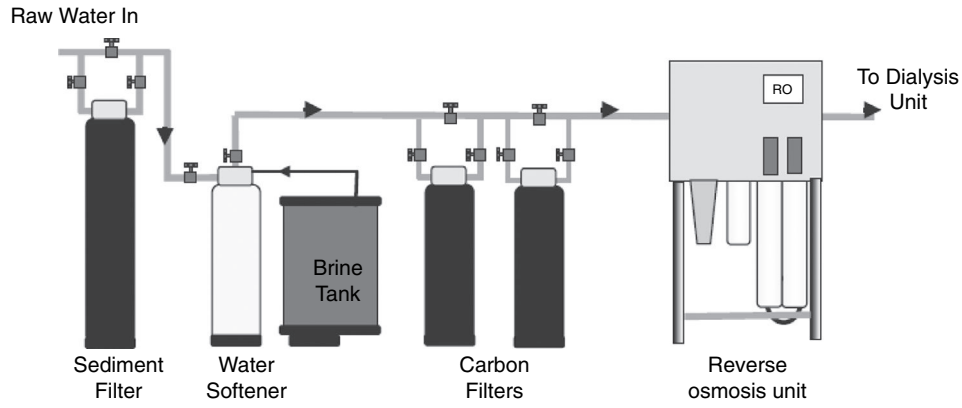


Figure 8.9 Simplified scheme of a water treatment system.

The softener is filled with resin beads, which attract and bind the polyvalent magnesium and calcium ions and instead release monovalent sodium ions, which can be easily removed by the RO membrane and rejected to drain. Softeners are also capable of removing other polyvalent cations such as iron and manganese, however being somewhat limited in this regard.

Chlorine added to the mains water supply to reduce the bacterial count can induce anaemia and nausea / vomiting in the patient (Ward 1996). Chlorine and chloramines breakthrough into the water loop have been associated with haemolysis and anaemia (de Oliveira *et al*. 2009; Junglee *et al*. 2010). The carbon filters remove the chlorine and chloramines (free chlorine) from the incoming water, before passing through the reverse osmosis (RO) unit. In addition, RO membranes are not very effective at removing chlorine and chloramine from the dialysis water, and the membranes can be damaged by chlorine and chloramine. The recommended limit for total chlorine is now 0.1 ppm (ISO23500 2011).

Carbon filtration removes chlorine and chloramines by means of a chemical process termed adsorption. As the input water flows down through the granular activated carbon (GAC), solutes diffuse from the water into the pores of the carbon and become attached to the structure. As an additional benefit, a wide variety of naturally occurring and synthetic organic compounds such as herbicides, pesticides and industrial solvents will be adsorbed too (Association for the Advancement of Medical Instrumentation 2004).

Reverse osmosis, as the name suggests, is the opposite to osmosis. In reverse osmosis the incoming water is forced to flow in the opposite, or unnatural, direction across a semi-permeable membrane by means of high pressure. Natural osmotic flow is overcome, and pure water passes through the membrane, leaving the dissolved solids (metals etc.) and other constituents (or waste) on the other side.

Reverse osmosis membranes reject dissolved inorganic elements such as ions of metals, salts, chemicals and organics including bacteria, endotoxin and viruses. Rejection of charged ionic particles ranges from 95–99%.

Standards for water quality have existed for many years, but in a number of countries in Europe there is no legal obligation to comply with the European Pharmacopoeia and testing is not mandatory. Box 8.2 shows the ISO standards that cover the production of dialysis water. Water should be regularly analysed to measure endotoxin levels and numbers of organisms to ensure that they do not exceed the standard for the dialysis

BOX 8.2

ISO standards that cover the production of dialysis water

- ISO 13959; 2009: water for haemodialysis and related therapies.
- ISO 11663; 2009: quality of dialysis fluid for haemodialysis and related therapies.
- ISO 26722; 2009: water treatment equipment for haemodialysis and related therapies.
- ISO 23500; 2011: guidance for the preparation and quality management of fluids for haemodialysis and related therapies.

unit. Regular testing of water used for dialysate should show a total viable bacterial count of less than 100 CFU/ml and an endotoxin level less than 0.25 EU/ml. If routine monitoring demonstrates microbiological contaminant levels in excess of 50 CFU/ml and 0.125 EU/ml for bacteria and endotoxin (50% of the maximum permitted levels) a programme of corrective measures should be commenced immediately (Mactier *et al*. 2011). The full Renal Association/ Association of Renal Technologists guideline can be found here: www.renal.org/Libraries/Guidelines/RA_and_ART_guideline_final_version_20_01_12_1.sflb.ashx (accessed 20 May 2013).

The trend today is to install water treatment plants that are capable of delivering ultrapure water as a standard. The microbial contaminant levels of ultrapure water are much less than the pure water standard, with biological contaminant levels of <0.1 CFU/ml and endotoxin level of <0.03 EU/ml. The UK Renal Association recommends that new water treatment plants are capable of delivering ultrapure water (Mactier *et al*. 2011). The rationale behind this recommendation relates to the increase in use of high flux dialysers and the risk of back filtration during treatment.

There are two main methods of disinfecting the water loop that delivers the treated water to the dialysis station, chemical disinfection and heat disinfection. Traditionally chemical disinfection has been used with a variation in frequency of disinfection cycles depending upon the age of the water loop and the bacteriology and water endotoxin levels. This is an effective method of keeping bacterial growth under control. However, there are safety implications for the staff undertaking the disinfection, and also potential exposure of the patients to the chemicals used after the disinfection has been carried out. Recently, there has been a move to installing new water treatment plants that are capable of heating the water loop to temperature of >90°C. This kills off any bacteria that may have found ingress into the loop. The main advantages to heat disinfection as associated with the frequency that it can be carried out. Some dialysis centres heat-disinfect the loop each night, but in most units the disinfection is conducted twice or once a week. This helps to prevent biofilm build up and reduces the need for chemical disinfection significantly.

Preparation of the dialyser

Priming and rinsing of the extracorporeal circuit is a crucial process in the preparation of the dialysis treatment. Manufacturers provide guidelines and recommendations for priming volume and rinsing time, however, there are two important aspects to consider:

- The removal of air. Air must be removed from the blood lines and from all surfaces of the dialyser membranes. Pockets of air retained in the dialyser will result in less efficient dialysis and will promote clotting in the dialyser.
- The removal of any chemicals or sterilising agents used during the dialyser manufacturing process.

In the past, the main concern was ethylene oxide (ETO), a gas that is a highly effective sterilant against all micro-organisms. It may, however, have toxic effects and cause hypersensitivity reactions in some patients (see section on first-use syndrome). Alternative sterilising methods are now routinely used, including heat sterilisation and gamma radiation. Even so, correct rinsing of the dialyser is still required to ensure removal of any residual chemicals left over from the manufacturing process (Uhlenbusch-Korwer *et al*. 2004). However, there are still rare instances where patients experience reactions to specific dialysers/membranes.

Dialysate composition

Dialysate is the term used to describe the fluid that is pumped through the dialyser on the opposite side of the semipermeable membrane to the patient's blood. The function of dialysis fluid is to correct the chemical composition of uraemic blood to normal physiological levels, the removal of excess uraemic wastes and electrolytes. In addition it is also responsible for the movement of buffering agents from the dialysate into the blood to restore the acid-base balance of uraemic patients.

Dialysate is produced by mixing a concentrated electrolyte solution (concentrate) with a buffer (bicarbonate) and purified water. Dialysate composition can be tailored to individual patient requirements (particularly potassium and calcium levels, and sodium levels if sodium profiling is being used to minimise hypotension) but on the whole the solution will be physiological, i.e. it will resemble normal serum biochemistry with specific deviations (Table 8.2).

Sodium

Physiological sodium This is the most common sodium dialysate concentration, (usually 135–140 mmol/l) and is normally adequate to remove enough sodium and water during the dialysis procedure. The use of physiological sodium means there is no large concentration gradient between plasma and dialysate; therefore there is little or no net diffusion of sodium. Fluid movement is thus not dependent upon variations in the sodium concentration but upon ultrafiltration. Sodium, if any is removed by convection. Dialysing with a sodium concentration of 140 mmol/l results in a reduced incidence of dialysis related hypotensive episodes when compared with a lower sodium dialysate (Hecking *et al*. 2012).

High Sodium Improvements in dialysis machine technology now allow the nurse to alter the sodium concentration during dialysis. Patients who cannot tolerate fluid

Table 8.2 Usual composition of haemodialysis dialysate

Solute	Concentration
Sodium (mmol/l)	135–143
Potassium (mmol/l)	0–4
Chloride (mmol/l)	100–111
Calcium (mmol/l)	1.25–1.75
Magnesium (mmol/l)	0.75–1.5
Bicarbonate (mmol/l)	30–35
Glucose (g/100 ml)	0–0.25

removal during dialysis, suffering hypotensive episodes, cramping and other cardiac related events, may benefit from part of the dialysis being conducted using a higher sodium dialysate – sodium profiling. Sodium diffuses into the blood from the dialysate, increasing the sodium concentration of the plasma. This osmotic imbalance helps to mobilise the intracellular fluid reserves, increasing the fluid shift from the intracellular fluid compartment to the intravascular compartment. Ultrafiltration is facilitated and the blood pressure remains stable. Care must be taken to ensure that the dialysate sodium is reduced during dialysis to physiological levels otherwise the patient will finish dialysis with a positive sodium load, leading to experiences of thirst resulting in an increased fluid intake and risk of hypertension (Lindley 2009).

Because of the risk of the patient finishing a dialysis treatment with a high sodium level, the use of sodium profiling is not as common in Europe, but is still used widely in the United States.

Low Sodium In hypernatraemic patients a low sodium dialysate may be considered an option. Low sodium dialysate leads to the transport of sodium from blood to the dialysis fluid. This creates an osmotic imbalance between the extra and intracellular fluid compartments, leading to greater fluid shifts and intracellular swelling, resulting in a form of dialysis disequilibrium. The lower the sodium dialysate level the more efficient the dialysis and the more pronounced the effect of sodium clearance. Care needs to be taken when using low sodium dialysate due to the resultant extracellular volume depletion and hypotension.

Potassium

Many renal patients present for dialysis with raised potassium levels and this is associated with morbidity and death among patients on dialysis. Most dialysis concentrates use a hypotonic concentration of potassium of 2 mmol/l. This is usually enough to reduce serum potassium levels of patients with hyperkalaemia. However, no-potassium dialysate can occasionally be used for patients with severe hyperkalaemia, but should be used with care. Potassium-free concentrates should be used only at the start of dialysis, and then changed to concentrate of 2 mmol/l. If this is not done then the patient may become severely hypokalaemic with attendant cardiac arrhythmias. Extra potassium can be added to concentrates if the patient is hypokalaemic. Patients who routinely present with lower potassium levels or those who are dialysing for the first time should dialyse against a solution containing 3.0 mmol/l reducing the risk of disequilibrium.

Calcium

Calcium dialysate levels should be in the range of 1.25–1.50 mmol/l, slightly below physiological levels (KDIGO 2009). The use of higher concentrations causes a positive calcium balance, with the long-term risk of development of metastatic calcifications. Lower concentrations induce release of parathyroid hormone, exacerbating the risk of secondary hyperparathyroidism. The increased use of calcium carbonate as a phosphate binder instead of aluminium derivatives, has led to the need to reduce calcium levels in dialysis fluid. Despite the use of lower calcium dialysate, care needs to be exercised to ensure the patient does not develop a negative calcium balance leading to increased secondary hyperparathyroidism (Fernandez *et al*. 1995). This emphasises the complex nature of calcium and phosphate management in patients needing dialysis.

Citrate

A new advance in dialysate concentrates relates to the use of citrate to acidify the bicarbonate dialysate. A number of studies have shown that there are benefits over the use of conventional acid-based dialysate. The inclusion of citrate has been found to reduce the

dose of anticoagulation during treatment (Cheung *et al.* 2011; Kossmann *et al.* 2009). This is an important factor when considering dialysing patients with a risk of bleeding during dialysis and for patients undergoing acute dialysis. Kossmann *et al.* (2009) also found that the use of citrate dialysate also improved dialysis adequacy, increasing *Kt/V* and clearance of creatinine and phosphate.

Anticoagulation

Heparin is the most common form of anticoagulant used, mainly because of its relative cost and short half-life. Heparin regimes are given either via intermittent or continuous infusion. Both require a loading dose, usually between 25–50 units/kg body weight, with further bolus doses given during the dialysis if on intermittent regimen, or continuously via syringe pump. The amount given depends upon the needs of the patient, and should be individually assessed using activated clotting times (ACT). Once a patient has been established on the appropriate regimen, it should be checked monthly, or if there is a change in the patient's condition.

Regular anticoagulation is given to patients on maintenance haemodialysis who have no or little risk of bleeding. Patients with acute kidney injury, or patients having dialysis for the first time, should be dialysed against a moderate or no-heparin regimen. Individuals at risk of bleeding (e.g. postoperative, post-transplant, bleeding, pericarditis) should be carefully dialysed with minimal or no-heparin if at all possible, to reduce the risk of bleeding complications.

In patients being dialysed via a fistula or graft the heparin infusion should be switched off **30** minutes before the end of the dialysis session to prevent the risk of bleeding from the access site post dialysis. Prolonged pressure on the fistula post dialysis, waiting for a clot to form after removal of the needles could damage the fistula. Patient dialysed via a subclavian or femoral line should not have the heparin discontinued until the end of dialysis.

Low-molecular weight heparin Low-molecular weight heparin (LMWH) is created by chemical degradation of crude heparin. It inhibits factors X and XII, but has little effect on thrombin and factors IX and XI. There are no direct bedside tests that can ascertain clotting times, so LMWH is given on a body weight basis. Because of the reduced systemic anticoagulant effect, LMWH is increasingly being used in patients with AKI and patients with an increased risk of bleeding. Bolus doses of LMWH can be as efficient in preventing clot formation within the filter as continuous infusion heparin (Bernieh *et al.* 2009).

Low-molecular weight heparin may cause less thrombus formation in the extracorporeal circuit than usual (unfractioned) heparin (UFH), and although can be more expensive than UFH for routine haemodialysis, prices have fallen. LMWHs are simple to administer, as a single bolus using a prefilled syringe, into the venous limb of the circuit and are often preferred (Davenport 2009).

Heparin-free dialysis Prostacyclin has been used as an anticoagulant in AKI for both intermittent dialysis and haemofiltration. Regional anticoagulation with citrate or the use of prostacyclins provide improved safety for patients because they do not increase the patient's risk of bleeding (Ronco *et al.* 2010). However, there is evidence that citrate based dialysate concentrates can assist in reducing the need for anticoagulants for patients at risk of bleeding (see section above).

Assessing effectiveness of anticoagulation

All patients should have regular assessment to determine their anticoagulation needs. Many of the assessments are quick and easy to conduct. Following the dialysis session, when the dialyser has been flushed there should be no clots visible, and the patient

should not be at risk of increased bleeding times. During dialysis, visual checks of the filter can indicate undercoagulation. If the colour of the blood within the filter becomes darker, or dark streaks appear then clotting of the filter has occurred. Changes in venous pressure and an increase in transmembrane pressure (TMP) could also indicate the presence of clots forming in the filter or bubble trap. Prolonged bleeding from the needling site post dialysis is an indication that the patient may have been over-heparinised during dialysis.

An objective form of assessment that can be conducted at the bedside is through activated clotting times (ACTs). In new patients a base line should be established before dialysis to compare results during the procedure and heparin given accordingly.

Activated clotting times are a simple, effective and timely method of assessing clotting times of haemodialysis patients. A sample is taken prior to any heparin being given to establish a base line. Depending upon the patient's condition, bleeding risk and anticoagulation requirements the clotting times vary. Patients with a clotting risk (for example, postsurgery) would require their clotting times to be maintained between 1.2–1.5 times their base line. Other low risk haemodialysis patients would be maintained 1.5–2.0 times their base line.

Prescribing the Dialysis Dose

For many years patients were given dialysis treatments based entirely on the subjective evaluation of blood biochemistry along with a general assessment of perceived patient wellbeing. Patients themselves have been held responsible for the success of their treatment in relation to these parameters by being instructed to adhere to restricted diets aimed at maintaining biochemistry within acceptable limits. Limited resources and lack of understanding have compounded this philosophy over time.

More recently there have been attempts to provide a more objective and scientific method of assessing dialysis adequacy. The aim of nursing care, utilising the dose of dialysis and nutritional parameters, should be to measure dialysis adequacy as well as encouraging patients to eat well.

Urea kinetic modelling

Many years ago the direct relationship between dialysis dose and long-term patient survival was demonstrated (Lowrie 1981). Today, the positive correlation between good dialysis adequacy and dialysis outcome still exists (Charra 2000). It is therefore essential that dialysis prescription be aimed at preventing or reducing the mortality and morbidity of patients receiving haemodialysis. High levels of urea clearance are correlated with improved patient outcomes. Recent data suggest that women and patients of low body weight may have improved survival rates if the URR is maintained above 70% or e*Kt/V* is at least 1.3 (Mactier *et al*. 2011). There is also some evidence to suggest that mortality rates can be reduced with a target *Kt/V* of 1.6.

One method of determining the dose is by the use of *Kt/V*. *Kt/V* is estimated by measuring pre- and post-dialysis urea concentrations. *K* equals the dialyser clearance of urea, *t* equals the treatment time and *V* equals the amount of urea distributed in the body water.

To complete the equation it is necessary to know the clearance of urea through the dialyser. This is estimated by the pre- and postdialysis urea ratio. To ensure an accurate assessment of *V* the nutritional status of the patient must be optimised, ensuring that the patient has an adequate protein intake. The patient's weight, height and gender are

included in the calculation to estimate the percentage of body weight that is water (usually 55% in women and 65% in men).

For accurate assessment of *K* it is essential to calculate the pre- and post-dialysis urea ratio. The dialyser data sheet may be cautiously used to estimate the dialyser clearance but it is wise to assume a 10–20% reduction on the manufacturers' in vitro values. An approximate example is given but more precise information is essential (i.e. the patient's height, and so forth) for accurate calculation. For example:

A woman weighs 60 kg, therefore, an approximate estimation of $V = 33$l

$K = 150$ ml/min, $t = 4$ h (240 min), $K \times t = 36$ l ($150 \times 240 = 36\,000$ ml), divided by $V = 36/33 = 1.09$.

Therefore $Kt/V = 1.09$

Another, and possibly simpler, method of assessing dialysis adequacy is through calculating the urea reduction ratio (URR). This is expressed as a percentage reduction:

$$\text{URR} = 100 \times (1—Ct/Co)$$

where Ct = post dialysis urea and Co = predialysis urea.

These parameters can now provide an acceptable standard for dialysis dose. The Renal Association (Mactier *et al*. 2011) recommends the following: a URR of 65% or a *Kt/V* should be greater than 1.2 in patients dialysing three times per week. However, it should be noted that these recommendations are individual targets that each patient should reach or exceed, and if a patient is found to be receiving less than this amount, steps should be taken to increase the blood flow, the dialyser size or the duration of dialysis.

Guidelines from the Renal Association (Mactier *et al*. 2011) recommend that haemodialysis adequacy should be assessed monthly. In order to achieve these targets in individual patients, clinicians should aim for a KtV >1.3.

The mathematical concepts of urea kinetic modelling (UKM) can be complicated but there are many computer software packages available to complete the calculations and to advise on corrective measures to achieve the desired *Kt/V*. However, it is important to be aware that there is no internationally agreed method for measuring *Kt/V* in everyday practice (Mactier *et al*. 2011). Some of these computer packages also measure protein catabolic rate (PCR), and this has been shown to be an increasingly important variable in patient morbidity and mortality, as it estimates daily protein intake (see Chapter 13).

What is vital is a clear understanding of the need for highly accurate sampling of pre- and postdialysis blood specimens and the comprehensive dietary support of the patient. Postdialysis blood samples should be collected either by the slow-flow method, the simplified stop-flow method, or the stop-dialysate-flow method (Mactier *et al*. 2011). Whichever process is used, it is important that consistency applied throughout the unit and across all samples collected.

Another significant role of the nurse is to ensure the delivery of the prescribed dialysis and to understand the effect of deviations in treatment on the dialysis dose and the subsequent effect this may have on the patient's wellbeing:

- *Prescribed dialysis dose versus delivered dialysis dose:* the dialysis prescription may be affected by a number of events that will effectively reduce the dialysis dose.
- *Errors of time (t):* the patient starts dialysis late; the machine is in bypass due to concentrate running out; there is another machine fault or isolated ultrafiltration; the patient comes off dialysis early.

- *Errors of clearance (K):* reduction in blood flow; incorrect dialyser used; recirculation.
- *Errors of volume (V):* residual renal function increases or decreases; excessive or inadequate protein intake; incorrect sampling.

High-flux/high-efficiency dialysis by *Kt/V* measurement and high-flux membrane dialysis treatment time can be shortened using rapid blood and dialysate flow rates. However, this is not recommended as most international standards recommend a minimum of 12 hours dialysis a week (Mactier *et al*. 2011). The benefits for the patient of less time on dialysis may be outweighed by the potential complications such as increased hypotensive episodes because of increased UF rates and the reduced time available to remove fluid during treatment. The use of short high-efficiency treatments is controversial—the long-term survival of patients has been correlated with longer treatment times. Longer treatment times have been shown to improve clearance of phosphate and β_2 microglobulin, which have an impact on patient morbidity and mortality (Cheung *et al*. 2011; Eloot *et al*. 2008).

Preparation for Haemodialysis

The period of time from diagnosis to commencement of RRT may be sudden, but often there is a period of time from a few months to several years when patients will have time to adjust their lifestyle and prepare for whichever form of dialysis is appropriate. The need for predialysis care, including psychological support as well as clinical monitoring of the progression of the renal disease, cannot be overemphasised.

For those requiring long-term haemodialysis there are a number of options to be considered in relation to the location of the haemodialysis treatment.

In-centre haemodialysis

Regional dialysis centres may provide both an acute and chronic haemodialysis service. In-centre haemodialysis may be offered, but the service may be overstretched in terms of available dialysis space. For this reason the options of home haemodialysis or satellite haemodialysis should be explored for those who choose haemodialysis.

Home haemodialysis

The patient who expresses a desire to take the home haemodialysis treatment option should receive support and encouragement from the multidisciplinary team. The patient, once established and familiar with the dialysis regime, may want to learn the technique quickly in order to be self-supporting at home at the earliest possible time. With support and cooperation a training programme can be completed in 6 weeks if the patient is well and has no other complications such as poor access, but most training programmes aim to get the patient home within 12 weeks.

To optimise training and learning opportunities the patient can be encouraged to come to the unit on nondialysis days to practise lining and priming the machine. Partners should be encouraged to attend as often as they can, but will need to negotiate a minimum amount of time with the nurse to learn emergency procedures. It should be emphasised to the patient and partner that the overall management of the treatment (setting up, monitoring and discontinuing the treatment) is primarily the responsibility of the patient. The partner is there to provide support and help, not to accept complete responsibility for the procedure.

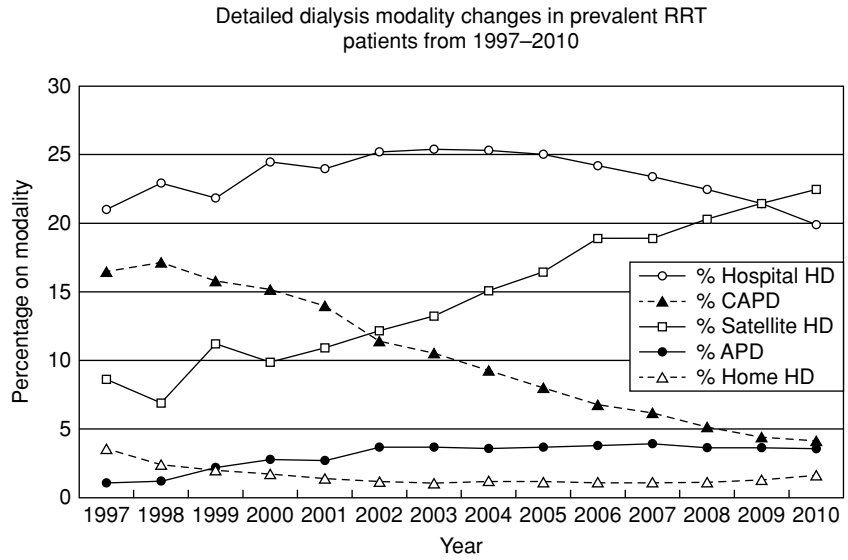


Figure 8.10 Changes in dialysis modality in the UK 1997–2010.

Source: The data reported here have been supplied by the UK Renal Registry of the Renal Association. The interpretation and reporting of these data are the responsibility of the authors and in no way should be seen as an official policy or interpretation of the UK Renal Registry or the Renal Association.

Home haemodialysis was declining in popularity in the UK in the 1990s (Ansell and Feest 2000), however with the proposed increase in provision of haemodialysis in the 2000s (Mowatt *et al.* 2002; Department of Health 2004) it was recognised that there was a role for home haemodialysis in delivery of quality treatment to patients. However, despite the promotion of home haemodialysis, the percentage of patients treated at home is only 1.5% 10 years later (MacPhee *et al.* 2012). Figure 8.10 shows that the percentage of patients on home haemodialysis has not increased by any significant amount over 10 years.

Satellite haemodialysis

The availability of satellite dialysis is increasing within the United Kingdom. Satellite centres provide an ideal setting for patients on maintenance haemodialysis. The centres are community based, closer to the patients' homes, making them more convenient and accessible. Satellite centres are often nurse managed and led. A nephrologist often oversees patient dialysis prescription and consultation, but day-to-day dialysis management is usually the responsibility of the nurse.

Assessment of the Patient

Before dialysis, the nurse must carry out a comprehensive predialysis assessment (see Figure 8.11).

General discussion

This includes discussing any concerns the patient may have in general, such as sleep, tablets or family issues, or concerns about the last dialysis session. There should be a

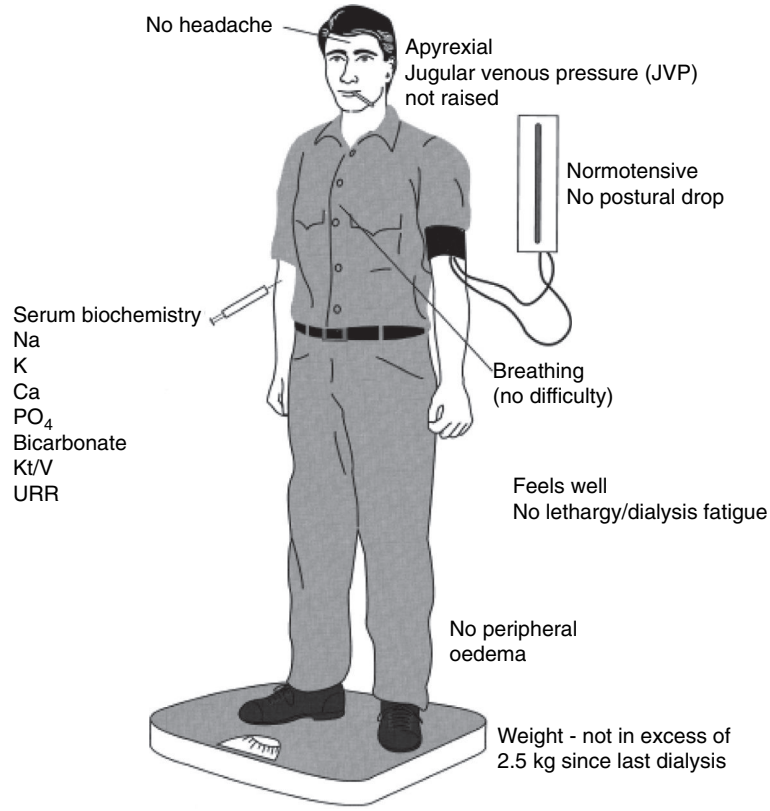


Figure 8.11 Predialysis assessment and postdialysis evaluation.

discussion about self-management of both dialysis and nondialysis-related activities, such as diet. The nurse should also read the notes of the previous dialysis session and ask the patient about any intradialytic problems. Measurement of blood pressure, fluid allowance and clinical assessment all contribute to the correct dry-weight assessment.

Weight

Regular assessment of dry weight is essential to enable the nurse and patient to determine the amount of fluid removal required during dialysis. The term 'dry weight' refers to the weight at which there is no clinical evidence of oedema, shortness of breath, increased jugular venous pressure or hypotension or hypertension. The term 'target weight' or 'ideal weight' is sometimes used instead of 'dry weight', but as there are subtle differences in definition it is important to check local policy and practice.

The initial determination of dry weight should involve the expertise of the nurse, doctor and dietician. However, on a day-to-day basis this remains the responsibility of the nurse and many nurses are now trained in the routine clinical skills of fluid assessment.

The aim of dialysis is to remove the excess volume of fluid to ensure that the patient comes off dialysis at the dry weight. To calculate this, the following formula is used:

Actual weight 68.5 kg

Target weight 66 kg

Weight gain 2.5 kg

Add any additional fluid intake during treatment

Washback of saline (300 ml)

Two drinks (300 ml)

Total fluid to be removed 2.5 + 0.3 + 0.3 = 3.1 L

Blood volume monitoring (BVM) is a relatively new addition to the armoury in assessing dry weight. The system relies on measuring a relative reduction in blood volume while continuously monitoring the patients' haematocrit during treatment. The aim is to reduce the blood volume by 10–15% through the treatment. A higher reduction of >15% that is also associated with hypotension and/or cramps indicates that the patient has been dialysed to below their dry weight. A lower blood volume reduction of <10% indicates that fluid is still retained and the dry weight may need to be reduced. Blood volume monitoring should still be used in conjunction with the global subjective assessment of dry weight. The merits and limitations of continuous blood volume monitoring during haemodialysis have been discussed (Lindley *et al.* 2006).

The use of bioimpedance to assess the patient's fluid status has grown since the early 2000s. Studies have shown that patients may have a normal or low arterial pressure, but were found to be over hydrated on assessment via bioimpedance (Chazot *et al.* 2012).

Blood pressure

Systolic hypertension with or without diastolic hypertension is a major problem for patients on haemodialysis (HD), and is associated with increased mortality (Agarwal 2012). Recommended predialysis blood pressures should be <140/90 mmHg, and <130/80 mmHg post-dialysis (Holt and Goldsmith 2011).

Blood pressure should be recorded predialysis to provide a baseline from which to measure any significant changes during treatment. If a patient is fluid overloaded prior to dialysis, blood pressure may be raised due to an increased circulating volume or lowered as in heart failure. A number of authors suggest that treatment of hypertension should first consider fluid and sodium control prior to the introduction of hypertensive medication. Correct assessment of dry weight often leads to a reduction in reliance on antihypertensive medication in a number of patients.

Patients taking antihypertensive medication who become hypotensive on dialysis may be find it necessary to omit the dose before or nearest to the next dialysis session, allowing greater cardiovascular compensatory systems to act during fluid removal on dialysis.

Postdialysis clinical observations of blood pressure and weight are completed to check that the patient has lost the desired weight and does not have hypo-/hypertension. It is important that patients are advised to wait until blood pressure is normalised, particularly if they are travelling home alone.

Temperature and pulse

The patient's temperature should be routinely recorded pre- and post-dialysis for patients with central lines, and if clinically required for fistulae and grafts. Pyrexia prior to dialysis should be investigated immediately. Pulse should be recorded on all patients.

Serum biochemistry and haematology

Blood tests are routinely carried out monthly but more frequent tests may be ordered as necessary. Target predialysis values recommended by the various national and international guidelines are shown in Table 8.3.

Table 8.3 A summary of target predialysis values recommended in national and international guidelines

	UK Renal Association	EBPG	KDIGO	KDOQI
Frequency of dialysis	x3/week[a]	x3/week[e]	x3/week	x3/week[h]
e*Kt/V*: >1.2	>1.2[a]	>1.2[e]	>1.2	>1.2[h]
URR: >65%	>65%[a]	>65%[e]		>65%[h]
Potassium	4–6 mmol/l[a]	NA	NA	NA
Calcium	2.2–2.5 mmol/l[b]		2.2–2.5 mmol/l[l]	2.1–2.37 mmol/l[k]
Phosphate	1.1–1.7 mmol/l[b]		1.1–1.7 mmol/l[l]	1.13–1.78 mmol/l[k]
Albumin	NA	40 g/l[g]	NA	40 g/l[j]
Haemoglobin	10–12 g/dl[d]	11–12 g/dl[g]	10–11.5 g/dl[m]	11–12[i]
Ferritin	200–500 ng/ml[d]	100–500 ng/ml[g]	≤500 ng/ml/l[m]	>200 ng/ml[i]
TSAT	>20%[d]	>20%[g]	<30%[m]	>20%[i]
Protein intake	1.2 g/kg IBW/day[c]	>1.1 g/kg IBW/day[f]	NA	1.2 g/kg IBW/day[j]
Calorie intake	30–35 kcal/kg IBW/day[c]	30–40 kcal/kg IBW/day[f]	NA	30–35 kcal/kg IBW/day[j]

Notes: [a] Mactier *et al.* (2011); [b] Steddon and Sharple (2011); [c] Wright and Jones (2011); [d] Mikhail *et al.* (2011; [e] Tattersall *et al.* (2007); [f] Fouque *et al.* (2007); [g] Locatelli *et al.* (2009a) ; [h] KDOQI (2006); [i] KDOQI (2007); [j] KDOQI (2000); [k] KDOQI (2003); [l] KDIGO (2009); [m] KDIGO (2012).

Infection control

The Rosenheim Report (Rosenheim 1972) set standards for infection control in relation to hepatitis B in renal units. Now patients and staff in renal units must acknowledge daily the risks associated, not just with hepatitis B, but with other blood-borne viruses (BBV) such as hepatitis C and human immunodeficiency virus (HIV). Recent guidelines (Geddes *et al*. 2009; Department of Health 2010) address the prevention of cross infection within the renal unit, detailing details on disinfection of equipment, routine protective testing of patients and staff, and immunisation protocols.

The guidelines suggest that carriers of hepatitis B should be dialysed separately on dedicated machinery, and carriers of hepatitis C should be dialysed in separate or single shifts, on dedicated machines but not necessarily isolated in separate rooms.

The practicalities of providing isolation for every patient with BBV will need to be explored along with the desired philosophy of care towards patients with BBV. Whilst the screening of patients for hepatitis is, on the whole, accepted, the screening of patients for HIV is controversial and nurses must ensure that they advocate for patients and are satisfied that the rationale for testing is in the patient's interests and is only carried out with informed consent.

Facilities and policies for the containment of meticillin-resistant *Staphylococcus aureus* (MRSA) in renal units must be available and should be drawn up with the local infection control team. The Renal Association Guidelines in 2009 recommended that patients colonised with MRSA must be isolated from other patients, however there is

currently variation in practice between hospitals. Universal precautions should be used as standard practice in the haemodialysis unit for the protection of the patients and the staff. Universal precautions require that body fluids of all patients are treated as potentially infectious and therefore protocols for handwashing, protective clothing, eyewear and disinfection of machinery should be strictly adhered to prior to nursing interventions with all patients. When universal precautions are used effectively the isolation of patients should be unnecessary unless it is to protect the immuno-compromised patient from opportunistic infections.

Haemodialysis Complications

Continuous and progressive development of equipment and expertise has ensured that haemodialysis is a safe procedure and, if prescribed and monitored correctly, serious complications should be rare. The treatment should only be carried out under the supervision of an expert practitioner. The aim of nursing care should be to prevent the occurrence of complications through comprehensive assessment and planning.

Intradialytic hypotension (IDH)

Hypotension is a very common complication associated with haemodialysis, estimated to occur in around 15–25% of dialysis treatment (Crews and Powe 2010), and is probably a reflection of the large amounts of fluid that is removed during the procedure as the patients near their target weight. It has been suggested that there is a relationship between IDH and two-year mortality (Palmer and Henrich 2008).

Symptomatic hypotension associated with relative hypovolaemia usually occurs towards the end of the dialysis session. Maintaining blood pressure is dependent upon the replacement of the fluid removed from the blood volume by fluid from the surrounding tissues. If fluid removal exceeds this inter-compartmental shift then the venous return will be reduced, resulting in a decreased cardiac output and hypotension.

Hypotension should be avoided wherever possible during dialysis through regular dry weight assessment, regular BP monitoring during dialysis and proactive actions when the patient's blood pressure trends downwards during treatment. Repeated hypotensive episodes during dialysis expose the patient to ischaemic cardiac tissue damage (Burton *et al*. 2009). Intradialytic hypotension is also an independent and negative predictor of long-term fistula survival (McCann *et al*. 2008).

To prevent hypotension, fluid removal should be controlled throughout the session. To achieve this, ultrafiltration (UF) control should be used. Without this, fluctuation in fluid removal can occur due to changes in pressure across the dialyser membrane. If a large amount of fluid needs to be removed, due to an excessive intradialytic weight gain or a previously short dialysis, then consideration should be made to prolonging the treatment time to remove the fluid without resorting to an aggressive ultrafiltration rate. Large amounts of fluid can be removed by stopping dialysis and putting the machine into sequential ultrafiltration mode. Because relatively few electrolytes are removed in UF, the patient is able to tolerate greater fluid removal. It is advisable to dialyse the patient for a short time (1 h) to remove potassium, before placing the machine into UF. This prevents haemo-concentration of potassium as fluid is removed, reducing the risk of cardiac arrhythmias. Once enough fluid has been removed, the session can then be returned to dialysis with a reduced TMP (see principles of haemodialysis above).

If the patient is dialysed below their dry weight, hypotension can result. The symptoms persist after dialysis and are associated with cramps and a 'washed out feeling'. Dry weights should be reviewed on a regular basis, using global subjective assessment in conjunction with blood volume monitoring, especially if symptoms persist after dialysis.

Reducing the temperature of the dialysate has been found to reduce the incidence of dialysis-related hypotension. Many dialysis patients have a subnormal temperature (Fine and Penner 1996) and with the standard dialysate temperature at approximately 36.8–37°C, the result is a warming effect on the patient causing peripheral vasodilation. Reducing the dialysate temperature to 36–36.5°C or lower, reduces this effect. Lower temperature dialysis has been related to a significant reduction in hypotensive episodes on dialysis (Hsu *et al.* 2011). Some dialysis machines incorporate a biofeedback system that reduces the dialysis temperature as the blood pressure falls, providing further patient protection.

Patients who cannot tolerate fluid removal, possibly due to cardiovascular stability, may benefit from sodium and ultrafiltration profiling (Cosar and Cinar 2009). Profiles that result in an overall neutral sodium balance at the end of dialysis have been associated with post dialysis weights close to dry weight targets (Song *et al.* 2004).

Dialysis related hypotension can also be induced by eating whilst on dialysis and has been associated with a decrease in the systemic vascular resistance (Shibagaki and Takaichi 1998). It may be appropriate to suggest to patients that they do not eat large amounts of food whilst dialysing, although there remains scepticism around the evidence base for this practice (Benner *et al.* 2012).

Nausea and vomiting

Nausea and vomiting occur in approximately 10% of dialyses. The causes are multifactorial. In the majority of cases they are probably due to hypotension but they may also be associated with disequilibrium and eating whilst on dialysis.

The prime point of caring for patients who may be suffering from nausea and vomiting during dialysis is to treat the cause. If the symptoms persist, then antiemetics may be necessary.

The most obvious preventative measure is to avoid hypotensive episodes. Reducing the blood flow rate at beginning of dialysis occasionally helps but may mean increasing overall time of dialysis to ensure an adequate dialysis.

Cramp

Patients on haemodialysis can be vulnerable to muscle cramps during and between treatments. Muscle cramps are defined as sudden onset of a prolonged involuntary muscle contraction that can be associated with severe pain (Kobrin and Berns 2007).

The pathogenesis behind the incidence of cramps associated with dialysis is generally unknown, but appears to be linked with a number of predisposing factors – hypotension, an incorrect dry weight, changes in plasma osmolality, hyponaturaemia, hypomagnesaemia, tissue hypoxia and large ultrafiltration volumes. Cramps usually occur late on in dialysis, when the net amount of fluid removed is at its greatest.

When cramp occurs on dialysis it can be a very painful and distressing condition for the patient and it is very important for the nurse to attend to it. Up to 75% of all patients have reported cramp at one time or another (Caplin *et al.* 2011). Patients are unable to move very much to alleviate the discomfort because they are still attached to the machine. A bolus infusion of normal saline or hypertonic saline may be beneficial, but care should be taken not to infuse too much fluid. Massaging the affected area helps to bring relief to the affected site, but also the physical contact can help to calm the patient.

Reducing the dialysate temperature has also been found to be beneficial in reducing the incidence of cramp during dialysis (Ayoub and Finlayson 2004; Selby and McIntyre 2006). If cramps persist, then altering the dialysate sodium to a higher concentration may prevent any further incidences. The use of variable-sodium dialysis has been found to reduce the problem of dialysis induced cramps.

The link between the removal of large fluid volumes and cramp suggests that prevention of fluid removal that is too rapid may result in a lower incidence of cramp. Educating the patient to prevent large interdialytic fluid gains should be a priority. Increasing the dialysate sodium concentration may be an option, however this may increase postdialysis thirst and consequent interdialytic weight gain. Administration of quinine sulphate administered prior to dialysis decreases the incidence of cramps on dialysis. The use of quinine sulphate has been found to be useful as a prophylactic measure. However, because cramp is a subjective symptom, the effectiveness of quinine may be open to question (Kobrin and Berns **2007**).

Disequilibrium

Dialysis relies upon the diffusion of solute across the semipermeable membrane of the dialyser. At the same time diffusion will be taking place across the semipermeable membranes between all body compartments from the intracellular, interstitial and intravascular compartments. The rate of diffusion should be equal to maintain equilibrium. If diffusion in the dialyser is highly efficient, the result will be disequilibrium in the body compartments. Rapid urea removal will result in the plasma in the intravascular compartment being hypotonic to the fluid in the cells. This will result in osmotic shifts of fluid from a region of low concentration to a region of high concentration. This is particularly significant in the cerebrospinal fluid and brain cells. Rapid changes in the pH of the cerebrospinal fluid may also predispose to disequilibrium (Bregman *et al*. 2006).

Symptoms of disequilibrium can be mild or severe. Mild symptoms may include headache, dizziness, nausea and vomiting, or disorientation. Severe symptoms include fits, coma and potentially death.

Patients who are acutely ill, have a very high urea predialysis or who are being dialysed for the first time, are considered most at risk of disequilibrium. For those considered at risk the nurse undertakes the following dialysis prescription to ensure that the blood urea level is only reduced by a maximum of 30%:

- Blood flow rates should not exceed 150–200 ml/min.
- Dialysers with low surface area should be used.
- Treatment time is limited to approximately 2 h.

This type of prescription may need to be performed daily until the patient is considered stable and risk of disequilibrium is reduced. If disequilibrium is suspected the dialysis should be discontinued: infusion of hypertonic solutions such as mannitol may help to correct the fluid shifts. However, the emphasis should remain on prevention of disequilibrium through careful predialysis assessment and altering the treatment prescription as required (Lopez-Almaraz and Correa-Rotter 2008).

Electrolyte imbalance

Haemodialysis is a relatively aggressive treatment. Plasma electrolyte balances are subject to large alterations during dialysis and these changes now occur over shorter periods of time with the trend towards shorter dialysis times. Because of these factors, selection of the appropriate dialysate concentrate takes on greater importance.

Inappropriate selection can at lead to mild but distressing complications through to potentially life threatening situations at worst.

Hyponatraemia

This is associated with using a dialysate containing a hypotonic concentration of sodium. Because of the osmotic imbalance between plasma and dialysate, sodium is removed from the plasma during dialysis, leading to hypotension, nausea, vomiting cramps, headaches and in extreme cases symptoms associated with disequilibrium syndrome. If a patients complains of any of these symptoms the dialysate and conductivity should be checked, and dialysis reinitiated with an appropriate concentrate solution.

Hypernatraemia

This results from using a hypertonic sodium concentrate, purposely or accidentally, or incorrectly programming the dialysis machine during sodium profiling. Patients complain of headache, nausea and thirst. Dialysis should be discontinued and recommenced using the correct dialysate.

Hypercalcaemia

This complication is usually associated with water treatment system failure, and primarily occurs in 'hard water areas' (hence the term 'hard water syndrome'). This emphasises the need for regular checks of the water quality, although it can also occur if a patient with hypocalcaemia is dialysed against a high calcium dialysate. Symptoms include nausea and vomiting, agitation, muscle twitching and hypertension, which appear about an hour after starting dialysis. Again dialysis should be stopped and recommenced with the correct dialysate or when the water softener is repaired. Because of the risk in hard water areas, the water should be checked daily before dialysis is started for the day.

Hypokalaemia

Hypokalaemia in patients undergoing maintenance haemodialysis is often associated with gastrointestinal loss through vomiting or diarrhoea. The use of a concentrate with no potassium can also be the cause. Care should be taken to avoid hypokalaemia because of the risk of cardiac arrhythmias, especially in a patient on digoxin (Rachoin and Weisberg 2008). Dialysis against a dialysate concentrate with a higher potassium concentrate should be considered, though this is not advisable for the whole dialysis, altering to a lower concentration towards the end of the treatment.

Potassium levels at the end of dialysis should be considered with care; there is a considerable potassium rebound 1–2 h after dialysis.

Hyperkalaemia

Hyperkalaemia is usually associated with nonadherence to dietary advice. Although it is not associated with the dialysis treatment, it does affect the decisions regarding time of dialysis, concentrate and filter to be used. Haemolysis during dialysis may the most likely cause of acute hyperkalaemia, initiated by transfusion incompatibility, over heated dialysate or chloramine breakthrough (Rachoin and Weisberg 2008).

Dialyser reactions (membrane reaction/first-use syndrome)

Allergic responses may occur as the patient's blood is exposed to foreign materials. Some examples include the dialyser membrane, the chemical sterilising agents such as ETO, and bacteria or endotoxin (Uhlenbusch-Kower *et al*. 2004). However, the incidence of

dialyser reactions has dropped considerably in recent years with the increase in steam and gamma irradiation being used to sterilise dialysis products. There are very few if any ETO sterilised dialysers now used in Europe, and the Renal Association does not recommend their use (Mactier *et al*. 2011).

Allergic reactions can be type A or type B. Type A is a severe anaphylactic reaction usually occurring within the first 5 min of dialysis. Symptoms can begin with an itchy rash and become severe, including dyspnoea and a burning sensation throughout the body. There may be laryngeal oedema and possibly cardiac arrest.

Treatment necessitates the immediate discontinuation of dialysis; the blood should not be returned to the patient. Maintenance of the airway is paramount and the administration of oxygen is required. The administration of adrenaline (epinephrine), chlorpheniramine and hydrocortisone may be necessary. Patients who have suffered this type of reaction should be dialysed against membranes that have been gamma irradiated or steam-sterilised. Extra rinsing of the dialysis circuit may also be advised.

Type B reactions are less severe and include chest pain. They may occur up to 1 h after dialysis is commenced. The cause is unknown but it is suggested that the use of synthetic membranes can be beneficial (Uhlenbusch-Kower *et al*. 2004).

Haemolysis

Haemolysis is the damage or rupture of red blood cells. As most of the body's potassium is contained within the cells, massive haemolysis can quickly lead to hyperkalaemia and cardiac arrest. Haemolysis may be caused by dialysing against dialysate that is too hot or dialysing against water or hypotonic dialysate.

Modern blood pumps have low shearing stresses and should not cause haemolysis but, if wrongly adjusted, the rollers of the blood pump may cause damage to cells. The high venous pressure resulting from occluded or obstructed (kinked) venous access or blood lines may also damage red blood cells. The patient will complain of chest pain and dyspnoea and may be in a state of collapse. If haemolysis is suspected the dialysis should immediately be discontinued and the blood should not be returned to the patient. Another machine should be prepared as a standby, as emergency dialysis may be needed to treat hyperkalaemia.

Air embolism

Modern monitoring equipment with integral ultrasonic air detectors provides some assurance to patients and nurses for the prevention of air embolism. But the equipment is only as good as its user and strict adherence to alarm and safety checks, prior to initiating each treatment, is essential.

Extreme care should be taken during the priming procedure and when connecting the patient to the extracorporeal circuit. The air detector should be activated during the priming procedure and any problems with false alarms resolved prior to the patient commencing dialysis. An air detector that persistently or intermittently alarms with no obvious cause should not be accepted as troublesome or oversensitive. The machine should not be used, and should be sent to the technicians for service.

In the event of a patient receiving an air embolus the nurse must stop dialysis and lay the patient on the left side with the head lower than the rest of the body. This will force air in the circulation into the ventricle to act as a bubble trap. Immediate medical assistance must be sought and emergency resuscitative measures commenced. Outcome may be related to the volume of air infused.

Clotting of the blood lines and dialyser

Clotting of the circuit will occur if anticoagulation is inadequate, if blood flow is inadequate or not continuous and if there is air in the circuit. A change in the pressure of the circuit will occur as a result of clotting. If the dialyser has clotted there will be a decrease in the venous pressure and possibly a rise in the arterial pressure. Clotting of the venous chamber will result in a raised venous pressure. If clotting occurs the treatment should be discontinued without returning the blood to the patient. The cause should be investigated, i.e. anticoagulation regime, access or dialyser preparation. Table 8.4 summarises the complications of haemodialysis.

Table 8.4 Complications of haemodialysis (summary).

Complication	Cause	Prevention	Treatment
Hypotension	Dry weight too low Excess UFR Antihypertensive drugs Eating on dialysis	Accurate and regular assessment of dry weight Correct UF calculation Suggest taking antihypertensive post dialysis No eating on dialysis	Lay patient flat Reduce UF rate 0.9% NaCl bolus 100 ml if no response to the above Recalculate UF rate
Cramp	Excessive UFR	Correct UF calculations Re-educate patient regarding fluid gains Quinine sulphate prior to dialysis	0.9% NaCl or hypertonic solution Heat pad/massage
Disequilibrium	Too efficient dialysis	Small surface area dialyser Reduce blood flow <150 ml/min Reduce time 2 h Consider daily dialysis until biochemistry satisfactory	Discontinue dialysis
Arrhythmias	Underlying hypertension Coronary artery disease Excess potassium shifts Digoxin	Identify cause Consider dialysis against dialysate of 3 mmol/l potassium or greater	Monitor
Membrane reaction	Complement activation on exposure to membrane and/ or ETO	Use gamma irradiated membranes Correct rinsing of disposables during preparation	Stop dialysis Do not return blood to patient Treat as anaphylaxis Adrenaline/ hydrocortisone/
Air embolus	Air entry into the patients circulation via dialysis circuit	Ensure all lines are secure Ensure correct and safe use of air detector Regular observation of circuit	Stop treatment Lay patient on left side and raise end of bed Give 100% oxygen
Haemolysis	Damage to red blood cells through pump or kinked lines Dialysate temperature too high	Low shearing pumps Ensure venous pressure is not high Check dialysate temperature during dialysis	Give oxygen Test for hyperkalaemia from damaged red cells Dialysis
Clotting of blood lines	Inadequate anticoagulation Incorrect priming procedure	Review anticoagulation regime Review priming procedure	Stop treatment Discard circuit and line to continue dialysis Review anticoagulation needs
Blood leak	A tear or rupture in the dialyser membrane	Careful handling of the dialyser Keep pressures within safe limits	Stop dialysis Discard circuit, do not return blood to the patient

Special Care on Haemodialysis

Diabetes mellitus

Diabetes is the leading cause of established renal failure in the Western world, and approximately 20–30% of those with type 1 or type 2 diabetes will develop overt kidney damage (Atkins 2005). The prevention of established renal failure in those with diabetes has been discussed in Chapter 6; many renal programmes in the United Kingdom have up to 25% of their dialysis population with diabetes as their underlying renal disease (Gilga *et al.* 2011).

The following points should be considered when caring for those with diabetes on dialysis:

- Care of those with diabetes and renal disease should be through joint renal–diabetes management, for example joint clinics.
- Those with diabetes should continue to attend specialist diabetes centres or specialist practice nurse clinics for annual review, to monitor complications of retinopathy, neuropathy and cardiac disease.
- Glucose monitoring should be individualised according to patient requirements – tight glycaemic control is preferable to avoid further complications of diabetes. Insulin requirements may either be reduced (dialysis reverses insulin resistance) or increased (dialysis may reverse anorexia and may increase dietary intake). Dialysate should contain glucose to avoid hypoglycaemia.
- Glycated haemoglobin (HbA1c) should be between 6.5% (48 mmol/mol) and 7.5% (58 mmol/mol).
- Tight blood pressure control is recommended (<130/80 mmHg), although it is recognised that hypotension on dialysis may be common. Sodium profiling may be helpful.
- Treatment guidelines for antidiabetic therapy rarely consider safe and efficacious management of patients with CKD, so drug therapy has to be considered carefully (Hamilton 2012).
- Good nutrition is important as patients may suffer gastroparesis and subsequent nausea and vomiting.
- Dialysis nurses should carry out foot examination at least once per month as foot lesions are the most commonly mismanaged problem (Meaney 2012). Patient teaching on foot care is vital.

The *Journal of Renal Care* published a special supplement on diabetes care in renal disease (2012) and it is recommended for further reading http://onlinelibrary.wiley.com/doi/10.1111/jorc.2012.38.issue-s1/issuetoc (accessed 20 May 2013).

Summary

Those requiring haemodialysis should have a named nurse who is responsible for the planning, delivery and evaluation of the highest standards of individual care. Patients should have the opportunity to participate in decision making related to all aspects of their care and have a right to be cared for by nurses who are competent in all aspects of haemodialysis treatments. Ideally this competence should be assessed in a formal and structured training programme. Finally, the skills needed to provide comprehensive nursing care to patients on haemodialysis cannot be measured solely by a nurse's competence to set up and use a haemodialysis machine or by the ability to insert a pair of fistula needles first time. The haemodialysis nurse is constantly demanding access to the

skills and knowledge which tacitly underlie the rapidly expanding scope of professional practice. There is a professional expectation of all nurses to ensure continuous learning and development in order to keep abreast of new research findings, new technology and the ever increasing needs and demands of the patient.

The nurse working within the haemodialysis unit is faced on a day-to-day basis with a practical changes. On the one hand, the working environment is highly technical and the delivery of optimal treatment is a cognitive challenge. On the other hand, the nursing focus must acknowledge the very special affective skills required in providing support, counselling and rehabilitative interventions to patients with chronic ill health. Although units will function with nurses whose strength or preference lies in one or other domain, it is the careful combination of the skills, knowledge and attitudes of both aspects that results in the advanced and expert practice of the nurse on the haemodialysis unit.

References

Agarwal, R. (2012) The Controversies of Diagnosing and Treating Hypertension among Hemodialysis Patients. In *Seminars in Dialysis*, **25** (4), 370–376.

Almehmi, A. and Wang, S. (2012) Partial aneurysmectomy is effective in managing aneurysm-associated complications of arteriovenous fistulae for hemodialysis: case series and literature review. *Seminars in Dialysis* **25** (3), 357–364.

Ansell, D. and Feest, T. (2000) *Third Annual Report of the UK Renal Registry,* UK Renal Registry, Bristol.

Association for the Advancement for Medical Instrumentation (2004) *Dialysate for hemodialysis* (ANSI/AAMI RD52:2004), Association for the Advancement for Medical Instrumentation, Arlington, VA.

Atkins, R.C. (2005) The epidemiology of chronic kidney disease. *Kidney International – Supplement,* **94,** S14-8.

Ayoub, A. and Finlayson, M. (2004) Effect of cool temperature dialysate on the quality and patients' perception of haemodialysis. *Nephrology Dialysis Transplantation* **19** (1), 190–194.

Benner, D., Davis, M., Stasios, M. and Burgess, M. (2012) Practices and opinions on in-center food consumption across 1223 facilities in the United States. *Kidney Research and Clinical Practice* **31** (2), A60.

Bernieh, B., Boobes, Y., Al Hakim, M.R. *et al.* (2009) Long-term use of low-molecular-weight heparin in hemodialysis patients: a 7-year experience. *Blood Purification* **27,** 242–245.

Betjes, M.G. and van Agteren, M. (2004) Prevention of dialysis catheter-related sepsis with a citrate-taurolidine-containing lock solution. *Nephrology Dialysis Transplantation* **19** (6), 1546–1551.

Bhimani, J.P., Ouseph, R. and Ward, R.A. (2008) Reducing dialysate boundary layer resistance by increasing dialysate flow rate increases diffusive mass transfer of phosphorus but not urea nor beta2microglobulin in dialyzers with fiber undulation. *Journal of the American Society of Nephrology* **19,** 460A.

Birchenough, E., Moore, C., Stevens, K. and Stewart, S. (2010) Buttonhole cannulation in adult patients on hemodialysis: an increased risk of infection? *Nephrology Nursing Journal* **37** (5), 491–498, 555.

Blankestijn, P.J., Ledebo, I. and Canaud, B. (2010) Hemodiafiltration: clinical evidence and remaining questions. *Kidney International* **77** (7), 581–587.

Bregman, H. Daugirdas, J.T. and Ing, T.S. (2006) Complications during haemodialysis., in *Handboook of Dialysis* (2nd edn), J. T. Daugirdas and T. S. Ing (eds), Little Brown, New York, pp. 149–168.

Brouwer, J. (2005) Needle placement is paramount to achieving effective dialysis and preserving vascular access. *Nursing Journal* **32** (2), 224.

Burton, J.O., Jeffries, H.J., Selby, N.M. *et al.* (2009) Haemodialysis-induced repetitive myocardial injury results in global and segmental reduction in systolic cardiac function. *Clinical Journal of the American Society of Nephrology* **4,** 1925–1931.

Canaud, B., Bragg-Gresham, J.L., Marshall, M.R. *et al.* (2006) Mortality risk for patients receiving hemodiafiltration versus hemodialysis: European results from the DOPPS. *Kidney International* **69,** 2087–2093.

Caplin, B., Kumar, S. and Davenport, A. (2011) Patients' perspective of haemodialysis-associated symptoms. *Nephrology Dialysis Transplantation* **26** (8), 2656–2663.

Castledine, C., Casula, A. and Fogarty, D. (2011) UK RRT Prevalence in 2010: national and centre-specific analyses. *UK Renal Registry,* www.renalreg.com/Report-Area/Report%202011/Chap02_Renal11_web.pdf (accessed 20 May 2013).

Chang, T.I., Paik, J., Greene, T. *et al.* (2011) Intradialytic hypotension and vascular access thrombosis. *Journal of the American Society of Nephrology* **22** (8), 1526–1533.

Charra, B. (2000) Improving adequacy improves haemodialysis outcome. *EDTNA/ERCA Journal* **26** (1), 6–10, 19.

Chazot, C., Wabel, P., Chamney, P. *et al.* (2012) Importance of normohydration for the long-term survival of haemodialysis patients. *Nephrology Dialysis Transplantation* **27,** 2404–2411.

Cheng, Y., Yu, A.W., Tsang, K., *et al.* (2011) Anticoagulation during haemodialysis using a citrate-enriched dialysate: a feasibility study. *Nephrology Dialysis Transplantation* **26** (2), 641–646.

Cheung, A.K., Rocc, M.V., Ya, G. *et al.* (2011) Serum beta-2-microglobulin levels predict mortality in dialysis patients: results of the HEMO study. *Journal of the American Society of Nephrology* 17, 546–555.

Coentrao, L., Martins, P., Leblanc, A. *et al.* (2010) Treatment of severe dialysis reactions with the AN69-ST membrane: biocompatibility does matter. *NDT Plus* **3,** 298–299.

Copley, J.B. and Lindberg, J.S. (2001) Nontransplant therapy for dialysis-related amyloidosis *Seminars in Dialysis* **14** (2), 94–98.

Cosar, A.A. and Cinar, S. (2009) Effect of dialysate sodium profiling and gradient ultrafiltration on hypotension. *Dialysis and Transplantation* **38** (5), 175–179.

Crews, D.C. and Powe, N.R. (2010) Blood pressure and mortality among ESRD patients: all patients are not created equal. *Journal of the American Society of Nephrology* **21**(11), 1816–1818.

Davenport, A. (2009) Review article: Low molecular weight heparin as an alternative anticoagulant to unfractionated heparin for routine outpatient haemodialysis treatments. *Nephrology* **14** (5), 455–461.

Davenport, A., Will, E. J. and Davison, A.M. (1994) Comparison of the use of standard heparin and prostacyclin anticoagulation in spontaneous and pump-driven extracorporeal circuits in patients with combined acute renal and hepatic failure. *Nephron* **66** (4), 431–437.

de Francisco, A.L. (1999) Clinical outcomes for patients with diabetic nephropathy *EDTN/.ERCA Journal* **25** (1), 23–27.

de Oliveira, R.M., Abaeté de los Santos, C., Antonello, I. *et al.* (2009) Warning: an anemia outbreak due to chloramine exposure in a clean hemodialysis unit – an issue to be revisited. *Renal Failure* **31,** 81.

De Sanctis, L.B., Stefoni, S., Cianciolo, G. *et al.* (1996) Effect of different dialysis membranes on platelet function. A tool for biocompatibility evaluation. *International Journal of Artificial Organs* **19** (7), 404–410.

Department of Health (2004) *The National Service Framework for Renal Services Part 1: Dialysis and Transplantation,* Department of Health, London.

Department of Health (2010) *Good Practice Guidelines for Renal Dialysis/Transplantation Units: Prevention and Control of Blood-Borne Virus Infection Department of Health*, Department of Health, London.

Eloot, S., van Biesen, W., Dhont, A. *et al.* (2008) Impact of hemodialysis duration on the removal of uremic retention solutes *Kidney International* **73,** 765–772.

English, D.J. (2005) Retrograde arterial needle placement improves dialysis adequacy. *Nephrology Nursing Journal* **32** (2), 225–226.

Ernandez, T., Saudan, P., Berney, T. *et al.* (2005) Risk factors for early failure of native arteriovenous fistulas *Nephron Clinical Practice* **101** (1), c39–c44.

Fernandez, E., Borras, M., Pais, B. and Montoliu, J. (1995) Low-calcium dialysate stimulates parathormone secretion and its long-term use worsens secondary hyperparathyroidism. *Journal of the American Society of Nephrology* **6** (1), 132–135.

Fine, A. and Penner, B. (1996) The protective effect of cool dialysate is dependent on patients' predialysis temperature. *American Journal of Kidney Diseases* **28** (2), 262–265.

Fluck, R. and Kumwenda, M. (2011) Renal Association Clinical Practice Guideline on vascular access for haemodialysis. *Nephron Clinical Practice* **118,** Suppl 1, c225–240.

Fouque, D., Vennegoor, M., Ter Wee, P. *et al.* (2007) EBPG guideline on nutrition. *Nephrology Dialysis Transplantation* **22** (suppl. 2), ii45–ii87

Geddes, C., Lindley, E. and Duncan, N. (2009) *Renal Association Guidelines – Blood Borne Virus Infection,* www.renal.org/Clinical/GuidelinesSection/BloodBorneVirusInfection.aspx (accessed 20 May 2013).

Gilga, J., Castledine, C. and Fogarty, D. (2012) *UK Renal Registry 14th Annual Report,* Chapter 1 UK RRT Incidence in 2010: national and centre-specific analyses. *UK Renal Registry,* www.renalreg.com/Reports/2011.html (accessed 20 May 2013).

Grooteman, M.P.C., van den Dorpel, M.A., Bots, M.L. *et al.* (2012) Effect of online hemodiafiltration on all-cause mortality and cardiovascular outcomes. *Journal of the American Society of Nephrology,* **23** (6), 1087–1096.

Hamilton, C.A. (2012) Pharmacological management of type 2 diabetes mellitus in patients with CKD. *Journal of Renal Care* **38**, 59–66.

Hecking, M., Karaboyas, A., Saran, R. *et al.* (2012) Predialysis serum sodium level, dialysate sodium, and mortality in maintenance hemodialysis patients: the Dialysis Outcomes and Practice Patterns Study (DOPPS). *American Journal of Kidney Diseases* **59** (2), 238–248.

Hoenich, N. A. and Levin, R. (2003) The implications of water quality in hemodialysis. *Seminars in Dialysis* **16** (6), 492–497.

Holt, S. and Goldsmith, D. (2011) Renal Association clinical practice guideline on cardiovascular disease in CKD. *Nephron Clinical Practice* **118** (suppl. 1), c125–144.

Hsu, H.-J., Yen C.-H., Hsu K.-H. *et al.* (2011) Association between cold dialysis and cardiovascular survival in haemodialysis patients. *Nephrology Dialysis Transplantation* **2** (6), 2457.

ISO 23500 (2011) *Guidance for the Preparation and Quality Management of Fluids for Haemodialysis and Related Therapies,* International Organization for Standardization, Geneva.

Jain, G., Ivan, D., Maya, I. D. and Allon, M. (2008) Outcomes of percutaneous mechanical thrombectomy of arteriovenous fistulas in hemodialysis patients. *Seminars in Dialysis* **21** (6), 581–583.

Jirka, T., Cesare, S., Di Benedetto, A. *et al.* (2006) Mortality risk for patients receiving haemodiafiltration versus hemodialysis. *Kidney International* **70,** 1524–1525.

Junglee, N.A., Rahman, S.U., Wild, M. *et al.* (2010) When pure is not so pure: chloramine-related hemolytic anemia in home hemodialysis patients. *Hemodialysis International* **14,** 327.

KDIGO (2009) Clinical practice guideline for the diagnosis, evaluation, prevention and treatment of chronic kidney disease-mineral and bone disorder. *Kidney International* **79** (suppl. 113), S50–S99.

KDIGO (2012) Clinical practice guideline for anaemia in chronic kidney disease. *Kidney International Supplements* **2** (4), 279–335.

KDOQI (2000) Nutrition in chronic renal failure. *American Journal of Kidney Diseases* **35** (6) (suppl.), S9–S10.

KDOQI (2003) *Clinical Practice Guidelines for Bone Metabolism and Disease in Chronic Kidney Disease,* www.kidney.org/professionals/KDOQI/guidelines_bone/index.htm (accessed 20 May 2013).

KDOQI (2006) Clinical practice guidelines and clinical practice recommendations updates: hemodialysis adequacy, peritoneal dialysis adequacy and vascular access. *American Journal of Kidney Disease* **48** (suppl. 1), S1–S322.

KDOQI (2007) *KDOQI Clinical Practice Guideline and Clinical Practice Recommendations for Anemia in Chronic Kidney Disease, 2007 Update of Hemoglobin Target,* www.kidney.org/professionals/KDOQI/guidelines_anemiaUP/guide1.htm (accessed 20 May 2013).

Kimmel, P.L., Varela, M.P., Peterson, R.A. *et al.* (2000) Interdialytic weight gain and survival in hemodialysis patients: effects of duration of ESRD and diabetes mellitus *Kidney International* **57** (3), 1141–1151.

Kobrin, S.M and Berns, J.S. (2007) Quinine – a tonic too bitter for hemodialysis-associated muscle cramps? *Seminars in Dialysis* **20** (5), 396–401.

Konner, K. (2004) Vascular access for dialysis in diabetic patients. *EDTNA/ERCA Journal* **30** (3), 148–150.

Kossmann, R.J., Gonzales, A., Callan, R. and Ahmad, S. (2009) Increased efficiency of hemodialysis with citrate dialysate: a prospective controlled study. *Clinical Journal of the American Society of Nephrology* **4,** 1459–1464.

Kronung G. (1984) Plastic deformation of Cimino fistulae by repeated puncture. *Dialysis and Transplantation* **13,** 635.

Labriola, L., Crott, R., Jadoul, M. (2008) Preventing haemodialysis catheter related bacteraemia with an antimicrobial lock solution: a meta-analysis of prospective randomized trials. *Nephrology Dialysis Transplantation* **23,** 1666–1672.

Lebedo, I. and Blanlestijn, P.J. (2010) Haemodiafiltration – optimal efficiency and safety. *Nephrology Dialysis Transplantation Plus* **3** (1), 8–16.

Leypolt, J.K. (2000) Solute fluxes in different treatment modalities. *Nephrology Dialysis Transpantation* **15** (suppl. 1), 3–9.

Lindley, E. (2009) Reducing sodium intake in hemodialysis patients. *Seminars in Dialysis* **22,** 260.

Lindley, E., Ward, R., Pearson, C. *et al.* (2006) Merits and limitations of continuous blood volume monitoring during haemodialysis: Summary of the EDTNA|ERCA Journal Club discussion: winter 2005. *EDTNA-ERCA Journal* **32** (2), 108–116.

Locatelli, F., Altieri, P., Andrulli, S. *et al.* (2010) Hemofiltration and hemodiafiltration reduce intradialytic hypotension in ESRD. *Journal of the American Society of Nephrology* **21** (10), 1798–1807.

Locatelli, F., Covic, A., Eckardt, K. *et al.* (2009a) Anaemia management in patients with chronic kidney disease: a position statement by the Anaemia Working Group of European Renal Best Practice (ERBP). *Nephrology Dialysis and Transplantation* **24,** 348–354.

Locatelli, F., Martin-Malo, A., Pedrini, L. *et al.* (2009b) Membrane permeability outcome (MPO) study group: effect of membrane permeability on survival of haemodialysis patients. *Journal of the American Society of Nephrology* **20,** 645–654.

Lok, C.E, Appleton, A., Bhola., K. and Richardson, R.M.A. (2007) Trisodium citrate 4% – an alternative to heparin capping of haemodialysis catheters. *Nephrology Dialysis and Transplantation* **22** (2), 477–483.

Lonnemann, G. (2004) When good water goes bad: how it happens, clinical consequences and possible solutions. *Blood Purification* **22,** 124–129.

Lopez-Almaraz, E. and Correa-Rotter, R. (2008) Dialysis disequilibrium syndrome and other treatment complications of extreme uremia: a rare occurrence yet not vanished. *Hemodialysis International* **12** (3), 301–306.

Lowrie, E.G., Laird, N.M. and Paker, T.F. *et al.* (1981) Effect of the haemodialysis prescription of patient morbidity. Report from the National Co-operative Dialysis Study. *New England Journal of Medicine* **305,** 1176–1181.

MacPhee, I,.Webb, L., Casula, A. and Udaya Udayaraj, U. (2012) *UK Renal Registry 14th Annual Report: Chapter 2 UK RRT Prevalence in 2010: National and Centre-Specific Analyses.* UK Renal Registry, www.renalreg.com/Report-Area/Report%20 2011/Chap02_Renal11_web.pdf (accessed 20 May 2013).

Mactier, R., Hoenich, N. and Breen, C. (2011) Renal Association guidelines. Clinical practice guideline on haemodialysis. *Nephron Clinical Practice* **118** (suppl. 1), C241–286.

Maggiore, Q. (2002) Isothermic dialysis for hypotension-prone patients. *Seminars in Dialysis* **15** (3), 187–190.

Masakane, I. (2010) High-quality dialysis: a lesson from the Japanese experience: Effects of membrane material on nutritional status and dialysis-related symptoms. *NDT Plus* 3: i28-i35

McCann, M., Einarsdóttir, H., Van Waeleghem, J.-P. *et al.* (2008) Vascular access management 1: an overview. *Journal of Renal Care,* **34** (2), 77–84.

McCann, M., Einarsdottir, H., Van Waeleghem, J.P., Murphy, F. and Sedgewick, J. (2010) Vascular access management III: central venous catheters. *Journal of Renal Care* **36** (1), 25–33.

McIntyre, C.W., Hulme, L.J., Taal, M. and Fluck, R. J. (2004) Locking of tunnelled hemodialysis catheters with gentamicin and heparin. *Kidney International* **66** (2), 801–805.

Meaney, B. (2012) Diabetic foot care: prevention is better than cure. *Journal of Renal Care* **38**, 90–98.

Mikhail, A., Shrivastava, R. and Richardson, D. (2011) Renal Association clinical practice guideline on anaemia in CKD. *Nephron Clinical Practice* **118** (suppl. 1), c101–104.

Mowatt, G., Vale, L., Perez, J. *et al.* (2002) *Systematic Review of the Effectiveness and Cost-Effectiveness of Home versus Hospital or Satellite Unit Haemodialysis for People with End Stage Renal Failure,* National Institute for Clinical Excellence, London.

Naroienejad, M, Saedi, D. and Rezvani, A. (2010) Prevalence of central vein stenosis following catheterization in patients with end-stage renal disease. *Saudi Journal of Kidney Disease and Transplantation* **21,** 975–978.

National Institute for Clinical Excellence (2002) *Guidance on Home Compared with Hospital Haemodialysis for Patients with End-Stage Renal Failure,* National Institute for Clinical Excellence, London.

Nystrand, R. (2009) Official recommendations for quality of fluids in dialysis – the need for standardisation. *Journal of Renal Care* **35** (2), 74–81.

Ozmen, S., Kadiroglu, A.K., Ozmen, C.A. *et al.* (2008) Does the direction of arterial needle in AV fistula cannulation affect dialysis adequacy? *Clinical Nephrology* **70** (3), 229–232.

Palmer, B.F. and Henrich, W.L. (2008) Recent advances in the prevention and management of intradialytic hypotension. *Journal of the American Society of Nephrology* **19** (1), 8–11.

Pratt, R.J., Pellowe, C.M., Wilson, J.A. *et al.* (2007) epic2: National evidence-based guidelines for preventing healthcare-associated infections in NHS hospitals in England. *Journal of Hospital Infection* **65S,** S1-S64.

Rachoin, J.S. and Weisberg, L.S. (2008) How should dialysis fluid be individualized for the Chronic Hemodialysis Patient? *Seminars in Dialysis* **21,** 223–225.

Ronco, C., Bellomo, R. and McCullough, P.A. (eds) (2010) *Anticoagulation for Renal Replacement Therapy: Different Methods to Improve Safety in Cardiorenal Syndromes in Critical Care,* Karger, Basel.

Rosenheim (Lord) (1972) *Hepatitis and the Treatment of Chronic Renal Failure: Report of the Advisory Group 1970–1972,* Department of Health and Social Security, London.

Roy-Chaudhury, P., Kelly, B.S., Melhem, M. *et al.* (2005) Novel therapies for hemodialysis vascular access dysfunction: fact or fiction? *Blood Purification* **23** (1), 29–35.

Scheltinga, M.R., Hoek van, F. and Bruyninck, C.M. (2009) Surgical banding for refractory hemodialysis access-induced distal ischemia (HAIDI). *Journal of Vascular Access* **10,** 43–49.

Schwalbe, S., Holzhauer, M., Schaeffer, J. *et al.* (1997) Bold beta 2-microglobulin associated amyloidosis: a vanishing complication of long-term hemodialysis? *Kidney International,* **52**, 1077–1083.

Selby, N.M. and McIntyre, C.W.(2006) A systematic review of the clinical effects of reducing dialysate fluid temperature. *Nephrology Dialysis Transplantation* **21** (7), 1883–1898.

Shearer, R., Milburn, J., Wilson, A. *et al.* (2012) The button hole method of fistula cannulation. Does it affect patency rates? *International Journal of Surgery* **10** (8), S103–S103.

Shibagaki, Y. and Takaichi, K. (1998) Significant reduction of the large-vessel blood volume by food intake during hemodialysis. *Clinical Nephrology* **49** (1), 49–54.

Shoji, T., Tsubakihara ,Y., Fujii, M. and Imai, E. (2004) Hemodialysis associated hypotension as an independent risk factor for two-year mortality in hemodialysis patients. *Kidney International* **66,** 1212–1220.

Song, J.H., Park, G.H., Lee, S.Y. *et al.* (2004) Effect of sodium balance and the combination of ultrafiltration profile during sodium profiling hemodialysis on the maintenance of the quality of dialysis and sodium and fluid balances, *Journal of the American Society of Nephrology,* www.jasn.org/cgi/content/abstract/ASN.2004070581v1 2004a (accessed 20 May 2013).

Steddon, S. and Sharple, E. (2011) Renal Association clinical practice guideline in mineral and bone disorders in CKD. *Nephron Clinical Practice* **118** (suppl. 1), c145–152.

Sukthinthai, N., Sittipraneet, A., Tummanittayangkoon, B. *et al.* (2012) Buttonhole technique better than area puncture technique on hemostasis and pain associated with needle cannulation. *Journal of the Medical Association of Thailand* **95** (suppl. 2), S208–212

Tattersall, J., Martin-Malo, A., Pedrini, L *et al.* (2007) EBPG guideline on dialysis strategies. *Nephrology Dialysis Transplantation* **22** (suppl. 2), ii5–ii21.

Tattersall, J., Canaud, B., Heimburger, O. *et al.* (2010) High-flux or low-flux dialysis: a position statement following publication of the Membrane Permeability Outcome Study. *Nephrology Dialysis Transplantation* **25** (4), 1230–1232.

Traut, M., Haufe, C.C., Eismann, U. *et al.* (2005) Increased binding of beta-2-microglobulin to blood cells in dialysis patients treated with high-flux dialyzers compared with low-flux membranes contributed to reduced beta-2-microglobulin concentrations. Results of a cross-over study. *Blood Purification* **25** (5–6), 432–440.

Uhlenbusch-Kower, I., Bonnie-Schorn, E., Grassmann, A. and Vienken, J. (2004) *Understanding Membranes and Dialysers*, PABST, Lengerich.

UK Renal Registry (2011) *The Fourteenth Annual Report of the UK Renal Registry,* UK Renal Registry, Bristol.

Vachharajani, T.J. (2012) Diagnosis of arteriovenous fistula dysfunction. *Seminars in Dialysis* **25** (4), 445–450.

Vanholder, R., Canaud, B., Fluck, R. *et al.* (2010) Diagnosis, prevention and treatment of haemodialysis catheter-related bloodstream infections (CRBSI): a position statement of European Renal Best Practice (ERBP). *NDT Plus* **3,** 234–246.

Van Loon, M., Goorvaerts, T., Kessels, A. *et al.* (2010) Buttonhole needling of haemodialysis arteriovenous fistulae results in less complications and interventions compared to rope-ladder technique. *Nephrology Dialysis Transplantation* **25** (1), 225–230.

Van Loon, M., Goovaerts, T., Kessels, G., van der Sande, M. and Tordoir, J.H.M. (2009) Buttonhole needling of haemodialysis arteriovenous fistulae results in less complications and interventions compared to the rope-ladder technique. *Nephrology Dialysis Transplantation* **25** (1), 225–230.

Van Loon, M., van der Mark, W., Beukers, N. *et al.* (2007) Implementation of a vascular access quality programme improves vascular access care. *Nephrology Dialysis Transplantation* **22,** 1628–1632

Vasquez, M.A. (2009) Vascular access for dialysis: recent lessons and new insights. *Current Opinion in Nephrology and Hypertension* **18,** 116-121.

Vilar, E., Fry, A.C., Wellsted, D. *et al.* (2009) Long-term outcomes in online hemodiafiltration and high-flux hemodialysis: a comparative analysis. *Clinical Journal of the American Society of Nephrology,* **4**(12), 1944–1953.

Ward, D. M. (1996) Chloramine removal from water used in haemodialysis. *Advances in Renal Replacement Therapy* **3** (4), 337–347.

Ward, R.A. (1995) Heparinization for routine haemodialysis. *Advances in Renal Replacement Therapy* **2** (4), 362–370.

Williams, M. (2001) Rehabilitating the frail and elderly on renal replacement therapy, *EDTNA/ERCA Journal* **27** (2), 64–65, 74.

Wright, M. and Jones, C. (2011) Renal Association clinical practice guideline: nutrition in CKD. *Nephron Clinical Practice* **118** (suppl. 1), c153–164.

Yahav, D., Rozen-Zvi, B., Gafter-Gvili, A. *et al.* (2008) Antimicrobial lock solutions for the prevention of infections associated with intravascular catheters in patients undergoing hemodialysis: systematic review and meta-analysis of randomized, controlled trials. *Clinical Infectious Diseases* **47,** 83–93.

Yevzlin, A.S. (2008) Hemodialysis catheter-associated central venous stenosis. *Seminars in Dialysis* **21** (6), 522–527.

Yevzlin, A.S., Schoenkerman, A.B., Gimelli, G. and Asif, A. (2009) Arterial interventions in arteriovenous access and chronic kidney disease: a role for interventional nephrologists. *Seminars in Dialysis* **22** (5), 545–556.

CHAPTER 9

Peritoneal Dialysis

Claire Main
Baxter Healthcare, UK

Learning Outcomes

- To recognise the importance of individualised care for those on peritoneal dialysis (PD).
- To review the anatomy and physiology of the peritoneum.
- To identify best practice for the care of the PD catheter and exit site and the best use of each PD therapy option.
- To understand the criteria for good patient selection for PD.
- To review all factors required to adequately dialyse a patient with PD.
- To review the complications of PD.
- To understand the importance of good ongoing education for those on PD.

Introduction

Peritoneal dialysis as a treatment for established renal failure (ERF) is a relatively simple and very effective technique. As such, it has been successfully developed as the preferred first option for home dialysis.

From its introduction in the late 1970s, PD has been refined and developed into a flexible and adaptable therapy that is the treatment of choice for many patients. It has been found to be most effective if performed as a continuous treatment, either by the patient during the day (continuous ambulatory peritoneal dialysis or CAPD) or by a machine, whilst the patient sleeps (automated peritoneal dialysis or APD). Owing to its continuous nature, patients who are treated by this therapy tend to have a more stable biochemical and fluid profile. Its flexible nature makes it suitable for almost all patients with ERF.

This chapter discusses the importance of having an individualised treatment for each patient, which is structured around both clinical and lifestyle needs. The chapter starts with an overview of the anatomy and physiology of the peritoneum and practical aspects of the therapy, and different therapy options on PD; complications and patient education and training are also discussed. As the therapy is predominately performed by the patients themselves, in the community, the main focus is on providing patients with not only an individualised treatment, but also adequate psychological and nursing care which are essential elements for the successful treatment of those needing PD and their families. The advent of assisted peritoneal dialysis has reduced this burden on vunerable patients and is now available in many centres.

Renal Nursing, Fourth Edition. Edited by Nicola Thomas. Published 2014 by John Wiley & Sons, Ltd.

Physiology of Peritoneal Dialysis

The peritoneal membrane, so called because it covers the abdominal cavity and is derived from the Greek word *peritonaion,* meaning 'to stretch around', has a surface area of up to 2 m^2. The peritoneal cavity is the potential space between the parietal membrane (which lines the abdominal cavity) and the visceral membrane (the inner layer which closely covers the organs and includes the mesenteries). Under normal circumstances this cavity contains between 50 and 100 ml of fluid which acts as a lubricant (Figure 9.1).

During PD, physiological solution or dialysis fluid is instilled into the peritoneal cavity. Uraemic toxins and solutes move across the membrane by the process of diffusion, from the blood stream into the dialysis fluid, or vice versa, depending on the concentration gradient. The composition of the dialysis fluid is near to that of normal extracellular fluid.

Fluid removal takes place by osmosis. The dialysis fluid is made hypertonic to plasma by the addition of osmotic agent, usually glucose. Other osmotic solutions are discussed later in this chapter.

The membrane is made up of three layers (Figure 9.2a):

- The mesothelium. Underneath this lies the connective tissue. The luminal side of the mesothelium is covered with numerous microvilli that are believed to increase the surface area of the peritoneum to up to 40 m^2 in a healthy individual (Figure 9.2b).

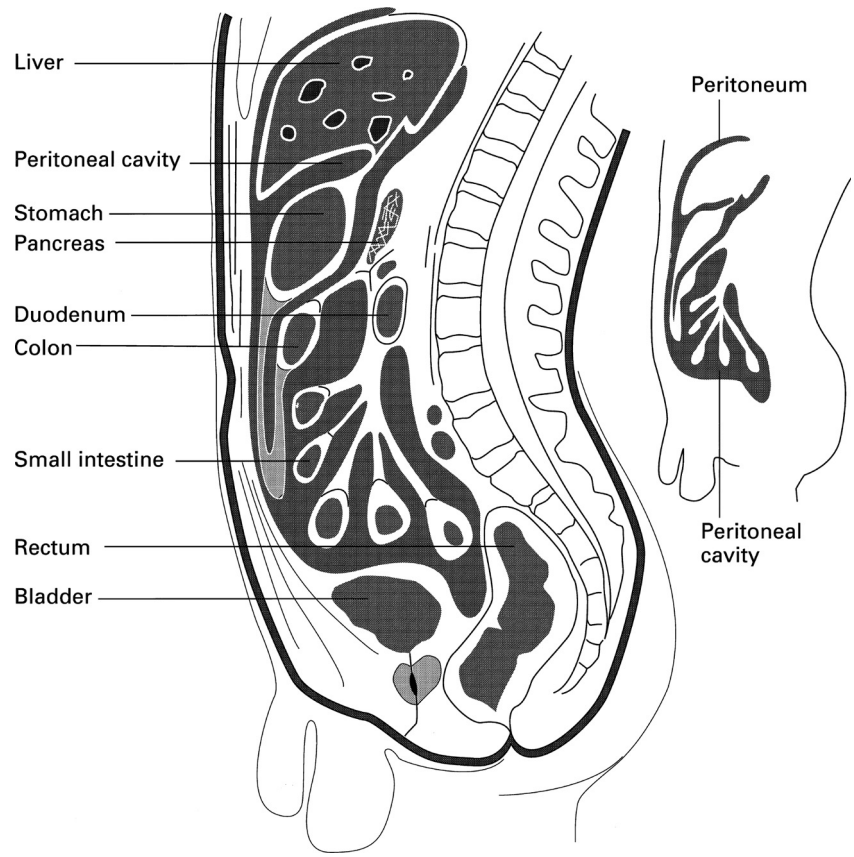


Figure 9.1 Location of the peritoneal cavity.

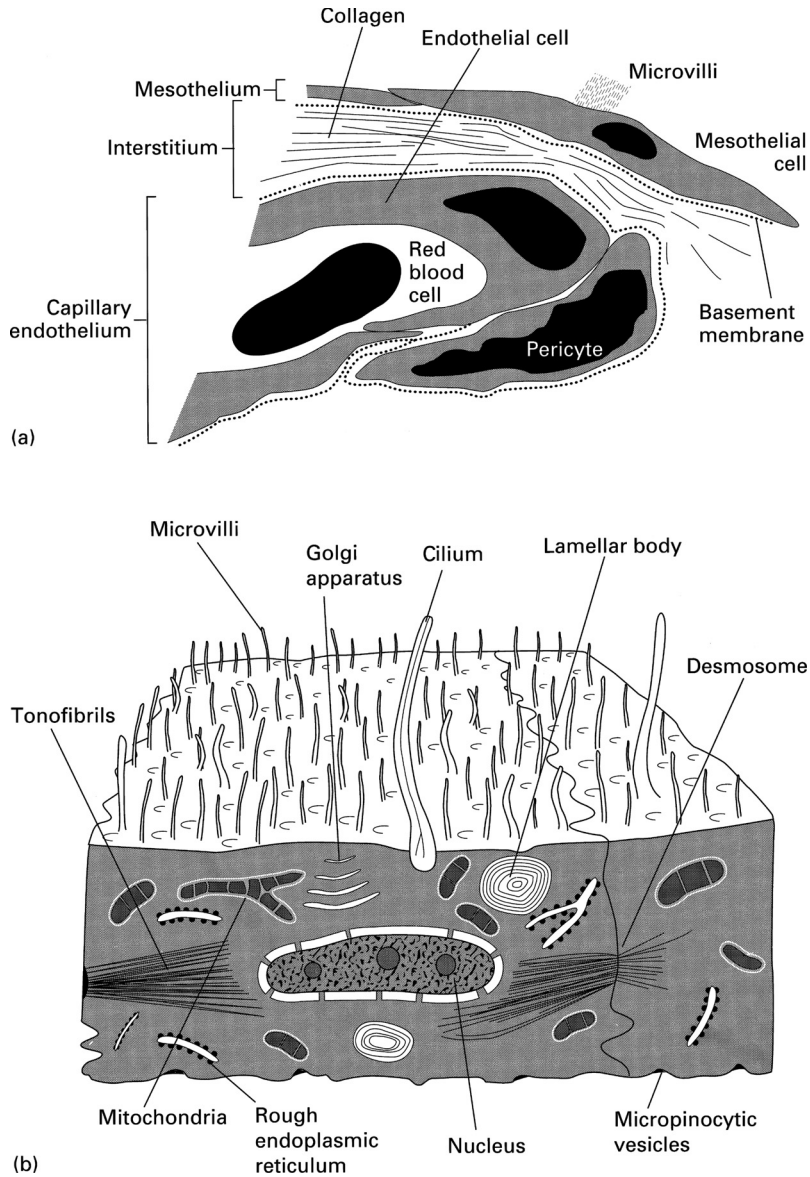


Figure 9.2 (a) The three layers of the peritoneal membrane. (b) Diagrammatic representation of a normal mesothelial cell.

- The peritoneal interstitium. This is composed of fibres and bundles of collagen.
- The capillary endothelium. This forms a complex branching system.

Blood supply

The visceral peritoneum is supplied by the superior mesenteric artery. The parietal peritoneum is supplied by the intercostal, epigastric and lumbar arteries. Venous return from the visceral peritoneum is to the portal circulation whereas that from the parietal

peritoneum goes into the caval circulation. This is important because it means that any drugs administered via the peritoneum will be transported to the liver, the normal route.

Lymphatic drainage

Lymphatic drainage from the peritoneal cavity returns excess fluid and proteins into the systemic circulation. Its other function is to remove foreign bodies from the peritoneal cavity. Lymphatic drainage is a one-way system, the flow rate of which may be affected by respiratory rate, intraperitoneal hydrostatic pressure, posture or peritonitis.

Peritoneal membrane transport characteristics

The peritoneal membrane is semipermeable and allows the passage of both water and solutes. During PD three processes are involved in removing fluid and wastes from the blood stream and balancing electrolytes. These are osmosis, diffusion and convection.

Osmosis

This is the movement of water through a semipermeable membrane from a solution of low concentration into a solution with a higher concentration. The solution into which the water moves in PD contains an osmotic agent, usually glucose (other osmotic agents are discussed later in this chapter). The higher the glucose concentration, the greater the osmotic effect will be, so removing more water from the patient's bloodstream (Figure 9.3).

Diffusion

This is solute exchange between two solutions, usually separated by a semipermeable membrane. The solutes will travel in either direction across the membrane until equilibrium is achieved. The direction and speed at which the solutes flow depend on the concentration gradient. Solutes will flow from the stronger solution into the weaker

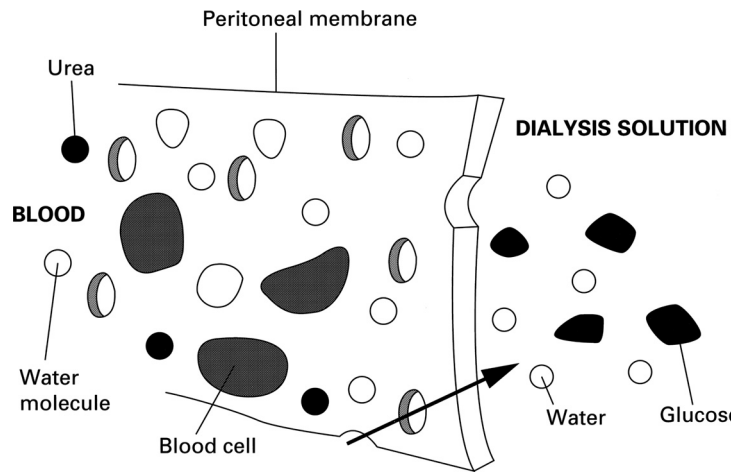


Figure 9.3 Osmotic ultrafiltration across the peritoneal membrane with a glucose dialysis solution in the peritoneal cavity.

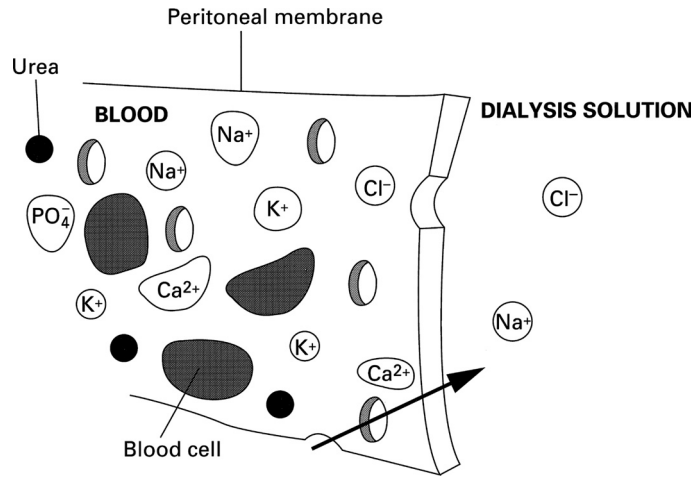


Figure 9.4 The peritoneum acts as a semipermeable membrane, allowing small solutes and water to diffuse through, but retaining large particles such as blood cells.

solution (Figure 9.4). Therefore, solutes can pass in either direction across the peritoneal membrane. Other factors that affect diffusion rate are molecular weight and membrane resistance.

Molecular weight

Diffusion is a spontaneous process whereby solutes move randomly. Lighter, smaller molecules will move quicker than larger, heavier molecules. Urea (which has a molecular weight of 60 Da) diffuses from blood to dialysate more rapidly than creatinine (molecular weight 113 Da) or vitamin B_{12} (molecular weight 1352 Da). Unlike haemodialysis, where the membrane pore size is controlled, the peritoneal membrane allows transport of large molecules and even proteins. Protein transport into the dialysate is unfortunate as this is an essential nutrient, particularly in dialysis patients who may be catabolic.

Membrane resistance

The permeability of the individual's membrane is an important factor controlling diffusion of solutes. Measurement of this is discussed later in this section.

A patient's peritoneal permeability may be changed during illness. Acute episodes of peritonitis appear to greatly increase the membrane permeability to both solutes and water. However, fibrotic thickening of the membrane, may lead to a severe reduction in its permeability. Further reading on the functional structure of the peritoneum can be found in Gotloib (2009).

Convection

Owing to the large amount of osmotic ultrafiltration that takes place during PD, convective flow transports or 'drags' water and solutes across the membrane. This occurs at a much faster rate than that which may be accounted for by diffusion alone.

The ability of glucose to exert an effective osmotic pressure depends on its ability to stay in solution in the dialysate. If the peritoneal membrane were perfectly semipermeable (i.e. only permeable to water), the osmotic pressure would be maximised. However,

the peritoneum is permeable to solutes as well as water, and therefore allows the glucose through. The osmotic gradient is therefore maximum at the beginning of the exchange. The ultrafiltration will decrease during the dwell time as glucose is absorbed into the blood stream. It is estimated that ultrafiltration is maximised at the beginning of the PD fluid exchange when the concentration gradient is highest. The total dialysate and ultrafiltrate volume continues to decrease after this point due to lymphatic absorption (Krediet *et al.* 2008).

Measurement of peritoneal permeability

The characteristics, pore size and dimensions of the peritoneal membrane do not come printed on the side of a packet as they do in haemodialysis. It's therefore important to determine the characteristics of the patient's peritoneal membrane before an appropriate prescription can be written. A number of methods have been described, including standardised peritoneal assessment (SPA), the Peritoneal Equilibrium Test (PET) including Fast or mini PET, Personal Dialysis Capacity (PDC) test and more recently double mini PETs. The PET is the most commonly used.

It was described in 1987 by Twardowski *et al.* and determines solute transport rates over time and the ultrafiltration capacity of the membrane. The results of the test can therefore be used to determine the optimum length of time that PD fluid should be left inside the peritoneal cavity to gain maximum fluid and solute removal. It also alerts the practitioner to any changes in membrane function that could affect patient's dialysis adequacy and outcomes. A review of evaluation methods of peritoneal membrane characteristics has been written (Van Biesen *et al.* 2010).

Performing a PET

The PET test was traditionally carried out by an experienced PD nurse in a clinic environment, however with the adoption of the 'fast' PET where blood samples are taken at 4 hours only (Kazancioglu *et al.* 2012) this can now be performed at home, allowing for greater flexibility. Prior to performing the test the patient's peritoneal dialysis catheter function should be checked so that poor drainage due to mechanical problems with the catheter (such as constipation) are not attributed to membrane function. In addition, patients should be normally hydrated, and patients with diabetes should have serum glucose levels within normal limits. This enables the results of the test to be interpreted accurately.

To enable accurate reproduction of the test according to Twardowski's original work, the following is the original protocol, which is the basis for all tests and should be used if there is any doubt over the reliability of the 'fast' or modified PET.

1. The patient attends the clinic with a 2.27% bag, which has dwelled in the peritoneum for between 8–12 hours. This is drained out, the volume and dwell time recorded and a sample taken.
2. The patient is then instilled with another bag of 2.27%. The volume should be the same as the overnight bag but ideally no smaller than 2000 ml.
3. This is drained in over 10 mins with the patient in a supine position rolling from side to side to ensure mixing whilst the fluid is infused.
4. Dialysate samples are taken at 0 hours, 2 hours and 4 hours with a serum sample at 2 hours.
5. It is essential to record the drain-out time and the drained out volume at 4-hours to assess the ultrafiltration capacity of the membrane.

6. Finally, the patient's usual PD solution is instilled before they are able to go home.
7. The samples are then sent for analysis of glucose and creatinine levels as soon as possible.

Calculating results

In order to determine the patient's membrane solute transport characteristics, the level of creatinine that is in the PD fluid at 0, 2 and 4 hours is compared with the level of creatinine in the patients plasma (D/P ratio). This gives a ratio of between 0 and 1. The closer the dialysate-to-plasma ratio is to 1, the faster solutes equilibrate across the membrane. Glucose absorption, from the PD solution into the patient's serum, is calculated in the same way. The level of glucose in the PD fluid at 0, 2 and 4 hours is compared with the level in the patient's serum (D/P ratio). The closer the ratio is to 1, the faster glucose crosses the membrane. Patients who equilibrate solutes fast will therefore have good solute removal during PD, however as glucose will also be absorbed quicker, the glucose concentration gradient will not be sustained. Thus, fluid removal will be poor.

The results can be plotted to determine the transporter status of the peritoneum.

Analysis of results

When the patient's transport characteristics have been identified, it is easy to tailor the treatment to suit the membrane. The patient's peritoneal membrane is categorised into one of the four membrane classifications. Each membrane classification has specific characteristics that guide the clinician in tailoring the patient's prescription (see Table 9.1)

Patients who have high transport membranes should have rapid exchanges of fluid, usually achieved by using APD. Patients who transport glucose and solutes more slowly are better suited to receiving CAPD where the fluid remains in the peritoneal cavity for longer periods. Any prescription modification should be accompanied by an assessment of the patient's lifestyle to ensure that the treatment is achievable within work and social constraints. By performing this test regularly it is possible to monitor peritoneal membrane function over time and therefore diagnose acute membrane injury, inadequate ultrafiltration and poor solute clearance.

Table 9.1 Classification of membrane type

Percentage of patients	Membrane type	4 h D/P creatinine	Characteristics
10	High	0.82–1.03	Very efficient membrane Transports solutes easily Increased glucose absorption May have difficulty achieving ultrafiltration At risk of low albumin
53	High Average	0.65–0.81	Efficient membrane Transports solutes well Ultrafilters well
31	Low Average	0.50–0.64	Less efficient membrane Transports solutes slowly Ultrafilters well
6	Low	0.34–0.49	Inefficient membrane Transports solutes slowly Ultrafilters well

A PET should be performed after 4–8 weeks on dialysis. It has been suggested (Renal Association 2010) that repeat tests should be routinely performed every one to two years or if problems arise such as an apparent loss of ultrafiltration or if there is a change in therapy such as transfer from CAPD to APD. Changes over time in the test results can then be related to clinical performance and treatment regimens may be altered accordingly.

Peritoneal Dialysis Access and Exit Site Care

Despite peritoneal dialysis (PD) catheter insertion being a relatively simple procedure, the implications of getting it wrong can be catastrophic for the patient at a most vulnerable time – when they are new to PD. Not only can poor insertion technique lead to a malfunctioning catheter; it can also be responsible for infections and the failure of PD in about 20% of patients (Flannigan 2005), which can be devastating for a patient who has chosen this therapy. Unsuccessful PD catheter insertion also has cost implications and can adversely affect the management of a renal unit.

There are many facets to successful PD access:

- choosing the right catheter type and length;
- good insertion technique;
- meticulous preoperative and postoperative care.

However, what is fundamental is effective teamwork from the multidisciplinary team, in particular the medical and nursing staff.

Types of catheters

The perfect PD catheter is one that provides reliable and rapid inflow and outflow from the peritoneal cavity without leaks or infections. Catheters should be designed to stay in the pelvic cavity and be easy to insert.

Peritoneal dialysis catheters generally have three portions (Figure 9.5):

- The outer segment, which connects via an adapter to the solution transfer set.
- The intramural segment. This has Dacron cuffs, spaced about 8 cm apart. By creating an inflammatory response, fibrous tissue fixes the catheter into position, thereby

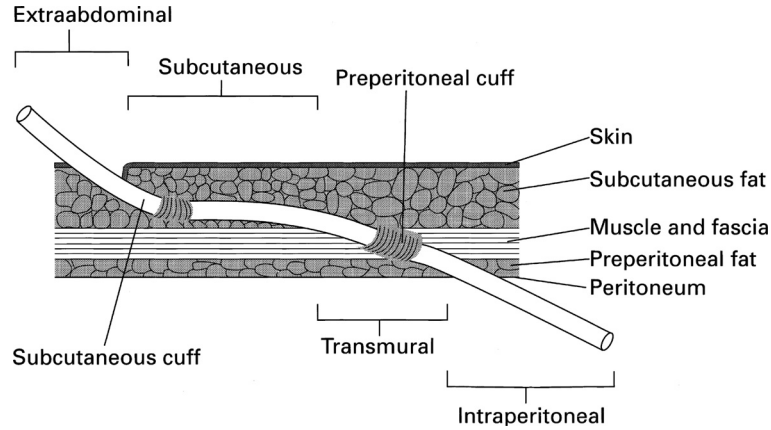


Figure 9.5 Functional parts of the peritoneal catheter.

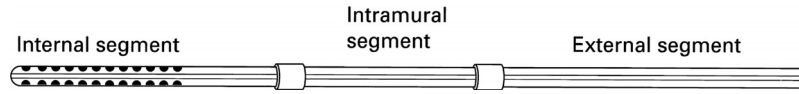


Figure 9.6 Straight Tenckhoff catheter

Figure 9.7 Curled Tenckhoff catheter

minimising leakage of dialysate and preventing bacteria entering the catheter 'tunnel' and intra-peritoneal segment

- The intraperitoneal part, which has many small holes up the side, is situated inside the peritoneal cavity for the in and outflow of the solution.

Variations in the design of catheters include the number of cuffs (one versus two), the design of the intramural segment (permanently bent versus straight), and the intraperitoneal portion (straight versus curled). Despite the number of types of catheters available the most widely used are the straight (Figure 9.6) and curled (Figure 9.7)Tenckhoff catheters. They are easily inserted under local or general anaesthetic and choice of catheter will usually depend on local preference.

The Swan-neck (Figure 9.8), and Toronto Western (Figure 9.9) catheters were both developed to aid outflow of the dialysate.

Swan-neck

With two downward-pointing segments, migration of this type of catheter is rare thereby serving to aid outflow. It is also thought to prevent infections at the exit site as this segment of the catheter also points downwards, thus preventing accumulation of sweat and pus.

Toronto Western

This has two discs at the intraperitoneal segment helping to prevent migration. This catheter also has a Dacron flange and bead at the deep cuff, which is sewn in position by a pursestring suture, helping to reduce leaks at the exit site.

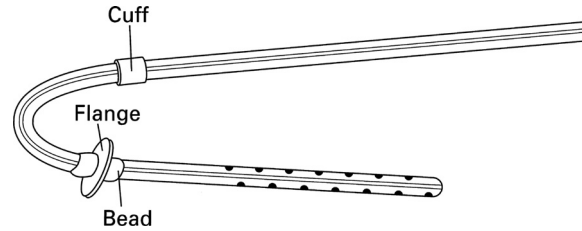


Figure 9.8 Swan neck catheter

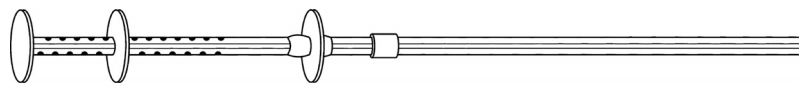


Figure 9.9 Toronto Western catheter

Literature shows that there is little difference between risk of infection for the various types of catheters, however one study showed that there was increased catheter survival in the coiled catheter when compared to the straight (36% v 77% p = 0.01 Neilson *et al.* 1995). If properly placed, dual-cuff Tenckhoff catheters have a lower incidence of infection and a longer lifespan than single cuff catheters (Ash 2003). Overall there seems to be no superior catheter to the standard straight Tenckhoff catheter.

Preinsertion preparation of the patient

A full preoperative assessment of the patient is essential to identify existing or potential hernias. If present these can be repaired during the catheter insertion. The catheter exit site should be determined before the catheter is inserted. The preferred site should first be discussed with the patient to help promote participation in and an understanding of the therapy. The following points should be followed when determining the exit site of the patient's catheter:

- the site should be determined whilst the patient is in a relaxed sitting or standing position;
- it should be either above or below the belt line, whichever the patient prefers;
- skin folds and abdominal scars should be avoided;
- the catheter exit site should be located where the patient can effectively carry out exit-site care;
- once the exit site has been determined, it should be marked clearly with a permanent skin marker.

The patients lifestyle, work and hobbies should be taken into consideration when placing the catheter

Preoperative care of the patient

On the morning of the operation, the patient should bathe or have a shower. If necessary, abdominal hair should be clipped (Leaper *et al.* 2008). A major cause of catheter failure, particularly at the start of PD, is constipation and it is therefore recommended that a powerful aperient such as Picolax is given the day before catheter insertion. It is also important that the patient has an empty bladder before the insertion procedure takes place. Other usual preoperative practices should also be followed.

Staphylococcus aureus screening

There is evidence (Piraino *et al.* 2005) that patients who have nasal carriage of staphylococcus aureus have an increased risk of exit site infection and peritonitis and that the use of Mupirocin cream or ointment at the exit site is recommended to reduce the incidence of infection. It is therefore advisable to screen all patients for *Staphylococcus aureus* prior to catheter insertion and treat accordingly.

Prophylactic antibiotics

There is evidence that prophylactic antibiotics prevent catheter infections and peritonitis (Galallah *et al.* 2000). Recently published guidelines recommend that prophylactic antibiotics should be administered at the time of catheter insertion (Piraino *et al.* 2005).

Psychological preparation of the patient

This is of absolute importance for someone who is new to PD and this is discussed in detail in Chapter 4.

Insertion techniques

Peritoneal dialysis is a life-maintaining therapy. Access to the peritoneal cavity, via the PD catheter, is therefore particularly important in ensuring its success (see Figure 9.10 for the correct position of the catheter in the abdomen). The insertion technique should be treated as a skill acquired by experienced surgeons physicians and specialist nurses, rather like implantation of a pacemaker or similar device. A team approach is essential and nurse involvement is most important. The nurse's role in insertion of PD catheters starts with the preoperative preparation described above, all of which can be carried out by the nurse. In many centres the PD nurse accompanies the patient to the operating theatre or procedures room to ensure correct procedures are carried out and that the catheter is functioning well before final wound closure is made.

The four most frequently performed methods of catheter insertion include:

- surgical placement by dissection;
- blind placement using Tenckhoff trocar;
- blind placement using guidewire;
- minitrocar placement using peritoneoscopy.

(Wilkie *et al.* 2008)

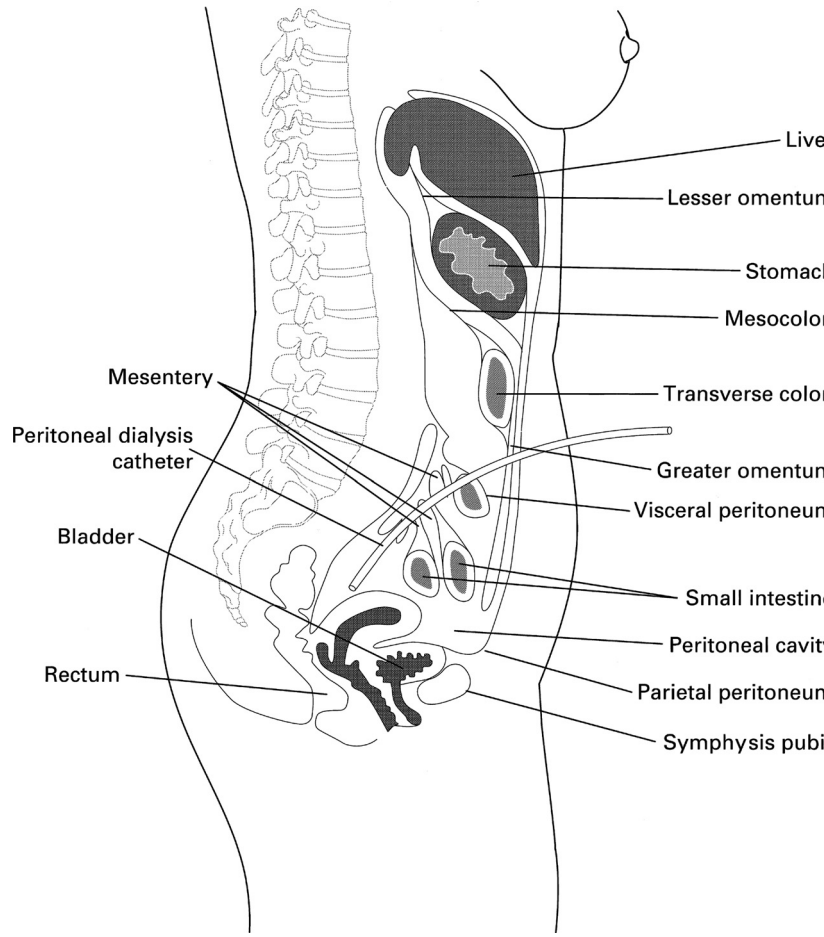


Figure 9.10 The position of a peritoneal dialysis catheter in the abdomen.

An alternative method of catheter insertion is performed by radiologists using a percutaneous modified Seldinger technique under fluoroscopic guidance and has been shown to be a clinically noninferior and cost-effective alternative to surgical laparoscopic insertion (Voss *et al*. 2012).

There is no evidence (with randomised controlled trials) to support one method of insertion over another; however, the method needs be determined by patient characteristics. For more complicated patients, including those with previous significant abdominal surgery, a technique that involves direct vision is necessary, such as laparoscopic or open insertion (Figueiredo *et al*. 2010).

Postoperative care of the patient

The goals of postoperative catheter care are to:

- minimise any bacterial colonisation of the exit and tunnel during the early healing period;
- prevent trauma to the exit site and traction on the cuffs by immobilisation of the catheter;
- minimise intra-abdominal pressure to prevent leakage.

Ideally, the exit site should be undisturbed for 7–10 days following insertion of the catheter. The patient may be discharged home during this period. If, during the first 10 days, the dressing becomes soiled, it should be redressed by a nurse. If it merely becomes dislodged, it should simply be replaced with a fresh sterile dressing. During this period, the catheter tubing must be immobilised by securely taping it to the patient's abdomen. Local unit policies will be in place and should be followed.

Before discharge from hospital, during this resting of the patient's catheter, clear instructions must be given as to the correct procedures for caring for the catheter at home. It may be appropriate to involve the community district nursing team if no specific community PD nurse is available. In this case, adequate training and support must be provided for the nursing team.

Directly following insertion of the catheter, it may be flushed with 500–1500 ml of PD fluid to check patency. It may then be 'capped off' using a small locking cap on the catheter adapter (this adapter is available in titanium metal or plastic) and left covered until PD commences. Ideally, PD should not be started until healing of the exit site and tissue ingrowth into the catheter's Dacron cuffs have taken place, usually after 10 days. If dialysis is necessary before this time, automated PD would be the preferred method. This is because this treatment will help to minimise the risk of leakage of PD fluid by allowing the patient to be treated using small fill volumes of fluid in a supine position. It is worth noting that patient-healing mechanisms may be altered in those patients who are uraemic or who have diabetes mellitus.

Long-term care of the exit site

As with any wound, care is aimed at keeping the site clear of exudate or debris that could encourage bacterial growth. A method of exit-site care that best fits in with the patient's lifestyle is most likely to encourage full participation in the treatment, and therefore reduce the risk of complications. A number of studies have been undertaken to attempt to ascertain which particular method of exit-site care is preferred. Various protocols do exist – for example cleansing with soap and water or cleaning with povidone-iodine; however, there is to date no consensus on which method will reduce the incidence of infection (Twardowski and Nichols 2009).

Whichever solution is chosen, the following points should be considered:

- Harsh solutions should be avoided as they have the potential to cause skin damage, which may predispose to bacterial colonisation.
- Different agents may be preferred in different circumstances. In an immunosuppressed patient the normal skin flora may represent an infection risk; in this case an antiseptic solution may be preferred.
- Whichever method is used, it is important to ensure that the exit site is carefully dried to avoid skin maceration, which could predispose the site to bacterial colonisation.

There is also some debate as to whether it is necessary to keep the catheter exit-site covered. The use of no dressing and a simple exit-site care routine for a well-healed exit site would appeal to many; however, most centres do use some kind of cover (Piraino 2008).

Catheter immobilisation

From the moment the catheter is inserted, it should always be securely anchored to the patient's skin to avoid torque movements at the exit site. This has been shown to reduce the risk of exit-site infection (Piraino *et al.* 2005) and can be achieved by using tape or a commercially available immobilisation device or tube holder.

Swimming and bathing

Swimming and bathing can be discussed with patients once the exit site is fully healed and ideally free from infection, with the following recommendations.

A waterproof or occlusive dressing should be applied (there are specialist products available) and the exit site should be cleaned and new dressing applied immediately after immersion in water using normal technique.

It is not recommended to immerse the exit site in water without a waterproof dressing, particularly hot tubs, jacuzzis and so forth. Diving should be avoided as this may put tension on the catheter at the exit site (Wild and Ansell 2010).

Indications for catheter removal

A PD catheter is designed to be a permanent access device, and its removal should not be routine. However, catheters may have to be removed under the following conditions:

- if they are no longer needed;
- in recurrent peritonitis without an identifiable cause;
- in peritonitis due to an exit-site and/or tunnel infection;
- with an unusual causative organism of peritonitis, for example fungus, tuberculosis;
- in bowel perforation accompanied by peritonitis;
- with persistent and severe pain due either to the catheter impinging on internal organs or during solution inflow;
- when there is Dacron cuff erosion and infection.

Peritoneal Dialysis Therapy Options

Dialysis should be prescribed according to each individual patient's clinical and lifestyle needs. The dose of PD can be increased or decreased by adjusting any one of the following parameters:

- dialysis fluid fill volume per exchange;
- number of dialysis fluid exchanges;
- length of dialysis fluid dwell time;
- osmotic strength or type of dialysis fluid.

By using the PET each patient's membrane characteristics can be determined, therefore allowing optimisation of the therapy. There are two general methods of performing peritoneal dialysis: CAPD and APD.

Continuous ambulatory peritoneal dialysis

Continuous ambulatory peritoneal dialysis (CAPD) (Figure 9.11) is carried out during the day time, manually by patients themselves or sometimes by a carer. Dialysis fluid is infused into the peritoneal cavity and left to dwell for between 3 and 10 h. After this time the dialysate is drained from the cavity, fresh solution is infused and the whole process starts again. Patients usually perform four exchanges of PD fluid each day, fitting them in as appropriately as possible with their normal lifestyle. For example, exchanges may be performed at breakfast, lunch and supper time with the last exchange of the day being carried out at bedtime. Each exchange takes about 20–30 min to complete.

Continuous ambulatory peritoneal dialysis is most suited to those patients whose membranes transport solutes at an average rate (i.e. low, low-average and high-average 'transporters') as it provides the opportunity for longer dwell times. This long dwell period is best achieved during the night time whilst the patient sleeps. Those patients whose membranes transport solutes quickly ('high transporters') may need to use an icodextrin solution for the longest dwell overnight. This will avoid dialysate fluid absorption which could occur in these patients during long dwell periods.

Automated peritoneal dialysis

Automated peritoneal dialysis (APD) is carried out by a machine, which performs the dialysis fluid exchanges at night whilst the patient sleeps. An APD machine automatically controls the fill volume, dwell time and length of treatment the patient receives. The dose of dialysis can easily be increased during APD as it is easy and convenient to alter the parameters of the treatment. Dialysis fluid fill volumes can be more safely increased due to the reduction in intraabdominal pressure achieved whilst the patient is supine. This not only decreases the risk of problems associated with high intraabdominal pressure such as leaks around the catheter exit site, abdominal hernias and back pain, but it also increases the amount of dialysis the patient can achieve.

The length of the dwell time and the number of exchanges can effectively be altered without disruption to the patient's lifestyle. This is a major advantage to 'high transporters'. Performing frequent exchanges is essential for these patients to achieve adequate dialysis but this can be inconvenient if the patient is on CAPD. APD provides an

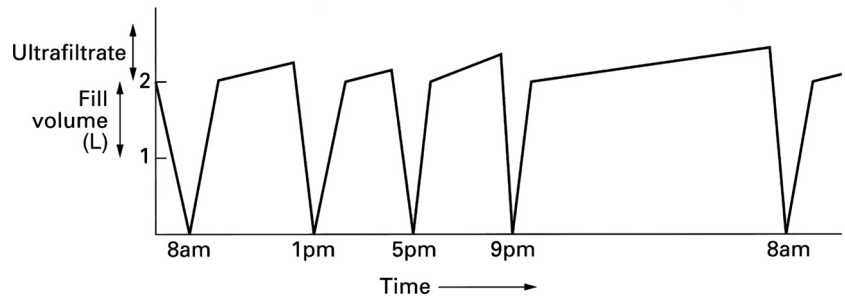


Figure 9.11 Continuous ambulatory peritoneal dialysis.

effective and convenient alternative by enabling rapid exchanges of dialysis fluid whilst the patient sleeps. This increases clearances of solutes whilst maintaining maximum ultrafiltration. As with CAPD, the osmotic strength of the fluid can be altered according to each patient's need.

Automated peritoneal dialysis is particularly suitable for those patients needing to be free during the day-time. Patients who work or who are studying can benefit from this treatment, as the preparation time for the treatment is short and the dialysis takes place whilst they sleep, leaving them free during the day. Automated peritoneal dialysis is also suitable for those patients who rely on a carer to perform their dialysis, for example children, older people or those with disabilities. The carer simply prepares the machine, connects the patient to the machine at bedtime and disconnects them the following morning. Automated peritoneal dialysis is therefore an effective therapy option for those patients who require more dialysis and/or freedom during the day time. However, in order to achieve adequate dialysis, many patients will also need to perform an exchange in the early evening.

Some APD machines have the facility to store information regarding the patient's therapy on a data card that is fitted inside the machine. This data card also stores the patient's individual prescription, enabling the prescription to be altered by a healthcare professional, without the need for the patient's intervention.

There are three different types of APD:

- continuous cycling peritoneal dialysis (CCPD);
- tidal peritoneal dialysis (TPD);
- optimised cycling peritoneal dialysis (OCPD).

Continuous cycling peritoneal dialysis (Figure 9.12)

The 'continuous' part of the acronym is derived from the fact that the patient has dialysis fluid in constant contact with the peritoneal membrane. There are typically between five and seven exchanges of fluid with relatively short dwell periods, so maximising the ultrafiltration and clearance capabilities of those patients whose membrane transports solutes quickly. The treatment regime can be programmed to end with a 'fill', giving the patient a 'wet day' (the fluid would be left inside the peritoneal cavity during the day and drained when the patient next starts treatment on the machine at bedtime). Icodextrin solution, designed for long dwells, should preferably be used in these circumstances.

Rarely, the treatment ends following the 'drain', giving the patient a 'dry day'. This may help to prevent absorption of the PD fluid in 'high transporters'. It should be noted, though, that utilising a 'dry day' will result in severely reduced clearances and possibly underdialysis.

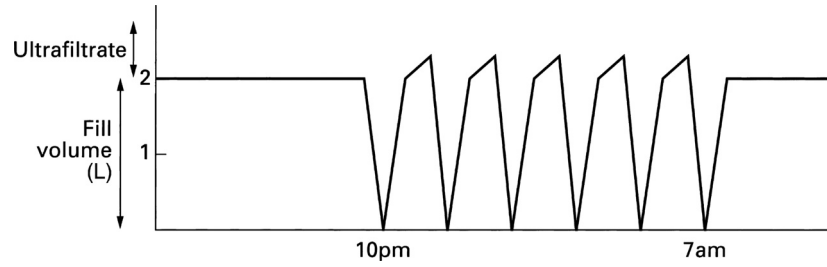


Figure 9.12 Continuous cycling peritoneal dialysis.

Tidal peritoneal dialysis (Figure 9.13)

Tidal PD is a form of APD where the dialysis fluid fill volume is not fully drained after each cycle. It is typically used for patients who experience pain at the end of each drain phase. Particularly new or acute patients getting used to the sensation of fluid in the peritoneal cavity. By leaving a small "sump" volume of about 10% of the dialysis fill volume in the patients peritoneal cavity at the end of each drain phase, pain is minimised. A full drain takes place at the end of the therapy during the final drain. The sump volume should be minimised as patient comfort allows to ensure the patient receives optimum therapy. It is important to remember to check the minimum drain volume parameters to avoid IIPV (Increased intraperitoneal volumes) and associated risks.

Optimised cycling peritoneal dialysis (OCPD) (Figure 9.14)

This method of APD enables the delivery of more dialysis as the patient's residual renal function declines. During OCPD the patient performs overnight CCPD or TPD as well as adding a day-time exchange of PD fluid. Some APD machines are designed so that the patient can perform both the night and day exchanges using the same disposable equipment and solution bags. The longer dwell of fluid during the day time will optimise clearance opportunities and the shorter dwells of the night-time dialysis will help to achieve ultrafiltration goals.

Whichever method of PD is chosen for the patient at any particular time, it should provide a balance between clinical and lifestyle needs. Figure 9.15 shows an example of an APD machine.

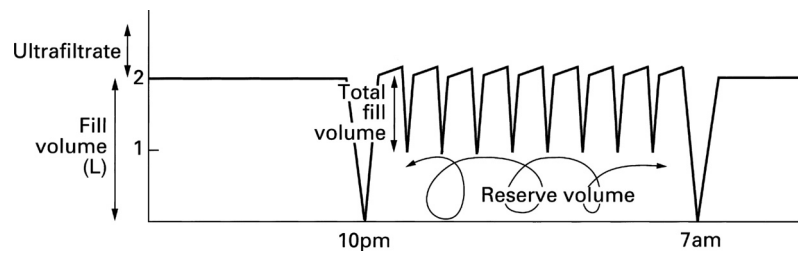


Figure 9.13 Tidal peritoneal dialysis

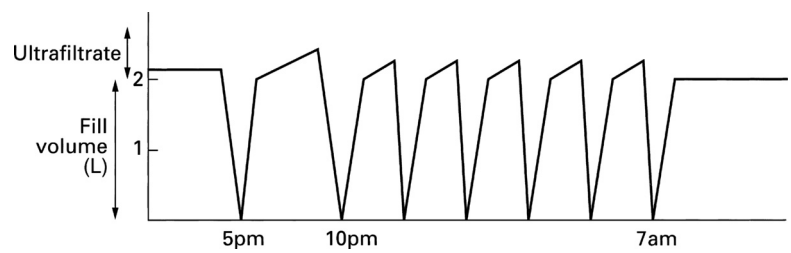


Figure 9.14 Optimised cycling peritoneal dialysis

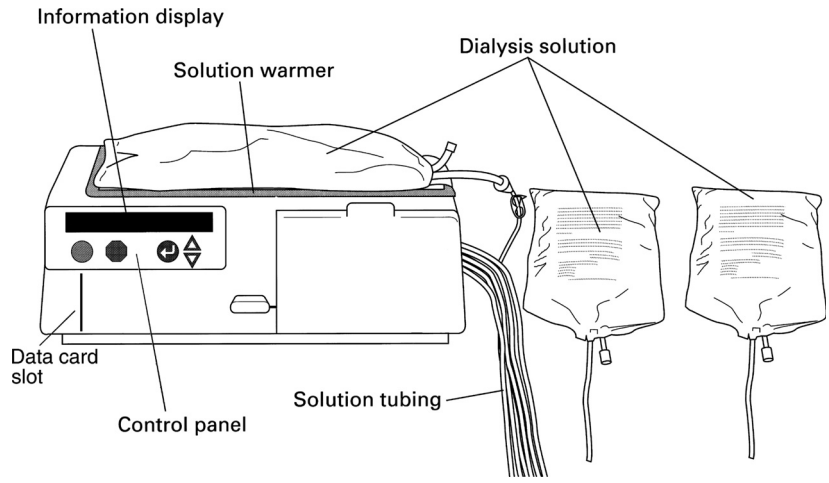


Figure 9.15 Baxter Healthcare Ltd HomeChoice Pro automated peritoneal dialysis machine (used with kind permission from Baxter Healthcare Ltd).

Patient Selection

An important consideration when developing a successful PD programme is good patient selection. Treating the most appropriate patients with PD will avoid the patient being subjected to increased risk of morbidity and mortality. In the early years of PD, selection was mainly based on the patient's inability to have haemodialysis – for example, those patients with poor or no vascular access, poor biochemical control on haemodialysis with high predialysis serum levels of creatinine, those patients with poorly controlled hypertension and those with excessive fluid gain between dialysis sessions. Positive selection criteria are now preferred as PD has proven to be a successful viable alternative to haemodialysis as a treatment for chronic renal disease.

The National Institute of Health and Clinical Excellence (2011) guidelines recommend that PD should be first line treatment for patients without significant co-morbidity and those with residual renal function. In 2011, Molnar published a paper reporting that PD pre-transplantation had a positive effect on survival post transplant. As there are two different therapy modes within the broad title of PD (i.e. CAPD and APD), the selection criteria for each are seen to be slightly different with many overlaps. Tables 9.2 and 9.3 indicate which patients are more suited to APD and those who are more suited to CAPD.

Peritoneal Dialysis for those with Diabetes

Diabetic nephropathy is the leading cause of end-stage renal disease worldwide (Atkins and Zimmet 2010). Although death rates of patients with diabetes on haemodialysis and peritoneal dialysis (PD) have decreased substantially, they remain higher than rates in nondiabetics on both modalities. PD offers equal survival compared with haemodialysis for younger patients with diabetes during early years of dialysis. Mehrotra et al. (2011) describes the benefit of preserving vascular access in patients who often have poor vasculature.

Table 9.2 Patients who are most suited to continuous ambulatory peritoneal dialysis (CAPD) or automated peritoneal dialysis (APD).

Suited to CAPD	Suited to either CAPD or APD	Suited to APD
Patients whose membranes transport solutes slowly or at an average speed.	Those who prefer a home-based therapy	Patients who seek day-time freedom to attend work or school
	Patients with complicating cardiovascular disease.	Patients at risk of complications associated with raised intraabdominal pressure
	Children with small body size.	Patients who require a carer to perform their dialysis
	Patients with poor vascular access.	Patients with chronic backache
	Patients with diabetes mellitus.	Patients who require enhanced dialysis, i.e those without residual renal function
	Patients with severe hypertension.	
	Patients with anaemia.	
	Patients who wish to travel.	

Blood glucose control

A patient using only glucose-based solutions will absorb between 100 and 150 g of glucose per day from the dialysis fluid. This can lead to problems, such as hyperinsulinaemia and premature arteriosclerosis. Alternative solutions offer benefits for those with diabetes. Glucose-free solutions (Icodextrin and amino-acid solutions) provide an excellent solution for people with diabetes as the use of these fluids significantly reduces the amount of glucose absorbed by the patient.

There are a number of methods of blood sugar control for patients with diabetes on PD. These include subcutaneous or intraperitoneal insulin, oral agents or dietary control. Any combination of these methods can be used. No single method has been shown to be more suitable than another for all patients as there appear to be no studies that compare the effectiveness of different methods of insulin administration; however, all methods appear to be effective in achieving metabolic control of blood sugar. Poor glycemic control appears to be associated with higher mortality in patients on PD (Duong *et al*. 2011). It is very important to be aware of the danger of

Table 9.3 Patients who are unsuitable for continuous ambulatory peritoneal dialysis (CAPD) or automated peritoneal dialysis (APD).

Unsuitable for CAPD	Unsuitable for either CAPD or APD
Patients with chronic back pain.	Patients with chronic obstructive lung disease.
Patients at risk of complications associated with raised intraabdominal pressure.	Patients with diverticular disease
	Patients who are unable to care for themselves and do not have the assistance of a full-time carer.

using inappropriate point-of-care glucose meters in patients using icodextrin dialysate (Perera *et al*. 2011).

Intraperitoneal insulin

There are many benefits to adding insulin via the intraperitoneal (IP) route. Insulin administered by the IP route crosses the peritoneal membrane by passive diffusion and is predominantly delivered to the liver via the portal circulation before reaching the systemic circulation. Following IP administration, the concentration of peripheral-free insulin is lower when compared to the peripheral free insulin concentration achieved following subcutaneous dosing. A proposed advantage of IP insulin administration is that insulin is delivered to the liver without creating hyperinsulinemia, a situation thought to be potentially atherogenic.

Absorption of insulin from the peritoneal cavity is concentration dependent. Insulin administered into an empty peritoneal cavity will be absorbed more rapidly and completely than if the insulin is administered in a large volume of dialysis solution. Direct injection of multiple daily doses of insulin into the peritoneum may be impractical for most patients. Therefore IP insulin is usually administered via the routine dialysis fluid exchange. Conversion from a stable subcutaneous insulin dose to IP insulin dosing at initiation of PD usually requires a 2.5 to 3.5-fold increase in the insulin dose. This increase is needed because of the incomplete absorption during the dialysate dwell period, an increased insulin requirement due to the hypertonic dextrose-containing dialysate, and possible adsorption (binding) of the insulin to the polyvinyl chloride surface of the dialysis bags. Approximately 10 to 20% of the administered dose may bind to the surface of the PD bag and tubing. Regular (shortacting) insulin should be used for IP dosing.

For patients using CAPD, the total daily insulin dose should be divided among the exchanges according to anticipated calorie intake from food and dialysate dextrose. Additional amounts of insulin may need to be added to exchanges containing more hypertonic dextrose concentrations. The exact amount varies between patients but may be assessed at onset by using a sliding scale of insulin with capillary blood glucose monitoring. Dose stabilisation may require several days. Insulin requirements often increase during episodes of peritonitis.

There are a few issues that should be taken into consideration when deciding to use this method of administration: Patients who have dexterity and/or visual problems may experience difficulties injecting insulin into the medication port and the potential exists for contamination of the sterile dialysate solution when adding any medicine via the intraperitoneal route. Patients also require frequent blood glucose monitoring when attempting to regulate IP insulin initially (Farina 2004).

Insulin should be added to the bag of dialysis fluid before it is connected to the patient. In this way, the bag may be discarded if accidentally contaminated or punctured by the needle. Strict aseptic technique must be followed when adding the insulin, which is usually done through the specially designed medication port. All bags should be inverted several times before the fluid is drained into the patient to ensure thorough mixing of the insulin. There is no evidence to suggest that IP insulin administration increases the risk of peritonitis (Williams *et al*. 2000).

A recent meta-analysis of subcutaneous versus IP insulin for patients with diabetes mellitus on continuous ambulatory peritoneal dialysis found that use of IP insulin provides adequate glycaemic control, which appears superior to that seen following treatment with conventional SC insulin. However the authors reported that research data are limited and further studies are needed to assess for the long-term safety of this approach (Almalki *et al*. 2012).

Solution Formulation

Peritoneal dialysis solution is presented in sterile plastic bags with a protective overpouch in volumes of 500, 750, 1000, 1500, 2000 and 2500 ml. Bags of 5000 ml are available for use with APD machines. The electrolyte concentration of dialysis fluid is similar to that of normal serum, with lactate acting as a bicarbonate-generating agent to combat metabolic acidosis, which is common amongst patients.Electrolyte composition of the dialysis fluid has been changed several times over the years. A major challenge when treating patients with kidney disease has been effective phosphate control. Consequently, dialysis fluid does not contain any phosphate, and patients are given oral phosphate-binding agents to help eliminate dietary phosphate intake from the body. Calcium is an effective phosphate binder given in the form of calcium carbonate or calcium acetate. These binders can lead to raised serum calcium levels, particularly if the patient is also having vitamin D therapy. This led to the manufacture of a dialysis fluids containing physiological levels of ionised calcium and this solution (a) is compared to the original solution (b) in Table 9.4.

Glucose-based solutions

Up until the early 1990s, the most commonly prescribed and the most widely available osmotic agent used in PD was glucose. Glucose based dialysis fluid comes in three strengths (1.36%, 2.27% and 3.86% monohydrate glucose). The strong (hypertonic) solutions provide the greater osmotic strength. Patients should use 1.36% glucose most often whilst their weight is within 0.5 kg of their 'dry' or 'target' weight. Hypertonic solutions should be used when the patient has fluid overload. Most patients ultrafiltrate an extra 200–600 ml by using a 2000 mL medium (2.27%) glucose solution bag and an extra 400–1000 ml by using a 2000 ml strong (3.86%) glucose solution bag. Patients should be taught to record their body weight on a daily basis and choose the appropriate solution strengths for that day.

Ultrafiltration by hypertonic solutions is maintained for approximately 8 h in most patients (Figure 9.17). After this time some reabsorption of fluid may occur. In those patients whose membranes transport solutes quickly (high transporters), reabsorption may occur sooner than 8 h, giving rise to the need to use an icodextrin fluid exchange for the longer dwell times (i.e. the overnight dwell in CAPD or the day-time dwell in APD).

Table 9.4 Comparison of dialysis fluid containing ionised calcium (a) with original solution (b).

	a (mmol/l)	b (mmol/l)
Sodium (Na)	132	132
Chloride (Cl)	95	95
Lactate	40	35
Magnesium (Mg)	0.25	0.75
Calcium (Ca)	1.25	1.75

Icodextrin peritonal dialysis solution

There are problems associated with the use of glucose as an osmotic agent, such as hyperglycaemia and hyperlipidaemia. Patients who have poor ultrafiltration provide the greatest challenge in this area. Worsening fluid balance results in reduced technique and patient survival. Icodextrin solution is known to improve ultrafiltration in the long dwell during PD (Paniagua *et al*. 2009).

Icodextrin 7.5% is a formulation of a large molecular-weight glucose polymer, which is a more biocompatible solution as it is approximately iso-osmolar with serum. The use of this larger molecule means that less glucose is available for absorption through the peritoneal membrane. Its long-acting ultrafiltration performance (up to 12 h) is combined with low carbohydrate absorption. Icodextrin reduces the exposure of the peritoneal membrane to glucose for more than 50% of the dialysis time if used for the long dwell and improves fluid balance and BP control compared with 2.27% glucose (Lin *et al*. 2009).

Paniagua *et al*. (2009) demonstrated that patients using Icodextrin had significally reduced glucose exposure and this was, in turn, associated with stabilisation of weight in patients with diabetes.

The 2010 Renal Association standards recommend that specialised solutions such as glucose polymers (Icodextrin) are preferable for patients with high or high average solute transport.

Bicarbonate/lactate-based peritoneal dialysis solutions

Bicarbonate/lactate solutions were developed following extensive research to identify the most suitable alternative formulation to the traditional lactate buffered solutions. The commercially available solution comes in a double-chambered bag because some of the compounds of the bicarbonate/lactate solution are not stable during the steam sterilisation process. Glucose needs to be in acidic conditions (low pH) in order to prevent caramelisation. Since the bicarbonate/lactate solution is neutral, the glucose has to be separated from the other compounds. The glucose sits in the upper, smaller chamber, together with calcium and magnesium salts, under acidic conditions. The bicarbonate, lactate and sodium salt sit in the lower, larger chamber. The two solutions are mixed just before infusion (usually whilst the patient is draining the used fluid during CAPD or during the set up of the APD machine).

This solution, with a combination of bicarbonate 25 mmol and lactate 15 mmol as the buffer, is intended for all exchanges. The solution has a physiological buffer system, with a physiological pH of 7.4, and reduced glucose degradation product levels. It allows a significant reduction of inflow pain and/or discomfort in sensitive patients and has a high potential for improved long-term preservation of the peritoneal membrane (Han *et al*. 2009).

The composition of a bicarbonate /lactate-based solution is:

- glucose monohydrate: 1.36%, 2.27% or 3.86%;
- sodium chloride: 5.38 g/l;
- calcium chloride: 0.184 g/l;
- magnesium chloride hexahydrate: 0.051 g/l;
- sodium bicarbonate: 2.10 g/l;
- sodium lactate: 1.68 g/l.

They have several advantages as a buffer for PD solutions

- physiological pH and bicarbonate concentration;
- reduced pain on infusion;
- improved membrane preservation;
- retrospective studies have suggested that biocompatible PD solutions may reduce the rates of peritonitis, although a long-term follow-up study not detect any clinically significant advantages in terms of technique survival or peritonitis (Srivastava *et al*. 2011);
- preservation of residual renal function (Johnson *et al*. 2012).

Physiological pH and bicarbonate concentration

Bicarbonate is the natural buffer of the body. As a result of the metabolism of ingested foods, our body produces hydrogen ions (protons). This acid must be excreted or neutralised in order to maintain the body's acid–base balance. The kidneys play a key role in maintaining the acid–base balance. Not only do they excrete hydrogen ions, but they also regenerate bicarbonate. In people with renal failure this function is impaired or lost. Therefore it is important to replace the lost bicarbonate to maintain the acid–base balance and prevent the occurrence of acidosis. Using bicarbonate in the PD solution is the most natural way of restoring the bicarbonate level. Alternative buffers, like lactate, need some conversion (metabolism) before they result in bicarbonate.

The biocompatibility of a PD solution has been defined as the ability of a solution formulation to permit adequate long-term dialysis without a clinically significant undesirable host response (Consensus Conference on Biocompatibility 1994). These objectives will best be met by solutions whose composition is identical to the composition of extracellular fluid in the body, in particular to the composition of blood. Bicarbonate and lactate PD solution has been developed as an alternative buffer component.

Reduced pain on infusion

A clinical study on the treatment of pain on infusion (Cho *et al*. 2012) compared a bicarbonate/lactate solution and another experimental solution based on 38 mmol/l of bicarbonate (without lactate). The experimental solution and the bicarbonate/lactate solution both reduced the infusion pain, but the bicarbonate/lactate mix appeared the most effective.

Improved membrane preservation

In a study comparing lactate and physioneal, physioneal showed significant improvements in cytokines and markers of peritoneal membrane damage such as effluent advanced glycosylation end-products (AGE) and IL-6 (Fusshoeller 2004).

Amino acid based peritoneal dialysis solution

Intraperitoneal amino acid (IPAA) solution contains 15 amino acids. Eight are essential amino acids, two are considered essential to patients with kidney disease and five are nonessential. The electrolyte formulation is shown in Table 9.5. The osmotic agent glucose is replaced by 1.1% amino acids, which have the comparative ultrafiltration capability of 1.36% glucose solution. After a 4–6 h dwell, 65–95% of the amino acids are absorbed, the equivalent to about 18 g (from a 2000 ml bag containing 22 g of amino acids) or 0.3 g/kg/day in a 70 kg patient. This is approximately 25% of the daily protein requirement for a patient on PD.

Intraperitoneal amino acid is administered in the same way as other PD solutions. It is prescribed for one exchange per day, replacing one of the usual glucose dialysis solution bags or mixed with overnight glucose solutions during APD. If given during the day, it should be given either at a main meal or with a high-calorie snack, as this

Table 9.5 The electrolyte formulation of intraperitoneal amino acid solution.

Sodium	132 mmol/l
Chloride	95 mmol/l
Lactate	40 mmol/l
Magnesium	0.25 mmol/l
Calcium	1.25 mmol/l

will ensure that the amino acids are used in the anabolic process to generate protein rather than being expended as an energy source. The use of 1.1% amino acid PD solution, when used instead of one glucose exchange decreases both peritoneal membrane glucose exposure and systemic glucose absorption.

It now seems obvious that patients will benefit from using a combination of all the available solution formulations, including amino acid, polyglucose, bicarbonate/lactate and glucose. Renal Association Guidelines offer advice on using different PD solutions (Woodrow and Davies 2011).

Assessing Peritoneal Dialysis Adequacy

It is well documented that many patients survive well on dialysis and this is due to its ability to remove nitrogenous waste products, correct electrolyte and acid-base imbalance, and remove excess fluid. Patients feel unwell if they are inadequately dialysed; they eat less, become malnourished, and are therefore at increased risk of infection. Inadequate fluid removal causes hypervolemia, which results in hypertension, fluid overload, and cardiac complications.

The goals of PD are to prolong life, reverse the symptoms of uraemia, maintain patients in positive nitrogen balance, have an adequate energy intake and have their maximum level of quality of life in a way that is least disruptive to their lifestyle. A major benefit of a home-based therapy is promoting patients' control over their own condition and treatment, which can have positive physical and psychological effects (Mathers 2011). This can be summarised by saying that well dialysed patients feel well enough to eat a sufficient diet rich in protein and experience a minimum of complications to their treatment.

There are a number of ways in which dialysis adequacy can be measured and all parameters must be taken into consideration:

- creatinine clearance – a solute-removal test based on body surface area;
- *Kt/V* – a urea index relating urea clearance to the volume of urea distributed in the body (see below);
- protein nutrition;
- general wellbeing.

Creatinine as a measure of dialysis adequacy

Creatinine is a metabolic product from the breakdown of muscle. Patients who have a larger muscle mass therefore tend to have higher serum creatinine levels. Creatinine, with a molecular weight of 113 Da, will equilibrate more slowly across the peritoneal membrane than urea (molecular weight 60 Da).

A normalised BSA of 1.73 m^2 is used to enable an assumption of the creatinine generation rate based on a patient's size, provided that the patient is infection free and in nitrogen balance.

Urea as a measure of dialysis adequacy

Urea is a metabolic product of the protein we eat. As more protein is eaten, more urea is generated. It therefore follows that when examining a patient's serum urea levels it is important to take into consideration recent protein intake. A low serum urea in a patient with ERF may simply be due to a low protein intake, rather than adequate dialysis. A high serum urea on the other hand may indicate increased catabolism, a deterioration in residual renal function or inadequate dialysis. Urea is a small molecule (molecular weight 60 Da), which is distributed in body water. It diffuses readily and is therefore easily removed from the blood.

The prescription index *Kt/V* was developed by Gotch *et al.* (1983) and Gotch and Sargent (1985) in the National Co-operative Dialysis Study of patients on haemodialysis. *Kt/V* is an index of urea removal, which is patient-specific as it looks at urea removal achieved over time ($K \infty t$) and measurement of urea in the body water (V) for each patient. Therefore: K = clearance; t = time; V = volume of body water in which urea is distributed.

The index does not account for dietary protein intake, protein catabolic rate or urea generation rate. It is just as important to measure residual renal *Kt/V* as it is to measure dialysis *Kt/V*. The two should be added together to give a total weekly *Kt/V* value. *Kt/V* for both the patient's dialysis regime and residual renal function can be calculated using the worksheet shown in Figure 9.16.

Protein nutrition

Malnutrition has been shown to be a major risk factor in survival of patients on PD (Carrero 2009). Various terms have been used to identify a patient's nutritional status; these include serum albumin level, dietary protein intake (DPI), protein catabolic rate (PCR) and subjective global assessment (SGA). A patient's nutritional status is an important factor in assessing a patient's dialysis adequacy but, as with all measures, it should not be taken in isolation.

Protein intake and PCR are important issues to be considered for those on PD. It is vital that the PD nurse and dietitian and the patient work closely together to avoid the complications associated with malnutrition.

SGA is a simple and reliable tool which is increasingly being used in the diagnosis of malnutrition amongst patients with ERF: see Chapter 13 for further details.

General wellbeing

Despite the efficacy of a combination of the above physical parameters for measuring adequacy of dialysis, there can be no doubt that the ultimate gauge of treatment success must increasingly become the overall quality of life of the patient. There is now widespread agreement that in assessing the effects of a treatment it is essential to assess both the quality and quantity of life. Healthcare purchasers are increasingly under pressure to demonstrate cost-effective utilisation of the limited resources available to them. Quality-of-life assessment is a key outcome measure in determining this cost-effectiveness, but its multidimensional and subjective nature means that it is problematic to measure.

Name patient:
Date:

*Kt/V**

1. Information required

a. Patient		b. 24 hour urine		c. 24 hour dialysate		d. Serum	
Weight	..... kg	Volume	 l	Volume	 l	Urea	..... mmol/l
Height	..... cm	Urea	..... mmol/l	Urea	..... mmol/l	Creatinine ($\frac{\mu mol/l}{1000}$)	..... mmol/l
		Creatinine	..... mmol/l	Creatinine ($\frac{\mu mol/l}{1000}$)	..... mmol/l		

2. *Kt/V* calculation

a. Residual renal *Kt/V*

Step 1:

$$\frac{\text{..... mmol/l}}{\text{..... mmol/l}} \times \frac{\text{..... l} \times 1000}{1440\ (\text{min. in 24 h})} = \underset{\text{Residual renal clearance}}{\text{..... ml/min}}$$

Step 2:

$$\frac{\text{..... mmol/l} \times 1440 \times 7}{\text{..... kg} \times (\male\ 0.6\ /\ \female\ 0.55) \times 1000} = \underset{\text{Weekly residual } Kt/V}{\text{.....}}$$

b. Dialysate *Kt/V*

$$\frac{\frac{\text{..... mmol/l}}{\text{..... mmol/l}} \times \text{..... l} \times 7}{\text{..... kg} \times (\male\ 0.6\ /\ \female\ 0.55)} = \underset{\text{Weekly dialysate } Kt/V}{\text{.....}}$$

3. Total *Kt/V*

$$\underset{\text{Weekly residual } Kt/V}{\text{.....}} + \underset{\text{Weekly dialysate } Kt/V}{\text{.....}} = \underset{\text{Weekly total } Kt/V}{\text{.....}}$$

4. Compare patient's weekly *Kt/V* with target

Patient ..... (Weekly total *Kt/V*) ≥ ..... Target

* *K* = Urea clearance (l/week) - *T* = Number of days per week the patient dialyses
V = Volume of urea distribution

Figure 9.16 *Kt/V* worksheet.

Preservation of residual renal function (RRF) is an important goal for dialysis and patients treated with peritoneal dialysis have been shown to have a 65% lower risk of RRF loss than those on haemodialysis (Moist *et al.* 2000). The direct mechanisms behind this are unknown but preservation of residual renal function is improved with better volume control, blood pressure management and superior nutritional status (Blake *et al.* 2011). This should all be taken into consideration when measuring the adequacy of dialysis.

Clinical guidelines

Current Renal Association guidelines (Renal Association 2010) recommend combined urinary and peritoneal small solute clearances of $Kt/V > 1.7$/week or a creatinine clearance of > 50 L/week/1.73 m^2 to considered as minimum treatment doses and should be measured 6 monthly in patients who are stable but more frequently if a patient's condition determines. The guidelines recommend that this is a minimum treatment dose and should be increased in patients experiencing symptoms, again reinforcing the importance of the patient's quality of life.

Various studies have explored increasing these clearances but have shown no survival benefit, and there is no clear evidence of this being affected by the patients transport status (Blake *et al.* 2011).

A study was conducted to demonstrate that PD can be a successful treatment for patients who do not pass urine (Brown *et al.* 2003). The European APD Outcome Study (EAPOS) was a two-year, prospective, multicentre study. A total of 177 patients were enrolled. The APD prescription was adjusted to aim for creatinine clearance (C_{crea}) of 60 L/wk per 1.73 m^2 and ultrafiltration (UF) of 750 ml/24 h during the first 6 months. Baseline solute transport status (D/P) was determined by peritoneal equilibration test. At one year, 78% and 74% of patients achieved C_{crea} and UF targets, respectively with 50% of patients using icodextrin. The two-year patient survival was 78% and technique survival was 62%. This study showed that patients who do not pass urine can successfully use APD. Baseline UF, not C_{crea} or membrane permeability, is associated with patient survival.

There are a number of computer programs available on the market that will calculate the patient's *Kt/V*, creatinine clearance and nutritional status. Some of these programs will also model the patient's treatment, allowing the nurse or physician to look at a wide range of PD therapy options for the optimal regime that meets the adequacy needs of each individual patient. This enables the clinician to eliminate the trial-and-error process of prescribing PD, takes away the need to perform manual calculations, and provides the renal unit with a database of their patients' quality of dialysis.

If patients are no longer achieving these adequacies the prescription can be increased taking into account the patient's lifestyle and how these changes can be accommodated within reason. As this potentially becomes more difficult with the membrane beginning to deteriorate with the loss of residual renal function the possible need for the change to haemodialysis should be explored to allow the patient time to rationalise this choice. Again the patients reasons for choosing PD should be remembered and the implications of changing therapies on their lifestyle should be balanced with the patients clinical condition to allow for a collaborative decision to be made.

Longitudinal Changes to the Peritoneal Membrane

The peritoneal membrane has proven to be remarkably resilient and there are a number of studies that have shown it to be stable over time (Selgas *et al.* 1998; Davies *et al.* 2001; Kendrick and Teitelbaum 2010).

Long-term changes, such as thickening of the peritoneal membrane, can cause a loss of ultrafiltration (Davies *et al.* 2005). This may be associated with exposure of the membrane to the harmful effects of glucose-based solutions (such a glucose degredation products), peritonitis or uraemic toxicity. In fact a marked thickening of the membrane is only seen in patients who experience more than two episodes of peritonitis but thickening was shown in patients who used hypertonic glucose solutions (Kendrick and Teiltelbaum 2010).

It has been demonstrated that by avoiding the use of hypertonic glucose solutions, functional changes in the peritoneal membrane can be avoided for at least five years (Davies *et al.* 2001), but the catheter itself can cause membrane changes (Kendrick and Teitelbaum 2010).

It is worth noting also that thickening of the peritoneal membrane has been seen in patients with uraemia before the onset of dialysis (Plum *et al.* 2001) suggesting that uraemia itself may cause peritoneal membrane changes.

In a small but significant number of patients, encapsulating sclerosing peritonitis (EPS) has been diagnosed, and seems particularly noted in patients when they stop PD. One study found the rate of EPS to be 1.5%, which equated to an incidence of 4.9 per 1000 person-years (Brown *et al.* 2009). EPS is characterised by persistent, intermittent, or recurrent adhesive bowel obstruction (Johnson *et al.* 2010). The pathogenesis of EPS is still not well understood, but it is known that patients who have been on PD for an extended time with associated loss of ultrafiltration have the greatest risk. These patients have tended to be on Icodextrin solutions but this doesn't appear to be a risk factor (Wilkie 2011). Therefore it is important that patients are regularly monitored for loss of ultrafiltration, changes to their membrane and decreasing adequacy of dialysis. These patients need to closely monitored and transition to alternative therapy discussed and planned carefully. The National Institute of Health and Care Excellence (2011) guidelines do not recommend the routine switching of patients from PD after a particular period of time. In patients where EPS is suspected there are designated centres that can diagnose this, as it is important not to confuse EPS with simple thickening of the membrane. One study of 111 patients in the United Kingdom with EPS (one of the largest cohorts of patients with EPS in the literature) found that long-term survival occurred in over 50%, regardless of the various treatments strategies undertaken by various centres (Balasubramaniam *et al.* 2009).

Fluid Management in Peritoneal Dialysis

During PD, hyperosmolar dialysis solution removes fluid by the process of osmosis. Water transport across the peritoneal membrane depends upon the concentration of glucose in the dialysis solution and the size of the pores in the peritoneal membrane. At the same time as fluid is being removed from the blood through osmosis, fluid is continually being reabsorbed through the lymphatic system. In addition the osmotic gradient is continually reducing due to dilution of the PD solution (by the ultrafiltrate) and absorbtion of glucose into the blood. Therefore there comes a point in time during the PD fluid exchange when fluid removal no longer takes place and fluid is reabsorbed back into the patient. This will occur before solute equillibrium.

Fluid removal and fluid balance can be enhanced in patients on PD by increasing the glucose concentration of the diaysate, increasing the volume of fluid used (although a substantial increase in intraabdominal pressure may reduce UF due to the increased pressure), optimising the dwell time/using APD, reducing sodium intake and by using Icodextrin solutions (Renal Association 2010).

Sodium sieving

Most ultrafiltration takes place during the first 30 minutes of an exchange (Venturoli and Rippe 2005). Due to the nature of the peritoneal membrane and the fact that the ultra-small pores are responsible for transporting water during the initial part of the exchange, no convection or diffusion takes places during this time. This results in a sieving process where no solutes are removed during the early stage of a PD exchange. It is important to take this into consideration when using rapid fluid exchanges such as in APD. The sieving effect, particularly of sodium, can have adverse effects on the patient. If rapid exchanges are continually used during the therapy, little sodium will be removed, giving rise to hypernatraemia and its possible effects such as hypertension in the longer term.

Problem-Solving in Peritoneal Dialysis

Protein loss

Protein is lost through the peritoneal membrane at a rate of 6–12 g/day even in patients who are stable. To compensate for this loss, patients on PD need to eat between 1.0 and 1.2 g/kg of body weight/day of dietary protein.

This loss is increased during peritonitis, when a patient can lose up to 20 g/day. Both oral supplements and amino acid dialysate can successfully improve nutrition in PD. Amino acid dialysate therapy lowers the phosphorus load, and perhaps hyperparathyroidism, which offers the patient a benefit to reduce cardiovascular risk (Dasgupta *et al.* 2002).

Cardiovascular and lipid problems

Many patients reach ERF with established left ventricular hypertrophy, coronary ischaemia and vascular disease. However, despite the fact that there have been many advances in the technology and analysis of adequacy of dialysis, cardiovascular morbidity and mortality remain very high in patients on dialysis and this is the most common cause of death (Krediet and Balafa 2010).

Patients experience raised levels of cholesterol and triglycerides within the first year on PD. This is mainly due to the glucose absorbed from PD fluid. Several studies have shown that these changes are not long-lasting and peak levels are usually reached within 3–12 months of starting dialysis.

Raised intraabdominal pressure problems

Raised intraabdominal pressure is caused by the pressure of high volumes of fluid in the peritoneal cavity. This pressure is further increased when the patient carries out strenuous exercise or suffers excessive coughing. Continuous raised intra-abdominal pressure can increase the risk of abdominal hernias such as inguinal, incisional, diaphragmatic or umbilical, and of dialysate leakage around the catheter exit site.

Oedema of the labia in females and the scrotum and penis in males is a distressing complication caused by dialysate leakage through soft tissues. It is usually easily rectified by stopping PD for a short period (usually up to 1 week). Hernias and persistent leaks require surgical repair, while stopping PD for a time to allow the site to heal. If haemodialysis is not an alternative form of treatment for the patient during this

temporary interruption to treatment, PD may be continued so long as the patient is lying down, therefore decreasing the intra-abdominal pressure (i.e. by using some form of APD).

In the event of dialysate leakage at the exit site, PD must be ceased immediately as the presence of a glucose-rich solution at a wound site gives rise to a markedly increased risk of infection. Leakage can be identified by using urine test sticks or blood glucose reagent strips at the exit site. The normal healing time for dialysate leakage is 1 week, but this may be increased in diabetes, severely uraemic or malnourished patients.

Patients with previous vertebral disease may experience back pain due to the raised intraabdominal pressure incurred in an upright position. In this situation APD may be the preferred therapy.

Drainage problems

These usually have a minor cause which, with proper patient training and education, can be rectified by the patients themselves at home. Reasons for poor inflow or outflow of dialysis fluid and their treatment are outlined below.

Kinks in the tubing

The most common cause of poor drainage or inflow of PD fluid is tubing kinks or closed clamps. Patients should be taught to check the tubing for kinks and closed clamps as a first line of action in the event of poor in- or outflow of dialysis fluid. Catheter kinks sometimes occur due to malpositioning during surgical insertion. This will become apparent shortly after insertion, if not during the insertion procedure, and can be confirmed by X-ray (the PD catheter has a radiopaque stripe along its length). This problem is usually rectified by surgical intervention; however, it can occasionally be improved if the patient has a bowel motion.

Constipation

Constipation should be avoided in patients on PD, not only because it causes problems with dialysate outflow but also because diverticulosis of the colon increases the risk of peritonitis. Constipation prevention is achieved by encouraging the patient to take a diet high in fibre along with a mild laxative if appropriate. Regular exercise is also recommended. If constipation does occur, treatment can be with laxatives or glycerine suppositories. The use of phosphate-containing enemas should be avoided due to the absorption of phosphate through the bowel during their administration.

Fibrin formation

Fibrin strands or plugs (a protein formed from fibrinogen in blood plasma in the process of clotting) in dialysate effluent are a common cause of poor drainage. The blockage, usually in the catheter or tubing, can normally be removed by 'milking' the tubing. Heparin may be added to the dialysis fluid (200–500 units/l) as a prophylactic measure, as it prevents the formation of fibrin.

If 'milking' the tubing does not remove the obstruction a fibrolytic agent can be used. Both streptokinase (250 000 i.u.) and urokinase (5000 i.u.) in 2–3 ml sodium chloride 0.9% for i.v. injection are available and should be infused into the catheter under aseptic conditions; the catheter should then be clamped and the drug left to infuse for 2 h. The catheter can then be checked for patency.

Malpositioned catheter

If catheter obstruction is not relieved by any of the above techniques, the problem may be due to obstruction caused by omentum attached to the catheter tip. The omental attachment usually causes the catheter to migrate out of the pelvic cavity. In such cases it often proves difficult to resolve this problem without surgery.

It is possible to remove omentum from the catheter whilst leaving it in place during surgical procedure. It is common for the surgeon to perform a local omentectomy at the same time to prevent further obstructions by omentum. If it proves impossible to rectify the obstruction or position of the catheter by surgical methods the final option is to remove the catheter completely and replace it with a new one.

Shoulder pain

Occasionally, patients complain of shoulder pain following the infusion of fresh dialysis solution. This is thought to be a referred pain caused by intraabdominal pressure or air under the diaphragm. Although it usually resolves within 10–20 min from onset, the patient may find relief by taking a mild analgesia such as paracetamol 1 g.

Blood-stained effluent

This is a comparatively rare complication occurring most commonly in menstruating females. It may be due to endometriosis or retrograde bleeding through the fallopian tubes. The bleeding is usually mild and self-rectifies within a day or two without specific intervention.

More severe IP bleeding, causing darkly blood-stained fluid, can be caused by haemorrhage. This could be due to the patient straining whilst lifting a heavy object or suffering trauma to the abdomen and should be investigated.

Infectious Complications of Peritoneal Dialysis

Peritonitis is a common clinical problem that occurs in patients with ERF treated by PD. It contributes to the failure of PD and hospitalisation. Severe and prolonged peritonitis can lead to peritoneal membrane failure (Piraino *et al.* 2005).

In the past, guidelines have focussed on the treatment of peritonitis, but more recent guidelines focus on the prevention of infection as this is one of the keys to success in PD.

Prevention of PD-related infections

Peritoneal dialysis programmes should carefully monitor the rate of infections – both peritonitis and exit-site infections. The cause of the infections should also be recorded as part of a continuous quality improvement programme. The incidence of relapsing peritonitis should be recorded and appropriate action taken for patients with recurrent infections. This might involve retraining or examining the PD catheter for signs of colonisation.

Rates of infection are expressed as episodes per patient month and are calculated by dividing the total number of episodes by the number of patients treated each month. For example if 100 patients were being treated with PD in January and four had an episode of peritonitis, the rate would be one episode in 25 or 1:25. Cumulative rates should be calculated over the course of a year. In this way interventions can be implemented if infection rates are rising to unacceptably high rates. The current recommended acceptable rate for peritonitis is 1:18 patient months (Piraino *et al.* 2005).

The Advisory Committee for European Best Practice Guidelines (Piraino *et al.* 2005) recommends the use of an assist device for all spiking procedures. The use of double-bag systems is preferred because they are more efficient in preventing peritonitis due to the flush-before-fill procedure.

The prevention of catheter exit-site infections is the primary goal of exit-site care. Once the catheter is placed, and until healing is completed, the dressing should be changed by a dialysis nurse using sterile technique. The exit site should be kept dry until well healed, which means that showers or baths should not be taken for this period, which can take up to 2 weeks. Once the exit site is well healed, the patient should be taught how to do routine exit-site care. Antibacterial soap and water are recommended by many centres. Use of an antiseptic to clean the exit site is preferred in some programmes (Piraino *et al.* 2005).

Training methods can influence the risk of PD infections (Hall *et al.* 2004). In general, patients must be taught aseptic technique, with emphasis on proper hand washing techniques. If the water the patient uses is thought to have a high bacterial count, then use of an alcohol hand rub should be encouraged although this is used routinely in many centres. The hands must be completely dried using a clean towel after washing, before starting the exchange. The place where dialysis exchanges are carried out must be clean, free from animal hair, dust, and fans. All patients must be taught what contamination is and what to do in the event of contamination (they should go to their dialysis unit for a tubing set change if the end of the tubing is accidentally touched). The PD nurses are central to a successful PD programme that has low infection rates. Unfortunately, there are few if any studies on nurse-to-patient ratios that lead to the best outcomes. Overburdening the nurse with excessive numbers of patients will result in shortened training times and difficulty in retraining as needed. The Advisory Committee (Piraino *et al.* 2005) recommends home visits. These may be very useful in detecting problems with exchange technique, but only can be carried out if the nurses have sufficient time to do such visits.

Causes of peritonitis

Most episodes of peritonitis are caused by organisms that are normal skin and nasal flora, for example *S. epidermidis* and *S. aureus*. Occasionally, water-borne organisms such as *Pseudomonas* may also cause this infection. There are five main routes of infection causing peritonitis, each one giving rise to common organisms.

Intraluminal (contamination at the solution bag and transfer set connection site)

This contamination occurs most frequently when poor techniques have been used to make the connection. Good patient training and education regarding bag exchange procedure techniques and handwashing are essential. The incidence of this cause of infection has reduced in recent years due to the use of disconnect systems. These systems incorporate a 'flush before fill' into the procedure, which has been shown to remove organisms caused by touch contamination (Kubey *et al.* 1998).

Periluminal (infection introduced via the catheter tunnel from the exit site)

Bacteria present on the skin surface can enter the peritoneal cavity via the catheter tunnel. This infection can occur if there is infection present at the exit site or in the subcutaneous tunnel which has migrated into the peritoneal cavity. The most common organisms seen when periluminal contamination has occurred are *S. epidermidis,*

S. aureus, Pseudomonas, Proteus and yeast. *S. aureus* nasal carriage is known to cause an increased risk of *S. aureus* exit-site infections, tunnel infections, peritonitis and catheter loss. Prophylaxis with intranasal mupirocin exit-site mupirocin, or oral rifampin has been shown to be effective in reducing *S. aureus* exit site infections. The use of mupirocin ointment at the exit site, however, should be avoided in patients with polyurethane catheters (Cruz catheters) as structural damage to the catheter has been reported. All patients at an increased risk for *S. aureus* infections, including *S. aureus* carriers, those with diabetes and immunocompromised patients, should be provided with prophylaxis. A practical approach is to prescribe exit-site mupirocin for all at-risk patients and so routine nasal swab tests are therefore not necessarily required in these patients.

Transmural (infection through the gut wall)
There is an association between both severe constipation and enteritis and peritonitis due to enteric organisms (Piraino *et al.* 2011). The most common organism seen as a transmural cause of peritonitis is *Escherichia coli,* although multiple contamination with anaerobes and fungi may also be isolated.

Haematogenous (infection via the blood stream)
This is a rare cause of peritonitis and it may be the peritonitis itself which causes septicaemia. The most common organisms associated with this cause of peritonitis are *Streptococcus* and *Mycobacterium*.

Vaginal (ascending through the vagina)
This is thought to be from bacteria entering the peritoneum via the fallopian tubes. The most common causative organisms seen here are *Candida* and *Pseudomonas*.

Diagnosis of peritonitis

Early diagnosis allowing prompt treatment of peritonitis is essential in minimising damage to the peritoneal membrane. Diagnosis is when two or more of the following conditions are present:

- cloudy PD effluent containing >100 white blood cells μ/l (more than 50% of which are neutrophils);
- abdominal pain and tenderness and pyrexia;
- identification of micro-organisms in the PD effluent by positive Gram stain or culture.

The process of diagnosis of peritonitis is summarised in Figure 9.17.

Obtaining a PD effluent specimen

CAPD
After disconnecting the drainage bag containing the effluent from the patient's transfer set, the bag should be inverted several times to mix the contents. Using strict aseptic technique a sample is taken by sterile needle and syringe from the sample port on the bag.

APD
A sample may either be taken from the daytime dwell, if the patient utilises a 'wet day' (i.e. dialysate in the peritoneum during the day), by attaching a drainage set and bag to the patient's extension set. The sample is then taken in the same way as for CAPD. Alternatively, if the patient is usually 'dry' during the day (i.e. no dialysate in the peritoneum

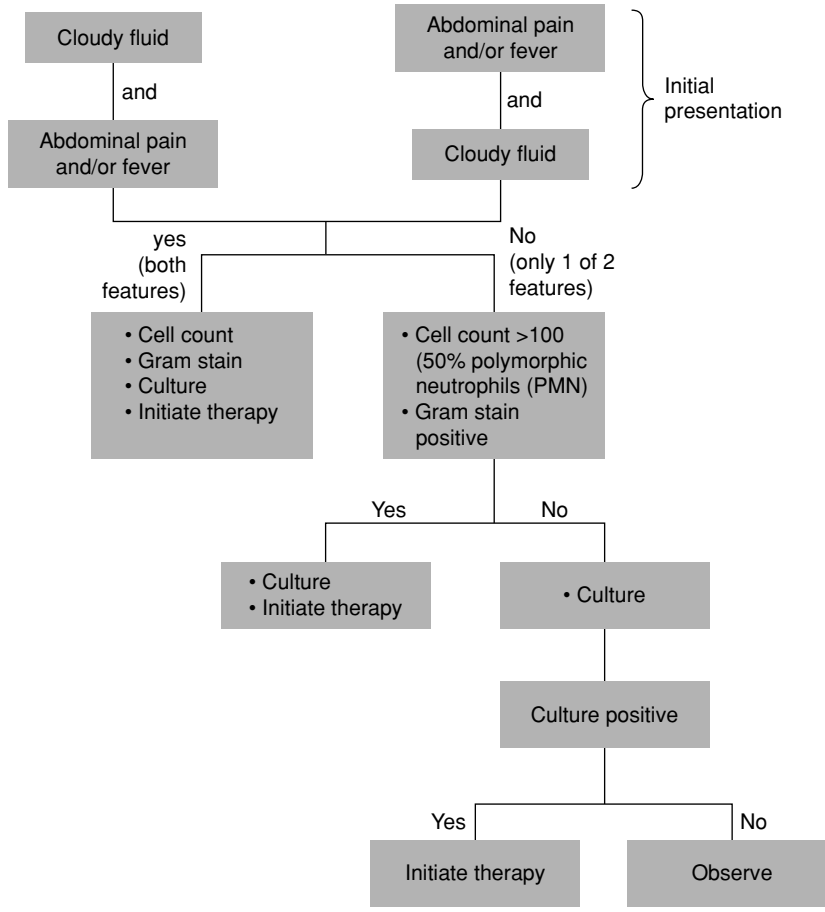


Figure 9.17 Initial clinical and laboratory assessment of a patient for peritonitis.

during the day), there are a number of options. Some APD machines have a sample bag that can be attached to the drainage tubing. Alternatively, the patient may be taught how to take a sample from the drainage solution containers. If this is not possible, the patient may be asked to detach the drainage solution container from the machine following treatment and take this into the unit.

There are many different protocols for the treatment of PD peritonitis. An ad hoc advisory committee has reviewed experiences reported in the literature and devised recommendations based upon these assessments. These recommendations were published in *Peritoneal Dialysis International*, most recently in 2005 (Piraino *et al.* 2005). Antibiotics have been administered i.p. or i.v. or orally, and a number of different dosing regimes have been utilised. The ISPD recommendations (Piraino *et al.* 2005) include advice on treating peritonitis due to the most common organisms such as coagulase-negative *Staphylococcus, Streptococcus, Enterococcus, Staphylococcus aureus, Pseudomonas aeruginosa,* and also polymicrobial peritonitis, fungal peritonitis, mycobacteria and culture-negative peritonitis. As always, individual clinical situations and variability in patient populations may necessitate modification of these recommendations.

Many peritonitis episodes are mild and can be treated at home. Usually the incubation period from time of contamination for bacterial peritonitis is 24–48 h. Any symptoms should resolve quickly following the initiation of therapy. If the infection shows either a slow response or no response to treatment, the choice of antibiotics could be inappropriate.

Those on PD should be taught how to recognise the signs and symptoms of peritonitis during their initial training period and at regular intervals. Ideally the patient, if on CAPD, should complete the bag exchange at home (the presence of PD fluid in the peritoneum may provide some pain relief from inflammation of the peritoneal membrane) and bring the bag of cloudy dialysate effluent into the clinic for sampling. Treatment can then be initiated immediately.

There is current debate as to the necessity to perform peritoneal lavage immediately after the diagnosis of peritonitis, as it is thought to reduce the number of phagocytes present in the peritoneum that are available to fight infection. Peritoneal lavage is therefore thought by some to be of benefit only to patients with purulent effluent and abdominal pain as a pain-relieving exercise. There is no evidence to suggest that a transfer set change performed at this time is of any benefit. On admission to the PD clinic the usual fill volume for the patient is medicated with antibiotics.

The patient or carer can be taught how to add the antibiotics to the dialysis fluid to facilitate self-care. Heparin (200–500 units/l) may also be added to the fluid to prevent the formation of fibrin, which is more likely in the presence of infection.

Automated peritoneal dialysis patients may receive antibiotics intraperitoneally by adding the antibiotics to the daytime dwell dialysis solution. Little is known about intermittent dosing requirements in patients treated with APD. In intermittent dosing, the antibiotic-containing dialysis solution must be allowed to dwell for at least 6 h to allow adequate absorption of the antibiotic into the systemic circulation. Most antibiotics have significantly enhanced absorption during peritonitis (e.g., IP vancomycin is about 50% absorbed in the absence of peritonitis, but closer to 90% in the presence of peritonitis), which permits subsequent reentry into the peritoneal cavity during subsequent fresh dialysis solution exchanges (Piraino *et al*. 2005).

Peritonitis is monitored closely and dialysate effluent should be clear within 48 h of commencing treatment. If the peritonitis resolves, antibiotics are discontinued 7–10 days after the start of therapy according to local protocol.

Absorption of antibiotics into the serum through the peritoneum from the dialysate is rapid. Therefore, in most cases, administration of intravenous antibiotics is unnecessary.

Permeability changes during peritonitis

The peritoneal membrane permeability tends to increase during episodes of peritonitis, perhaps due to increased blood flow through the peritoneum. Clearances of both large and small molecules increase, as does the absorption of glucose. This can result in marked increases in protein loss through the peritoneum and poor ultrafiltration. Patients need to be educated as to the need to increase dietary protein intake during episodes of peritonitis and to care for their fluid balance ensuring that, if they have no residual renal function, fluid intake is kept to a minimum. Rarely, patients are severely ill with peritonitis and need to be treated in hospital.

Culture-negative peritonitis

Occasionally (less than 20%), cultures may be negative for a variety of technical or clinical reasons. Duration of therapy should be 2 weeks. If, on the other hand, no clinical improvement occurs within 96 h, repeat cultures should be taken with consideration of mycobacteria or fungi, and catheter replacement or removal should be considered.

Fungal peritonitis

Catheter removal is indicated immediately after fungi are identified by microscopy or culture (Chang *et al.* 2011).

Relapsing peritonitis

Relapsing peritonitis is diagnosed as a recurrence of the same organism within 4 weeks of completion of the course of antibiotics. These infections should be treated in the same way as the initial peritonitis; however, the reason may be due to abscess formation, colonisation of the catheter or subcutaneous catheter tunnel infection. If there is no response to the antibiotics within 96 h, consideration should be given to catheter removal and replacement at a later date.

Exit-site infection

An exit-site infection is defined by the presence of purulent drainage with or without erythema of the skin at the catheter–epidermal interface (Piraino *et al.* 2005).

A culture of the drainage from around the exit site should be obtained. Antibiotic therapy may be initiated immediately if the infection looks severe, or delayed until the results of the culture are available. Therapy should be continued until the exit site appears completely normal. Prolonged antibiotics may be necessary. If 3–4 weeks of antibiotics fails to resolve the infection, the catheter may be replaced.

Redness and swelling around the catheter exit site without purulent drainage are sometimes an early indication of infection. If infection is suspected, then therapy should be initiated: this may be either intensified local care, a local antibiotic ointment or an oral antibiotic that covers Gram-positive organisms. An alternative approach is careful observation for additional signs of infection.

Tunnel infection

Tunnel infection can present as an extension of the exit-site infection into the catheter tunnel: swelling, pain and redness over the subcutaneous tunnel may be observed. Tunnel infections do not often respond well to antibiotic treatment and it is usual to remove the PD catheter in these cases, reinserting a new one after about 1 month. Antimicrobial therapy should be given to the patient in the interim to resolve the infection, preventing migration of the organisms into the peritoneum, and therefore predisposing to peritonitis.

Peritoneal dialysis-related infection recommendations (update) were published in 2010 and provide an overview of the topic in this section (Li *et al.* 2010).

Education and Training for those on Peritoneal Dialysis

It is essential that effective education takes place before patients can be expected to treat themselves at home. Upwards of 90% of the care received by home dialysis patients is self-administered in the home. 'It is a common but erroneous belief that anyone can teach PD, but … success depends upon the approach adopted' (Uttley and Prowant 2000). Literature is scarce regarding PD training programmes. Finkelstein *et al.* (2011) described components of a successful CAPD education programme based on adult learning principles. Adults are usually motivated to learn and are often learning from

choice. They bring a wealth of life experiences with them that influence their learning and response to teaching. However, there are often many challenges for nurses, including working with patients who are ill and have to self-care and this poses many problems and barriers to learning. However with the emergence of assisted PD this has successfully been used as a interim supportive method to build confidence, particularly in patients who live alone or start when they are acutely unwell.

Barriers to learning

People who are just about to start dialysis are often frightened – the prospect of dialysing oneself at home may not appeal. Many new patients have uraemia; symptoms may include nausea, vomiting, sleep disturbances and confusion. Some patients feel so physically unwell by the time they are to commence dialysis that they lack the motivation to learn, feeling that they will never recover.

Teaching this group of patients can be made all the more difficult when other barriers to learning become apparent. A fundamental barrier is language. In the United Kingdom, for instance, there is a growing ethnic population, giving rise to a growing proportion of people who speak little English. There are limited resources available for translation and it is frequently the responsibility of a younger member of the family, often a son or daughter, to act as translator during training. It may thus be difficult to assess who is learning, and with no knowledge of the language that is being translated, the trainer finds it difficult to ascertain just who has grasped the concept or answered the question – the patient or the translator? Language may also become a barrier when speaking to patients with no previous medical knowledge. Jargon and clinical terminology can be frightening and confusing.

Many older patients have to learn PD and having to learn new concepts and procedures on which their life will depend may seem an overwhelming task. This sometimes makes learners feel vulnerable and inadequate, particularly if they are slow to learn. Short-term memory loss is a problem suffered by many elderly patients and is a source of great frustration to both learner and trainer. These patients frequently have added physical barriers to learning, such as poor vision or lack of manual dexterity. Varying levels of deafness may also be a problem – the learner is trying not only to understand what has been said but is also straining to hear.

A report by the Skills for Life national needs and impact survey, DfES in 2003 found that the literacy levels in England were quite poor, with 16% of the population between 16 and 65 being below entry level (Entry level 3 is the level expected of an 11 year old). If we consider this problem in relation to the concepts and procedures that need to be taught to patients on dialysis, it becomes apparent that the information given must be clear, unambiguous and readily understood, particularly if the patient's literacy difficulty is paired with a second or even a third barrier to learning.

The learning environment

The PD training setting was discussed by Castro *et al.* (2012) who described increased patient, nurse and physician satisfaction with home administered PD training. The main objective of home training is to establish, early on, the patient's social environment and psychological status, and to assess how these influence aspects of learning and adapting to PD. When training was individualised to the patient, Davies *et al.* (2000) saw in-home patient training as more efficient than in-centre training as measured by time required to train.

Training materials

Keeping *et al.* (2001) examined informal learning in patients on PD and found that learning increased when learners were asked to discuss their experiences or answer direct questions. This concept has been further developed by Hall *et al.* (2004). The group set out to develop a PD training programme based on what the learner needed to know rather than on what the teacher needs to teach. Although their curriculum took on average 28% longer than traditional methods, this was offset by a reduction in retraining time, exit site infections and peritonitis better fluid balance compliance.

Recommendations for training within renal units

- Set aside an area specifically for teaching purposes. The area should preferably be away from the ward, and be nonclinical and quiet. A television and DVD or PC can be used in this area for teaching.
- Designate a team of nurses for training duties only. Establish some continuity of care by allocating each patient to a designated nurse.
- Invite family members or partners to participate in the teaching programme.
- Use a wide variety of training materials. Five points to good presentation of these materials:
  - Teach the smallest amount possible for the job required;
  - make the point as vividly as possible;
  - review repeatedly;
  - have the learner restate and demonstrate material;
  - the subject matter should be relevant.
- Any material should be presented in a way that is comprehensible to the learner.
- Despite the fact that the readability of the material can be measured by the same formula, readers' skills may vary with their interest and background of experience in a particular topic area.
- Training materials are most effective when presented in an interesting and appropriate manner. Both the language used and the material's degree of complexity need to be taken into account.
- The material should be presented in a memorable fashion. Any visual aids need vivid, simple messages which are easy for patients to remember.
- Finally, but perhaps most importantly; it is essential that the patients want to learn what is being taught.

The training programme should be designed to prepare patients fully for return to the community. The aim of a training programme is to educate patients to a standard whereby they can confidently care for themselves and perform PD in the community. For some learners this may mean that they learn only how to perform PD, troubleshoot and manage their renal diet. For others much more detail may be desired, for example, learning how dialysis works.

Group teaching is an excellent way for patients to learn. This not only enables patients to learn from each other, but also helps the teacher, as many patients can be taught the same subject at the same time. The bulk of the training programme should focus on the patients themselves, relating all they are learning to their disease, treatment and, ultimately, their lifestyle. Sessions should be designed to last for no longer than 20 min and visual aids such as flipcharts, acetates and videos are used to make the material interesting and varied.

On-line resources are a useful tool in the education of people with kidney disease. It provides many advantages in that the information is available 24 h a day 7 days a week. There are now many web sites dedicated solely to the education of patients with kidney failure. The following list proves a useful addition to any training programme:

- www.kidneypatientguide.org.uk (accessed 20 May 2013);
- www.kidney.org/patients/(accessed 20 May 2013);
- www.edren.org/pages/edreninfo/dialysis-and-endstage-renal-failure.php (accessed 20 May 2013).

What to teach patients

It is important that patients new to PD are discharged from the renal unit with enough knowledge to care for themselves safely on dialysis. Broadly speaking, when each patient is taught, priority should first be given to what they must know, then to what they should know, and finally to what they could know. However, all learning objectives should be patient centred.

The following topics should be included in a PD training programme:

- Medication. The patient's own medicines can be used as the central focus for this session. The aim is to ensure that the patient knows how often and why each medicine is taken.
- Normal functions of the kidney. This session can be given in groups using visual aids to explain in a simple way the basic functions of the kidney, relating these to the symptoms they suffer when kidneys fail.
- CAPD and APD procedures. These are most easily taught on a one-to-one basis. Demonstration techniques can be used to explain the procedure. A PD simulator (plastic torso with a PD catheter) is an excellent tool on which patients can practise their exchanges.
- Catheter and catheter exit-site care. This can be taught to the patient on a one-to-one basis. The PD simulator can be used to practise exit-site dressing technique, as can getting the patient to practise the technique in front of a mirror. Photographs are useful to help explain visually the difference between a healthy and an infected exit site.
- How PD works. Osmosis and diffusion can be explained using simple experiments or diagrams.
- Diet. Eating is an activity which most people enjoy and which therefore takes up a rather large part of our lives. Maybe it is for this reason that many patients focus on diet and want to know all there is to be taught. Plastic models of food can be used in training sessions to make the learning fun.
- Infections. It has been well documented that peritonitis is a major complication of PD and it is therefore important that peritonitis is explained to patients well, using a purpose-printed flipchart.
- Fluid balance. Fluid overload can be associated with excessive fluid intake and poor education. It is a common experience that one of the most difficult aspects of treatment to adhere to is the reduced fluid allowance. This subject can also be taught in groups using a purpose-printed flipchart. Weighing a jug of fluid can also be useful to demonstrate the difference between fluid weight and flesh weight.
- Fertility and sexuality. It is important to discuss sexuality and body image with patients on PD. Having the PD catheter present in the abdomen may inhibit some people (either the patient or partner) and it is essential that any anxieties are discussed. Fertility should also be discussed with patients and partners where appropriate, as it is possible for PD patients to conceive.
- Employment. Having dialysis is not a reason for giving up work. The training period is a good time to discuss work options with patients.

- Ordering and delivery of PD supplies. The practicalities of ordering and delivery of the PD supplies to the patient's home prove a great worry for many patients and their families. This can often be compounded by the problem of where to store this large amount of equipment. Patients can be encouraged to talk amongst themselves to gain ideas from each other as well as utilising the experience of nurses.
- Holidays and travel. It is possible to travel whilst being treated with PD and many patients go on holiday frequently. The practicalities of travel and holidays should be discussed during the training period and on an ongoing basis if appropriate.
- Exercise. The nurse's role is to promote a healthy lifestyle for patients. The training period is an ideal opportunity to discuss which type of activities are best suited to that individual patient.

To complement the training programme, reading materials should be made available, along with posters and DVDs. Many training materials have been translated into other languages for use by those patients whose first language is not English.

Assessment of how much information the patient has retained is difficult to make accurately. Testing can be seen as a threatening procedure, even though it is essential. Games, therefore, make a valuable contribution to the task of assessing learning and can be used in a variety of forms. Simple homemade crosswords, word searches and quizzes can be incorporated for patients and relatives to do at the end of their training.

Summary

There have been considerable advances in the delivery of PD, resulting in a cost-effective therapy, which now has equivalent – if not better – outcomes as compared with HD (Mehrotra *et al.* 2011). Technological advances (such as APD), the ability to deliver adequate dialysis (both solute and fluid removal), and the minimisation of damage to the peritoneal membrane (biocompatible solutions, less peritonitis) will surely improve the outcome of patients in the future.

References

Almalki, M.H., Altuwaijri, M.A., Almehthel, M.S. ***et al.*** (2012) Subcutaneous versus intraperitoneal insulin for patients with diabetes mellitus on continuous ambulatory peritoneal dialysis: Meta-analysis of non-randomized clinical trials. *Clinical and Investigative Medicine* **35** (3), E132.

Ash, S.R. (2003) Chronic peritoneal dialysis catheters: overviewe of design, placement, and renewal procedures. *Seminars in Dialysis* **16** (4), 323–334.

Atkins, R.C. and Zimmet, P. (2010) Diabetic kidney disease: act now or pay later. *Nephrology Dialysis Transplantation,* **25** (2), 331–333.

Balasubramaniam, G., Brown, E.A., Davenport, A. ***et al.*** (2009) The Pan-Thames EPS study: treatment and outcomes of encapsulating peritoneal sclerosis. *Nephrology Dialysis Transplantation* **24** (10), 3209–3215.

Bargman, J.M., Thorpe, K.E., Churchill, D.N. for CANUSA study group (2001) Relative contribution of residual renal function and peritoneal clearance to adequacy of dialysis: A reanalysis of the CANUSA study. *Journal of the American Society of Nephrology* **12,** 2158–2162.

Baxter Healthcare (**1992**) *UK PET Survey,* Baxter Healthcare, Thetford.

Blake, P., Bargman, J., Scott Brimble, K. ***et al.*** (2011) Clinical practice guidelines and recommendations on peritoneal dialysis adequacy 2011. *Peritoneal Dialysis International* **31** (2), 218–239.

Brown, E., Davies, S.J, Rutherford, P. (2003) Survival of Functionally Anuric Patients on Automated Peritoneal Dialysis: The European APD outcome Study. *Journal of the American Society of Nephrology* **14,** 2948–2957.

Brown, M.C., Simpson, K., Kerssens, J.J. and Mactier, R.A. (2009) Encapsulating peritoneal sclerosis in the new millennium: a national cohort study. *Clinical Journal of the American Society of Nephrology,* **4** (7), 1222–1229.

Carrero, J.J. (2009) Identification of patients with eating disorders. Clinical and biochemical signs of appetite loss in dialysis patients. *Journal of Renal Nutrition* **19** (1), 10–15.

Castro, M., Celadilla, O., Munoz, I. *et al.* (2012) Home training experience in peritoneal dialysis patients. *EDTNA-ERCA Journal* **28** (1), 36–39.

Chang, T.I., Kim, H.W., Park, J.T. *et al.* (2011) Improves patient survival in peritoneal dialysis patients with fungal peritonitis: results of ninety-four episodes of fungal peritonitis at a single center. *Peritoneal Dialysis International* **31** (1), 60–66.

Cho, Y., Badve, S., Hawley, C. *et al.* (2012) Biocompatible peritoneal dialysis fluids: clinical outcomes. *International Journal of Nephrology* Article ID 812609.

Chow, J., Munro, C., Wong, M. *et al.* (2000) HomeChoice automated peritoneal dialysis machines: the impact of reuse of tubing and cassettes. *Peritoneal Dialysis International* **20** (3), 336–338.

Danielsson, A., Blohme, L., Traneus, A. and Hylander, B. (2002) A prospective randomised study of the effect of a subcuteneously 'burried' peritoneal dialysis catheter technique versus standard technique on the incidence of peritonitis and exit site infection. *Peritoneal Dialysis International* **22,** 211–219.

Dasgupta, M.K., Kerr, L., Kennedy, M. *et al.* (2002) Randomized crossover study of aminoacids dialysate or oral nutritional supplements for correction of malnutrition in peritoneal dialysis. *Journal of the American Society of Nephrology* **13,** 2A

Davies, S.J., Tatchell, S., Davies, D. *et al.* **Routine peritoneal dialysis training in the home: extending community treatment.** *Peritoneal Dialysis International* **20, S83.**

Davies, S.J., Philips, L., Naish, P.F., Russel, G.I. (2001) Peritoneal glucose exposure and changes in membrane solute transport with time on peritoneal dialysis. *Journal of the American Society of Nephrology* **12,** 1046–1051.

Davies, S.J., Brown, E.A., Frandsen, N.E. *et al.* (2005) Longitudinal membrane function in functionally anuric patients treated with APD; Data from EAPOS on the effects of glucose and icodextrin prescription. *Kidney International* **67,** 1609–1615.

Detsky, A.S., Mclaughlin, J.R. and Baker JP (1987) What is subjective global assessment of nutritional status? *Journal of Parenteral and Enteral Nutrition* **11,** 458–482.

Di Paolo, N., Garosi, G., Petrini, G. *et al.* (1995) Peritoneal dialysis solution biocompatibility testing in animals. *Peritoneal Dialysis International* **15** (suppl.), S61–S70.

Dubois, D., and Dubois, E.F. (1916) A formula to estimate the approximate surface area if height and weight is known. *Archives of Internal Medicine* **17,** 863–871.

Duong, U., Mehrotra, R., Molnar, M.Z. *et al.* (2011) Glycemic control and survival in peritoneal dialysis patients with diabetes mellitus. *Clinical Journal of the American Society of Nephrology* **6**(5), 1041–1048.

Farina, J. (2004) Peritoneal dialysis and intraperitoneal insulin: how much? *Nephrology Nursing Journal* **31** (2), 225–226.

Figueiredo, A., Goh, B.L., Jenkins, S. *et al.* (2010) Clinical practice guidelines for peritoneal access. *Peritoneal Dialysis International* **30** (4), 424–429.

Finkelstein, F.O., Ezekiel, O. and Raducu, R. (2011) Development of a peritoneal dialysis program. *Blood purification,* **31**(1–3), 121–124.

Flannigan, M. and Gokal, R. (2005) Peritoneal catheters and exit site practices toward optimum peritoneal access: a review of current developments. *Peritoneal Dialysis International* **25,** 132–139.

Fusshoeller, A., Plail, M., Grabensee, B. and Plum, J. (2004) Biocompatibility pattern of a bicarbonate/lactate-buffered dialysis fluid in APD: a prospective randomized study. *Nephrology Dialysis Transplantation* **19,** 2101–2106.

Galallah, M.F., Ramdeen, G., Mignone, J. and Patel, D. *et al.* (2000) Role of preoperative antibiotic prophylaxis in preventing post operative peritonitis In newly placed PD catheters. *American Journal of Kidney Disease* **36** (5), 1014–1019.

Gokal, R., Ash, S.R., Holfrich, B.G. *et al.* (1998) Peritoneal catheters and exit site practices. Toward optimum peritoneal access. Update. *Peritoneal Dialysis International* **18,** 29–39.

Gotch, F.A. and Sargent, J.A. (1985) A mechanistic analysis of the National Co-operative Dialysis Study (NCDS). *Kidney International* **28,** 526–534.

Gotch, F.A., Sargent, J.A., Parker, T.J. *et al.* (1983) National co-operative dialysis study: comparison of the study groups and a description of morbidity, mortality, and patient withdrawal. *Kidney International* **26** (suppl. 23), S42–S49.

Gotloib, L. (2009) Functional structure of the peritoneum as a dialyzing membrane. *Nolph and Gokal's Textbook of Peritoneal Dialysis*, Chapter 5, pp. 73–135.

Hall, G., Bogan, A., Dreis, S. *et al.* (2004) New directions in peritoneal dialysis patient training. *Nephrology Nursing Journal* **31** (2), 149–154, 159–163.

Han, S.H., Ahn, S.V., Yun, J.Y., Tranaeus, A. and Han, D.S. (2009) Mortality and technique failure in peritoneal dialysis patients using advanced peritoneal dialysis solutions. *American Journal of Kidney Diseases* **54** (4), 711–720.

Johnson, D.W., Brown, F.G., Clarke, M. *et al.* (2012) Effects of biocompatible versus standard fluid on peritoneal dialysis outcomes. *Journal of the American Society of Nephrology* **23,** 1097–1107.

Johnson, D.W., Cho, Y., Livingston, B.E.R. *et al.* (2010) Encapsulating peritoneal sclerosis: incidence, predictors, and outcomes. *Kidney International* **77** (10), 904–912.

Kazancioglu, R., Topcuoglu, D., Kiricimli, N. *et al.* (2012) Comparison of fast peritoneal equilibrium test with the standard method: a pilot study. *Journal of Renal Care* **38** (1), 29–33.

Keeping, L., English, L. and Fleming-Couts, M. (2001) Informal and incidental learning with patients who use CAPD. *Nephrology Nursing Journal* **28,** 313.
Kelman, B. (1995) The roles of the peritoneal dialysis nurse. *Peritoneal Dialysis International* **15,** 114–115.
Kendrick, J. and Teitelbaum, I. (2010) Strategies for improving long-term survival in peritoneal dialysis patients. *Clinical Journal of the American Society of Nephrology* **5** (6), 1123–1131.
Krediet, R.T. and Balafa, O. (2010) Cardiovascular risk in the peritoneal dialysis patient. *Nature Reviews Nephrology* **6** (8), 451–460.
Krediet, R.T., Coester, A.M., Parikova, A. *et al.* (2008) New insights into the physiology of peritoneal fluid transport. *Peritoneal Dialysis International*, **28** (supplement 3), S144–S149.
Kubey, W., Straka, P. and Holmes, C.J. (1998) Importance of product design on effective bacterial removal by fluid convection in Y-set and twin-bag systems. *Blood Purification* **16,** 154–161
Leaper, D., Burman-Roy, S., Palanca, A. *et al.* (2008) Prevention and treatment of surgical site infection: summary of NICE guidance. *British Medical Journal* **337,** 1924.
Li, P.K.T., Szeto, C.C., Piraino, B. *et al.* (2010) Peritoneal dialysis-related infections recommendations: 2010 update. *Peritoneal Dialysis International* **30** (4), 393–423.
Lin, A., Qian, J., Li, X. *et al.* (2009) Randomized controlled trial of icodextrin versus glucose containing peritoneal dialysis fluid. *Clinical Journal of the American Society of Nephrology,* **4** (11), 1799–1804.
Mathers, N. (2011) Care planning: improving people's lives with long term conditions. RCGP.
Mehrotra, R., Chiu, Y.-W., Kalantar-Zadeh, K., *et al.* (2011) Similar outcomes with hemodialysis and peritoneal dialysis in patients with end-stage renal disease. *Archives of Internal Med*icine **171** (2), 110–118.
Moist, L.M., Port, F.K., Orzol, S.M. *et al.* (2000) Predictors of loss of residual renal function among new dialysis patients. *Journal of the American Society of Nephrology* **11,** 556–564,
Mupirocin Study Group (1996) Nasal mupirocin prevents Staph. aureus exit-site infection during peritoneal dialysis. *Journal of the American Society of Nephrology* **7,** 2403–2408.
National Institute for Health and Care Excellence (2011) *Peritoneal Dialysis: Peritoneal Dialysis In the Treatment of Stage 5 Kidney Disease* (Guideline **125**). National Institute for Health and Clinical Excellence, London.
Nielsen, P.K., Hemmingsen, C., Friis, S.U. *et al.* (1995) Comparison of straight and curled Tenchkoff peritoneal dialysis catheters implanted by percutaneous technique: a prospective randomised study. *Peritoneal Dialysis International* **15,** 18–21.
Paniagua, R., Amato, D., Mujais, S. *et al.* (2001) Summary results of the Mexican Adequacy (ADEMEX) clinical trial on mortality and morbidity in peritoneal dialysis. *Journal of the American Society of Nephrology* **12,** 235A.
Paniagua, R., Ventura, M., Avila-Díaz, M. *et al.* (2009) Icodextrin improves metabolic and fluid management in high and high-average transport diabetic patients. *Peritoneal Dialysis International* **29** (4), 422–432.
Park, M.S., Lee, H.B., Lim, A.S. *et al.* (1996) Effect of prolonged subcutaneous implantation of peritoneal catheter on peritonitis rate during CAPD: a prospective randomised study. *Peritoneal Dialysis International* **16** (suppl. 2), S54.
Park, M.S., Yim, A.S., Chung, S.H. *et al.* (1998) Effect of prolonged subcuteneous implantation of peritoneal catheter on peritonitis rate during CAPD: a prospective randomised study. *Blood Purification* **16,** 171–178.
Perera, N., Stewart, P., Williams, P. *et al.* (2011) The danger of using inappropriate point-of-care glucose meters in patients on icodextrin dialysis. *Diabetic Medicine* **28** (10), 1272–1276.
Piraino, B. (2008) Preventing peritonitis in PD patients. Dialysis and transplantation **40** (8), 367–371.
Piraino, B., Bailie, G.R., Bernardini, J. *et al.* (2005) ISPD guidelines/recommendations. Peritoneal dialysis related infections recommendations: 2005 update. *Peritoneal Dialysis International* **25,** 107–131.
Piraino, B., Bernardini, J., Brown, E. *et al.* (2011) ISPD position statement on reducing the risks of peritoneal dialysis-related infections. *Peritoneal Dialysis International* **31** (6), 614–630.
Plum, J., Hermann, S., Fusshöller, A. *et al.* (2001) Peritoneal sclerosis in peritoneal dialysis patients related to dialysis settings and peritoneal transport properties. *Kidney International* **59** (suppl 78), S42–S47.
Renal Association (2010) *Treatment of Adult Patients with Renal Failure,* Royal College of Physicians and the Renal Association, London.
Selgas, R., Bajo, M.A., Paiva, A. *et al.* (1998) Stability of the peritoneal membrane in long-term peritoneal dialysis patients. *Advances in Renal Replacement Therapy* **5,** 168–178.
Srivastava, S., Hildebrand, S. and Fan, S.L.S. (2011) Long-term follow-up of patients randomized to biocompatible or conventional peritoneal dialysis solutions show no difference in peritonitis or technique survival. *Kidney International* **80** (9), 986–991.
Tranaeus, A.P., Mactier, R.A., Sprosen, T.S. *et al.* (1998) Bicarbonate and bicarbonate/lactate peritoneal dialysis solutions for the treatment of pain on infusion. *Kidney International* **53,** 1061–1067.
Twardowski, Z.J. and Nichols, W.K. (2009) Peritoneal dialysis access and exit site care including surgical aspects. In *Nolph and Gokal's Textbook of Peritoneal Dialysis,* 3rd edn, Springer, pp. 307–361.
Twardowski, Z.J., Nolph, K.D., Khanna, R. *et al.* (1987) Peritoneal equilibration test. *Peritoneal Dialysis Bulletin* **7,** 138–147.

Uttley, L. and Prowant, B. (2000) Organisation of a CAPD programme – the nurse's role. In R. Gokal, R. Khanna, R. Krediet ***et al.*** (eds) *Textbook of Peritoneal Dialysis,* Kluwer, Dordrecht, pp. 363–386.
Van Biesen, W., Heimburger, O., Krediet, R. ***et al.*** (2010) Evaluation of peritoneal membrane characteristics: clinical advice for prescription management by the ERBP working group. *Nephrology Dialysis Transplantation* **25** (7), 2052–2062.
Venturoli, D. and Rippe, V. (2005) Validation by computer simulation of two indirect methods for quantification of free water transport in Peritoneal Dialysis. *Peritoneal Dialysis International* **25,** 77–84.
Voss, D., Hawkins, S., Poole, G. and Marshall, M. (2012) Radiological versus surgical implantation of first catheter for peritoneal dialysis: a randomized non-inferiority trial. *Nephrology Dialysis Transplantation* **27** (11), 4196–4204.
Wikdahl, A.M., Engman, U., Stegmayr, B. ***et al.*** (1997) One-dose cefuroxime i.v. and i.p. reduces microbial growth in PD patients after catheter insertion. *Nephrology Dialysis Transplantation* **12,** 157–160.
Wild, J. and Ansell, T. (2010) Caring for patients with peritoneal dialysis catheters and exit sites. *Journal of Renal Nursing* **2** (1), 28–32.
Wilkie, M. (2011) Exploring the association between icodextrin and encapsulating peritoneal sclerosis. *Peritoneal Dialysis International* **31,** 259–262.
Wilkie, M., Barrett, J., Diament, R. ***et al.*** (2008) *Report of the Renal Association Working Party on Peritoneal Access.*
Williams, P., Marriot, J., Coles, G. (2000) Insulin efficacy with a new bicarbonate/lactate peritoneal dialysis solution. *Peritoneal Dialysis International* **20,** 467–469.
Woodrow, G. and Davies, S. (2011) Renal Association clinical practice guideline on peritoneal dialysis. *Nephron Clinical Practice* **118** (1), c287–c310.
Wolters, J., Van Der Sande, F.M., Leunissen, K.M.L. (2003) Effect of icodextrin on volume status, blood pressure and echocardiographic parameters: a randomized study. *Kidney International* **63,** 1556–1563.

Additional resources

Renal Association Guidelines for PD, www.renal.org/Clinical/GuidelinesSection/PeritonealDialysis.aspx#Summary5 (accessed 20 May 2013).
ISPD Guidelines, www.kdigo.org/guidelinescompare/ebpg.html (accessed 20 May 2013).

CHAPTER 10

Renal Transplantation

Victoria Dunsmore
Barts Health NHS Trust, UK

Learning Outcomes

- To analyse the risks and benefits of renal transplantation.
- To identify the contraindications to transplantation.
- To understand the importance of pretransplant assessment and the nursing role in the pretransplant clinical care pathway.
- To explore donor and recipient matching and its relevance to graft survival.
- To understand deceased and living donation.
- To evaluate critically the possible options to increase deceased donor supply.
- To outline the nursing care for the renal transplant recipient in the pre-, peri and post-operative stage.
- To explain the use of immunosuppressive regimens in individual recipients.

Introduction

Renal transplantation is now widely acknowledged as the treatment of choice for those with established renal failure (ERF). Since the time of the first transplants in the 1950s, advances in antirejection therapies, surgical techniques and tissue matching have enabled kidney transplantation to evolve from an experimental procedure to the treatment that can offer good quality of life and the most cost-effective care for patients with kidney disease.

A successful transplant offers freedom from the practical and psychological difficulties and restrictions of long-term dialysis; freedom from dependence upon a machine or fluid bag; freedom from fluid and dietary reductions; a return of sexual functioning and fertility with the possibility of parenthood; and a return to an almost normal lifestyle.

Most research studies clearly show that for the majority, kidney transplantation has the greater rehabilitation potential and that the quality of life for patients with functioning grafts is superior to that which is usually achieved on dialysis (Kovacs *et al.* 2011; White and Gallagher 2010). Research into quality of life has received much criticism, and individual perception and assessment of quality of life is known to be affected by a wide range of independent and personal variables. However, for many of those

Renal Nursing, Fourth Edition. Edited by Nicola Thomas. Published 2014 by John Wiley & Sons, Ltd.

with renal failure, transplantation offers an improved quality of life, and may be the most significant factor for patients when considering transplantation.

Cost-effective care

Transplantation is the most cost-effective treatment option for ERF. The cost of a year of haemodialysis or peritoneal dialysis is similar to that of a renal transplant in the first year. However, thereafter the cost of continuing care for a patient with a transplant is one-fifth of the cost of dialysis per year.

National waiting-list figures for kidney transplant

The improvement in quality of life and cost-effectiveness of transplantation support the suggestion that renal transplantation is the treatment of choice for the majority of patients. Unfortunately, such a goal is not possible at present because of the limited supply of deceased donor organs. The current UK waiting list for kidney transplantation stands at more than 6000 patients (Figure 10.1). Approximately 2800 renal transplants were performed in the UK in 2011–2012 (NHSBT 2012).

We therefore need to explore ways of increasing donor numbers in order to offer all suitable patients the chance of a transplant.

Contraindications to Renal Transplantation

Although the majority of patients may request a transplant, transplantation may not be suitable for all those with ERF because of possible medical complications.

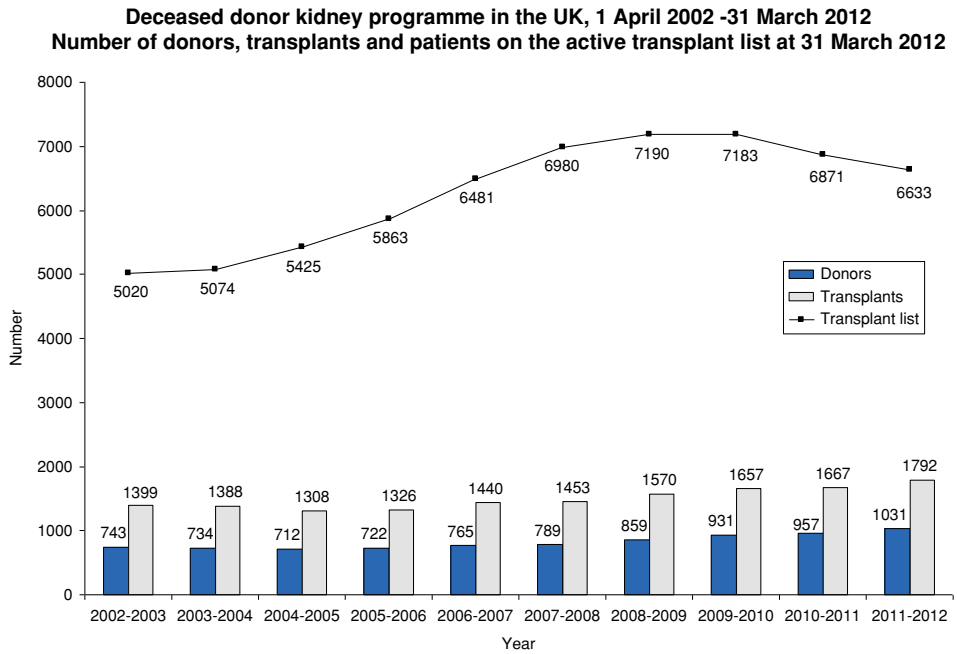


Figure 10.1 Deceased donor kidney programme in the United Kingdom, 1 April 2002–31 March 2012. Number of donors, transplants and patients on the active transplant list at 31 March 2012.

Source: from *Transplant Activity in the UK 2011–2012,* NHS Blood and Transplant.

Malignancy

Malignant disease must be excluded prior to transplantation as the immunosuppressive regime may cause accelerated growth of the malignancy and may encourage secondary spread. If the patient is known to have had cancer in the past, it is important to ascertain the type of malignancy, the stage of development and the treatment received. Transplantation may still be possible provided that curative treatment has been given and sufficiently long follow-up has occurred to exclude recurrence. Current UK guidelines recommend a potential recipient be disease free for two years prior to listing for transplant (Dudley and Harden 2011). However, certain cancers, such as breast, colorectal and melanoma carry a higher risk of recurrence and a disease free period of five years may be required. The importance of time to transplant following treatment of a malignancy is shown by Penn's (1997) paper using data from the United States: in 1137 recipients who had been treated for a malignancy prior to transplantation, the recurence rate was:

Treatment <2 years pretransplant 54%

Treatment 2–5 years pretransplant 33%

Treatment >5 years pretransplant 13%

The risk of recurrence of cancer should be discussed fully with the recipient prior to listing for transplant. Guidance regarding specific malignancy and risk of recurrence can be obtained from the Israel Penn International Transplant Tumor Registry (www.ipittr.org, accessed 20 May 2013).

Recurrent disease

It is important to consider the patient's primary renal disease as in some cases the disease may recur and destroy the new kidney. Renal disorders with a very high recurrence rate include primary focal segmental glomerulosclerosis (FSGS) (causing massive proteinuria and scarring of the glomeruli), mesangiocapillary glomerulonephritis (an immunological disorder of the glomeruli) and IgA nephropathy. Recurrence of disease is estimated to account for up to 5% of graft loss post transplant (Chadban 2001). Transplantation can still be considered but only after counselling and explanation of the risks to the patient. Many centres would advise against living related donation in this situation, however it may still be possible providing both donor and recipient are fully aware of the risk of recurrence.

Other conditions, such as Goodpasture's syndrome and the other vasculitic illnesses need to have been fully treated before going ahead with transplantation because of the risk of damage in the new kidney in the presence of active disease. Twelve months is normally considered the earliest that transplantation would be considered following initial presentation of the disease. Several other diseases, such as diabetes, can cause microscopic changes in the kidney after many years, but rarely lead to graft loss.

Hepatitis virus and human immunodeficiency virus (HIV)

Patients who are hepatitis B or hepatitis C positive may be at risk of progressive liver disease after transplantation due to the impact of the immunosuppressive therapy. Consultation with a hepatologist maybe required and possibly liver biopsy in order to determine activity of the virus and presence of liver damage. Many patients who are hepatitis B or C positive have no disease or quiescent disease and are therefore suitable for transplantation. Careful monitoring in this group of patients is required after transplant to ensure early detection of increased viral activity and to ensure antiviral therapy is continued. Previously, infection with HIV was considered an absolute contraindication to

transplantation, however the advent of highly active antiretroviral therapy (HAART) as a means of controlling HIV infection has made transplantation possible in this group of patients, with studies showing no difference in graft or patient survival when compared with non-HIV infected transplant recipients (Martina *et al.* 2011).

Diabetes mellitus and cardiovascular disease

Many people with diabetes can receive a renal transplant, but they are at risk from other complications of their diabetes. Cardiovascular disease is seen primarily in those with Type 2 diabetes, and may contribute to higher levels of morbidity and death. It is important to assess vessel patency prior to transplantation, as severe atherosclerosis of the iliac vessels may at worst preclude transplantation and at best complicate the transplant surgery.

Evaluation for Transplantation

Age

Morbidity and mortality after kidney transplantation tend to increase with age and therefore the age of the recipient must be classed as a risk factor. Age must also be considered within the context of other risk factors, such as advanced cardiovascular disease and diabetes. There is no age barrier for transplantation, health is assessed on an individual basis, and physiological rather than chronological age and the existence of other risk factors are seen as the important assessment issues. Many units have patients of 70 years and over who have progressed well following a kidney transplant. However, with demand far exceeding supply and studies reporting smaller changes in improvements in quality of life for the older age groups and a significantly increased risk of death within five years of transplantation for those over 60 years of age (Johnson *et al.* 2010), some may question the use of such a precious and scarce resource in this group (Box 10.1).

Polycystic kidney disease

This inherited kidney disease can result in several members of a family receiving ERF therapies. The native cystic kidneys may be very large, thus leaving little space for the transplant, and there may also be an increased risk of bleeding and infection. It may be necessary to perform a unilateral, or in severe cases a bilateral nephrectomy prior to listing for transplantation.

Urinary tract

It is important to assess that there are no problems with the bladder and urethra and that there will be no difficulties following transplantation; if it is felt that the bladder capacity

BOX 10.1

Ethical Discussion Point on Shortage of Donor Organs

- Renal transplants: demand far exceeds supply.
- Younger patients are shown to gain greater life satisfaction after a transplant.
- Older patients are at greater risk of complications.

Discussion

- Should younger patients be given priority over the older group?

is unacceptably low, surgical enlargement may be possible. In the presence of a history of repeated urinary tract infections with bilateral reflux, it may be necessary to undertake a bilateral nephrectomy prior to transplantation to reduce the risk of posttransplant infection.

Cardiac disease

Cardiovascular disease is known to be a major cause of comorbidity in the renal population. Routine investigations such as an electrocardiogram (ECG) and echocardiogram and a cardiac history are essential for all patients undergoing assessment for transplantation. Those patients who are in the high-risk groups for cardiovascular disease (e.g. older patients and those with diabetes) maybe reviewed by a cardiologist and undergo further investigation. There is no evidence at the present time that intervention in this high risk group results in better outcomes following transplantation, cardiac screening may be most useful in identifying the high risk patient in order to exclude them from the transplant waiting list (Dudley and Harden 2011).

Peptic ulceration

A history of indigestion and/or peptic ulceration must be noted and endoscopy undertaken if active ulceration is a possibility, as those with active ulceration risk bleeding after transplantation due to the action of the steroid therapy. Treatment with a proton pump inhibitor (PPI) in combination with antibiotics if required to eradicate *Helicobacter pylori* should be given prior to transplantation if active disease is present. Many centres also use PPI as prophylaxis in all recipients during the first 3–6 postoperative months.

Respiratory disease

Pulmonary tuberculosis will require treatment before listing for transplantation. Patients with a history of tuberculosis and those who have visited or lived in high-risk areas will require prophylaxis with isoniazid for at least a year following transplantation.

Patients should also be strongly advised to stop smoking and should be offered information regarding smoking cessation strategies and support systems.

Obesity

Obesity may make the transplant surgery difficult and increase the risk of postoperative complications. Nutritional advice should be given before and after transplantation (Chapter 13).

Oral hygiene

Dental hygiene and assessment of dental state are essential. Any gum infection or dental problems should be dealt with prior to transplantation. Calcineurin inhibitors (CNIs) can cause gum hypertrophy, which is made much worse in the presence of poor hygiene.

Pretransplantation Preparation

Patients may be referred for transplantation during different phases of the disease process; some may be in the predialysis stage, others may already be established on dialysis therapy. UK guidelines allow a patient to be listed on the deceased donor list once

he/she is within approximately 6 months of requiring dialysis (GFR of <15 ml/min). A pre-emptive transplant gives a better outcome compared to having to spend time on dialysis. Additionally a waiting time of more than 6 months has been linked with an increased risk of graft failure, however this risk does not increase further if waiting time increases beyond 2 years (Johnson *et al.* 2010). A planned pre-emptive transplant from a living donor gives the best outcome in terms of graft success and recipient health. Early transplantation before the need for dialysis therapy is welcomed from a clinical perspective, but may prove difficult psychologically if emotional adjustments have not been successfully negotiated and the patient and family are still reeling from the impact of the disease. A structured approach to predialysis education and counselling should include discussion of suitability for transplantation, and the likelihood of any potential living donors being found. Suitable patients can then be seen for pretransplant education and assessment, and friends or relatives who are interested in living donation can be contacted at this early stage. An overview of the psychological support required prior to transplantation is outlined in Chapter 4.

Boxes 10.2–10.4 show useful checklists for the pretransplant stage. Pre transplant assessment is usually a multi-disciplinary process, involving medical, surgical and specialist nurse input. A systematic approach to assessing patients for suitability for transplantation should include those approaching ERF as well as those on dialysis. This is of particular importance when a suitable living donor may be found, thus allowing pre-emptive transplantation.

BOX 10.2

Pretransplant Information and Assessment Checklist used by the Transplant Nurse Specialist: Information and Discussion

1. Desire to receive a transplant.
2. Benefits of a renal transplant:
   - improved quality of life;
   - freedom from dialysis;
   - freedom from fluid and dietary restrictions;
   - freedom to travel (advise to wait until 1 year post transplant before travelling aboad);
   - employment;
   - improved fertility (majority) – contraception.
3. Risks/disadvantages of a renal transplant:
   - immunosuppression;
   - adherence with medication and healthcare advice, frequent clinic attendance;
   - drug side effects;
   - susceptible to infections and viruses;
   - lymphoma and cytomegalovirus infection – risks and treatment;
   - risk of rejection/biopsies.
4. Practical information

Orientation	Tour of the transplant unit
Waiting list	How it works, how to manage waiting time
Planning for the transplant call	Arrange child/pet/others care
Transplant call	What to expect, transport arrangements
Contact numbers	Holiday arrangements
Inpatient care	
Pre- and postoperative care	What to expect, discharge arrangements, followup
Transplant nurse specialist	Contact card – further contact

BOX 10.3

Pretransplant Information and Assessment. Checklist used by the Transplant Nurse Specialist: Clinical Information and Investigations

1. Blood group.
2. Tissue typing.
3. Biochemistry.
4. Haematology.
5. Liver function tests.
6. Lipid levels.
7. Virology screen:
   - hepatitis B and C;
   - cytomegalovirus;
   - human immunodeficiency virus;
   - Epstein–Barr virus;
   - varicella zoster virus.
8. Midstream urine.
9. Further specific investigations as required.

Clinical information

- Dental check: date of last check.
- Female patients, last cervical smear: date of last smear and result.
- Breast self-examination.
- Weight.
- Height.
- Body mass index.

BOX 10.4

Pretransplant Information and Assessment Proforma: Checklist used by the Physician/Surgeon to Evaluate Clinical Assessment and Information

Clinical assessment

Clinical history

1. Renal disease and disease progression: dialysis status.
2. Previous medical history, noting previous blood transfusions, pregnancies and previous transplants.
3. Previous surgery.
4. Current clinical status.
5. Social history, family status.
6. Smoking, alcohol, recreational drugs.
7. Current medications, allergies.
8. Immunological status, blood group.

Clinical assessment

1. Cardiac assessment, including baseline echocardiogram.
2. Respiratory assessment, tuberculosis risks/contacts.
3. Urological assessment.
4. Abdominal assessment – previous surgery, Tenckhoff site.
5. Vascular assessment – assess pulses.
6. Dentition.
7. Gynaecological status.

(Continued)

BOX 10.4 *(Continued)*

Information: discussion

1. Risks
   - Surgical, anaesthetic, patient survival rates.
   - Graft survival rates–deceased and living donor.
   - Lymphoma.
   - Cytomegalovirus.
   - Cardiovascular.
   - Skin cancer.
2. Further investigations required.
3. Live donor possibility or deceased donor list.
4. Immunosuppression regimen required.
5. Decision.
   - On deceased donor transplant waiting list.
   - Living donor programme.
   - Await further investigations and/or referral.
   - Patient undecided – does not want a transplant.
   - Unsuitable for transplant due to . . .

Specific Pretransplant Anxieties and Fears

Specific issues concerning body image are discussed in Chapter 4: other anxieties include acceptance of the transplant as part of the 'self' and guilt over benefiting from traumatic death. There are also very specific challenges relating to patients' education and understanding of their immunosuppressive therapy.

It is vital that patients understand the need to continue with their antirejection therapy for as long as they have their transplant. Many patients believe that it will only be necessary to take the drugs until the kidney settles into the body. There are great challenges for the transplant team to ensure that patients are well informed about their medication.

There is evidence that non adherence to prescribed medication in transplant recipients leads to an increased risk of graft loss (Pinsky *et al.* 2009). A meta-analysis of 147 studies regarding the prevalence of non adherence in solid organ transplant recipients found that immunosuppression non adherence was highest in kidney transplant recipients (Dew *et al.* 2007). A variety of explanations have been given for these difficulties. These include the effects of immunosuppression on physical appearance, inability to accept the lifestyle limitations, misinformation given by one patient to another, poor education given by staff and fear of long-term side effects. Sometimes, those who have had difficulty in accepting dialysis are exemplary transplant recipients because the post-transplant lifestyle is especially precious.

It is inappropriate to refuse transplantation to patients who are perceived as high risk for nonadherence. It is important to offer extensive pretransplant counselling to explore the reasons for not taking healthcare advice and to ensure additional posttransplant support is available to facilitate adherence to medication therapies. This may necessitate changing to an immunosuppression regime with a different side effect profile. Close monitoring of immunosuppressant levels and ensuring attendance at clinic visits are vital basic steps to detect possible non adherence.

Transplant Waiting List

Once the pretransplant assessment has been completed satisfactorily and the tissue-typing and blood-grouping details are finalised, the name of the patient will be added to the national waiting list. Waiting time is impossible to predict.

It is important to explain to patients that the transplant waiting list is very different from other hospital waiting lists in that they do not simply have to wait until their name reaches the top to receive a graft. The transplant list is essentially a pool of recipients, and each transplant is allocated on the basis of the closest match. Therefore, their name will join the recipient pool and they must wait for the best match for them. This is a difficult concept to understand and some patients become distressed if another patient, who has waited less time, is transplanted before them.

It is also important that patients do not sit by the phone all day waiting for 'the call', thus greatly restricting their lifestyle. Patients are encouraged to keep as active and as healthy as possible whilst waiting and to continue as normal a lifestyle as possible. Some patients may still feel ambivalent about a transplant at this time. Specific fears and anxieties may need to be explored and support given within the context that patients must be allowed the time to decide the best treatment for themselves. Ongoing contact with the transplant nurse specialist is vital during the waiting time and it is recommended that those who are waiting are contacted every 12 months and offered support and reassurance. Support is especially important at times of additional stress such as when a fellow dialysis patient receives or rejects a kidney.

Donor and Recipient Matching

Immune system: overview

The human body has a complex system of defences that can provide protection against infection and disease. This system has the ability to target, isolate and destroy potentially harmful invaders. This destruction is achieved in three stages – first by the recognition of structures on the invader (antigens) which are not present in the host. Antibodies and T cells that can recognise the antigens as 'foreign' are then produced. These antibodies and T cells then attach to the invader and destroy it both directly and by recruiting other mechanisms of destruction. Exactly the same happens to a transplant unless it is from an identical twin. The 'foreign' antigens on the transplant induce antibodies and T cells. These target the transplanted organ and do their very best to destroy it. The term 'transplant antigens' is used to describe those antigens that are most important in this regard. Only two are really important: the human leukocyte antigen (HLA) system and the ABO system (see below). In order to prevent rejection it is necessary to circumvent the immune system (by matching and cross-matching) and to suppress the immunological response.

Components of the immune system

Leukocytes (white blood cells)

These comprise the cells that produce the antibody (B lymphocytes), recognise the foreign antigens (T lymphocytes), directly destroy invaders (activated T lymphocytes), or can be called in to help with the destruction process (monocytes, polymorphs and eosinophils). Thus, it can be seen that the lymphocytes play several roles and therefore have the major influence on graft acceptance.

Lymphocytes

These comprise 20% of the total white blood cell count and are made up of several groups of cells with specialised functions. The term 'orchestra' is often used to describe the mode of operation. Each section of the orchestra is made up of individuals with similar but not identical characteristics. The overall result of the orchestra playing is a result of each section performing in concert with the others.

Lymphocyte types

- T cells: these have antigen recognition structures fixed to their surface.
- B cells: these have antigen recognition structures that can be secreted (antibodies).

T cells and B cells can be naive or activated. T cells can be activated to various functions, namely helper, killer or tolerant status. B cells can be activated to produce antibody or memory.

Each naive lymphocyte has an antigen recognition structure that is unique, for example different from other members of its section and thus capable of seeing a different antigen. In this way literally millions of 'foreign' antigens can be recognised. Each time a recognition event occurs, a naive cell becomes activated and divides. Thus, even if a single cell recognises an antigen as foreign it keeps dividing until it forms a significant number of identical cells (a clone), all capable of recognizing the antigen.

Depending on influences from other sections, T cells can help B cells produce antibody (helper T cells), kill targets bearing the antigen directly (killer T cells), or become tolerant (i.e. capable of recognizing the antigen but not producing a damaging response to it). B cells can produce antibody in around 8–10 days if they see it for the first time (naive B cells) or within 24 h if they have seen it before (memory B cells). B cells produce much more antibody if they get help from the T cells, which can themselves see the same antigen.

One point about antibody production that is relevant to transplantation is that the process that produces it is long lived. This is very positive for vaccination programmes, where having antibody around for years and years is very beneficial, although negative of course for transplantation.

ABO blood groups

The ABO system of human blood groups was described by Landsteiner in 1902. (Nobel Prize 2013). Blood group is determined by A and B antigens on the surface of the red blood cells. Each individual has one of the four basic blood group types – O, A, B or AB.

Each individual has antibodies to the blood group antigens that they do not express (Table 10.1). Antibodies against the blood group antigens can cause hyperacute rejection and therefore matching of blood group between donor and recipient is vital. Blood group O organs can be transplanted into all groups; O is classified as the universal donor. Blood

Table 10.1 The ABO blood group system.

Blood group	Percentage of population	Antigens expressed	Antibodies expressed	Acceptable donor blood group
O	47%	None	Anti-A, Anti-B	O
A	42%	A	Anti-B	O, A
B	8%	B	Anti-A	O, B
AB	3%	AB	None	O, A, B, AB

group AB recipients can receive organs from all groups; AB is classified as the universal recipient. A small proportion of people with group A belong to a subgroup defined as A2, and have reduced expression of A antigen. These kidneys may be successfully transplanted into O or B, or A2B into AB, recipients with low anti-A titres (Bryan *et al.* 2007).

Recent advances in pretransplant care have allowed transplants to take place between a blood group incompatible (ABOi) donor and recipient. Such programmes are suitable only for living donor transplants due to the pretransplant treatment required for the recipient. Antibodies can be removed from the recipient using various strategies, including plasmapheresis and immunoadsorption. More potent immunosuppressive medications may also be required. This strategy allows transplants to take place between donor and recipient pairs that would previously have been unsuitable, thus increasing the chance of transplantation for many recipients. The risk of rejection of the transplant, failure of the graft and of serious side effects of immunosuppression are higher than with a blood group compatible transplant. It is important that recipients of this type of transplant are fully informed of the risks prior to undertaking this procedure.

Histocompatibility antigens

A further set of proteins that can trigger the B and T cell response are the transplantation antigens or the histocompatibility antigens. The histocompatibility antigens can be divided into two groups – major and minor.

Major histocompatibility complex (MHC)

This system, first discovered in the mouse by Peter Gorer at Guy's Hospital in the late 1930s, is, as the name suggests, the most important system in transplantation and indeed in immunity to infection. The human system is termed HLA (for human leukocyte antigen) and was first identified in the 1960s. The sera from pregnant women were found to have antibodies that recognised lymphocytes from their partners and from some random blood donors. The reason for this is that pregnancy is in some ways like a transplant. Passage of blood from partner or child to mother results in T cells and antibody being produced to the foreign antigens on the blood cells. Since the most potent foreign antigens are those of the HLA system, most of the mother's response is directed against them and the long-lived antibody-producing cells remain in her blood. These antibodies can persist for over 40 years.

The HLA system is complex. There are four main series important for transplantation – A, B, C and DR. There are over 30 antigens in each series. Each person can have two from each series (one from each parent). The permutation on 2/30 from A, 2/30 from B, 2/30 from C and 2/30 from DR means that, outside a family, it is very rare for individuals to have identical HLA types. Luckily for matching in renal transplantation, DR is dominant. However, most of the antibody and T-cell response is produced to A, B and C.

The rules for HLA and matching are not nearly so clear-cut as the rules for ABO, but there are several strong guidelines:

- Transplantation of a kidney into someone who has antibodies directed to a foreign (mismatched) HLA antigen on that kidney will result in hyperacute rejection.
- Transplantation of a kidney into someone who has strong memory to a foreign (mismatched) HLA antigen on that kidney will result in very rapid rejection.
- Transplantation of a kidney with two mismatches at DR will have more rejection than one with no mismatch at DR. However, rejection episodes can be treated or mismatched patients given additional immunosuppression. The total number of mismatches has a bearing on long-term outcome (Figure 10.2).

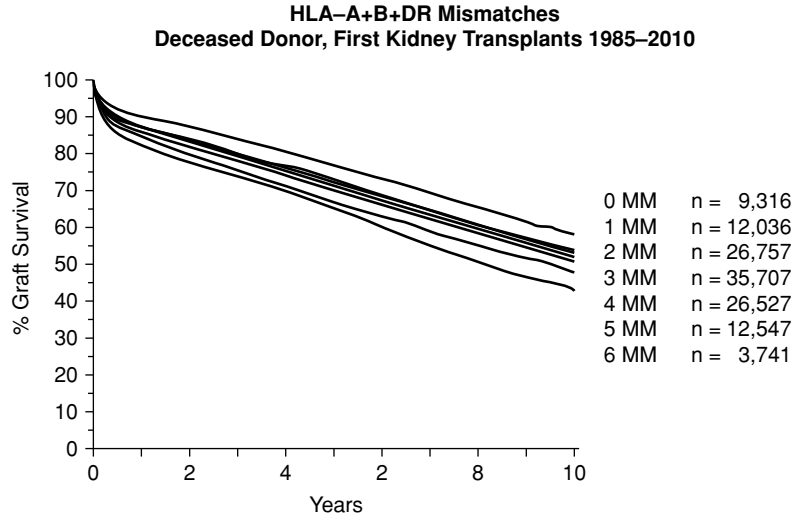


Figure 10.2 Influence of HLA matching on renal allograft survival.
Source: CTS (2012).

Newer techniques allow organs to be transplanted where there is HLA incompatibility (HLAi) providing antibodies are removed or lowered to an acceptable level prior to transplantation. There are various techniques used to remove antibodies, for example, plasmapheresis and immunoadsorption, in a similar strategy to that used in ABOi transplantation. This procedure is only suitable for living donation as the antibody removal must be carried out in the period leading up to the transplant operation. The risks of transplant rejection, graft failure and serious infection are twice as high as for antibody compatible transplants so patients contemplating this procedure must be fully aware of the risks before proceeding. Despite the risk this treatment may offer some patients their only chance of receiving a transplant, particularly as they may be unlikely to be offered a deceased donor kidney if highly sensitised, and many are willing to accept the risks involved.

Donor and recipient matching

The majority of organs for transplant come from deceased donors. It is essential to match for blood group and to achieve the best DR match possible. Since antibodies can be induced to pregnancies, transfusions or previous transplants and can be boosted by infection, regular screening of patients on the waiting list is necessary to maintain knowledge of their current antibody status. Donors are avoided if they contain any mismatch to which the recipient has antibodies in current or recent serum.

Pretransplant cross-match

Immediately prior to transplant a cross-match test is performed in the tissue-typing laboratory. A recent blood sample and selected past samples from the recipient are checked against donor lymphocyte cells. If the donor cells react (die), the result is termed a positive cross-match; the recipient is adversely reacting to the donor antigens. In the presence of a positive cross-match, transplantation cannot proceed, as the transplant would be rejected.

Traditionally a cross-match was performed prior to deceased donor transplantation and the results were obtained before the transplant operation could proceed. Recognition of the significance of shorter cold ischaemic times (CIT) in improved short-term graft success rates (Johnson *et al.* 2010) has led to the introduction of retrospective cross-matching. In this situation the transplant proceeds without waiting for the cross-match result to be available. This can only occur if the recipient has had regular blood samples sent to the laboratory for antibody testing and is known to be nonsensitised. Careful history should be taken at time of transplant to ensure the recipient has not received any recent blood transfusions that would affect antibody status.

Sensitisation

When there is a positive cross-match, the recipient is sensitised to that donor. The higher the level of sensitisation, the greater will be the difficulty in finding a transplant that will not reject.

Sensitisation can occur during pregnancy (to partner's antigens), during blood transfusion and after transplantation. In order to reduce the risk of sensitisation it is important to minimise the giving of blood transfusions.

Some recipients may have a high level of sensitisation. The patient's serum is tested periodically against a representative panel of cells from many donors. If the patient does not react with the various donors tested then they are classified as unsensitised. If the blood reacts with 50% of donors (50% of the panel or 50% Panel Reactive Antibody (PRA)) they are 50% sensitised, and if blood reacts with 100% of donors they are highly sensitised. Unfortunately, some highly sensitised candidates wait many years for a compatible transplant, although the antibodies responsible for sensitisation can decrease with time.

United Kingdom matching system

Within the United Kingdom, each transplant centre has a local list of recipients awaiting transplant. There is a national database held at NHS Blood and Transplant (NHSBT) in Bristol. Each deceased donor is tissue-typed at the local transplant centre and the details sent to NHSBT, where the closest tissue match is found from the central computer. The kidneys are then sent to the recipient centre for transplant.

A new scheme for the national allocation of kidneys was adopted in the United Kingdom in 2006. The scheme is based on HLA matching, gives priority to paediatric and highly sensitised patients (i.e. patients with high levels of HLA antibodies) and uses a point score to differentiate between equally matched patients. The aim of this scheme was to reduce the variability in deceased donor waiting times across the United Kingdom.

The scheme has five tiers. Tier 1 kidneys are offered to paediatric patients with no mismatched HLA antigens at HLA-A, -B and -DR (termed a 000 mismatched transplant) who are known to be highly sensitised. If there are no such patients in tier 1, then kidneys are offered in tier 2 to 000 mismatched, nonsensitised paediatric patients. If there are no patients in either tier 1 or 2 then kidneys are offered in tier 3 to 000 mismatched adult patients who are highly sensitised. If no match is found in tier 3 then the offer moves to tier 4 which includes all other 000 mismatched adult patients and favourably matched (i.e. no mismatch at HLA-DR and a maximum of one mismatched antigen at both the HLA-A and HLA-B locus; 100, 010, 110 mismatch grades) paediatric patients. Tier 5 includes all other patients. Paediatric patients in tiers 1 and 2 are prioritised according to waiting time. In the remaining tiers, patients are prioritised according to a points score, including: waiting time, age, donor recipient age difference, geographical location of patient relative to donor (NHSBT 2012).

Review of the scheme has shown that matching is still relevant, however, advances in immunosuppression over the last ten years have meant that only the most poorly matched grafts (two antigen mismatch at HLA-DR locus) are associated with worse outcomes when compared to 000 mismatched grafts (Johnson *et al.* 2010).

Deceased Donation

The majority of renal transplants currently performed in the United Kingdom are from from deceased donors. Deceased donors fall into two categories, donation after brain death (DBD) or donation after circulatory death (DCD). Donation after brain death donors are patients who have suffered irreversible brain stem damage (brain stem death) and are maintained on a ventilator within a critical care unit.

Causes of brain stem death

The most common causes of brain stem death are listed in Box 10.5.

Cerebral swelling resultant from trauma or anoxia and intracerebral bleeding can cause raised intracranial pressure, which forces the cerebral hemispheres through the tentorial hiatus, thus compressing the brain stem and interrupting its blood supply. Such herniation of the cerebral tissue is usually described as 'coning' and results in irreversible damage to the brain stem.

Brain stem functions

The brain stem is responsible for the capacity to breathe spontaneously and the capacity for consciousness. If the brain stem is irreversibly damaged then there is loss of function and it is argued that 'death entails the irreversible loss of those essential characteristics which are necessary to the existence of a living human person'.

Brain-stem death diagnosed by signs of irreversible damage to the brain stem is an accepted concept in most countries of the world.

Brain-stem death diagnosis

Tests to diagnose brain-stem death originated from the Harvard Medical School criteria (Harvard Medical School 1968) which were published in the United States in 1968. A UK Code of Practice for the diagnosis of brain stem death was agreed by the Conference of Medical Royal Colleges in 1976 and most recently updated in 2008.

BOX 10.5

Common Causes of Brain Stem Death

- Intracerebral bleed or infarction.
- Head trauma.
- Cerebral hypoxia due to:
  - respiratory arrest;
  - cardiac arrest.
- Smoke inhalation/carbon monoxide poisoning.
- Cerebral tumour.
- Drug overdose.
- Intracranial infection.

Certain conditions must be met before brain-stem death testing can take place:

- The patient is deeply comatosed, unresponsive and apnoeic with lungs artificially ventilated.
- There is a positive diagnosis or known condition that has led to the diagnosis of irreversible brain damage.
- Potentially reversible causes of coma have been excluded.

Possible causes of coma that must be excluded are primary hypothermia (the patient's temperature must be greater than 34 °C for testing to take place), effect of depressant drugs, potentially reversible circulatory, metabolic and endocrine disturbances and potential causes of apnoea. Testing will then take place to ascertain the absence of brain stem reflexes:

- the pupils are fixed and do not respond to sharp changes in light intensity;
- there is no corneal reflex;
- the oculovestibular reflexes are absent;
- no motor responses within the cranial nerve distribution in response to stimulation of any somatic area;
- there is no cough reflex response to bronchial stimulation by a suction catheter placed down the trachea to the carina, or gag response to stimulation of the posterior pharynx with a spatula;
- there is no evidence of spontaneous respiration or respiratory effort during the apnoea test (loss of capacity for spontaneous breathing).

Declaration of brain-stem death

The UK Code of Practice recommends that brain-stem death testing should be carried out by two medical practitioners who have been registered for a minimum of five years and 'who have expertise in this field'. At least one should be a consultant. Testing should be performed by two doctors together and should be performed completely and successfully on two occasions. Neither of the doctors should be a member of the transplant team or associated with potential transplant recipients.

Time of death

The time of completion of the first set of tests is legally the time of death, and this should be recorded as such on the death certificate.

Contraindications to organ donation

- Known or suspected Creutzfelt–Jacob disease (CJD) and other neurodegenerative diseases associated with infectious agents.
- Known HIV disease (but not HIV infection alone).

The following conditions may preclude donation but individual donors should be discussed with the Specialist Nurse for Organ Donation as they may still be suitable:

- disseminated malignancy;
- melanoma (except local melanoma treated $>$ 5 years before donation);
- treated malignancy within 3 years (except nonmelanoma skin cancer);
- age $>$ 90 years;
- known active tuberculosis;
- untreated bacterial sepsis.

It is recommended that critical care staff consider organ donation in all those with brain stem death and refer to the Specialist Nurse for Organ Donation for a decision regarding medical suitability. The Organ Donation Task Force recommends that consideration for organ donation should be a routine part of end of life care (Department of Health 2011).

Patients from high-risk groups (as defined by the Department of Health 2011) should also be excluded. In order to keep transplants safe, the Department of Health guidelines state that 'certain medical and social information' must be given. Therefore, donor families are given an information sheet (Box 10.6) and asked to read these questions and answer 'to the best of their knowledge'.

Asystolic donation (nonheart beating)

An initiative at the Leicester General Hospital in 1992 showed that asystolic (nonheart-beating) donation could become an increasingly important source of renal organs. Leicester identified asystolic donors in the medical wards and the accident and emergency department of the local hospital. At the time of asystole and following certification

BOX 10.6

Keeping Transplants Safe: Donor Data Collected by the Specialist Nurse-Organ Donation on the Donor Assessment Form

General Health: Visit to GP within 24 months (details)

Diabetes, Cancer: investigations or treatment (details)

Recent infections or contact with infection (details)

Ever had hepatitis, jaundice or liver disease (details)

Neurosurgical surgery or implantation of dura mater before August 1992

Blood transfusion before 1980

Any type of brain disease (details)

Ever received pituitary extract (details)

History of autoimmune/chronic disease (details)

Ever had serious infection, such as, TB, West Nile Virus, typhoid, toxoplasmosis, brucellosis, rabies, Lyme disease (details)

Acupuncture, body piercing, tattoo, botox or collagen injection (details)

Ever had a sexually transmitted disease, such as, syphilis, gonorrhoea, genital herpes or warts (details)

Travel risk assessment (details)

Behavioural risk assessment: Alcohol, Smoking

May be infected with HTLV (Human T cell lymphotropic virus), HIV, HBV, HCV

Ever injected with nonprescription drugs

Ever been given payment for sex with drugs or money

Ever had oral/anal sex with another man (male donors only)

Had sex within 12 months with a man who has had sex with another man

Has been in prison for $>$ 3 days within last 12 months

Had sex in the last 12 months with anyone who is HIV or HTLV positive, HBV or HCV positive, had sexually transmitted disease, given payment for sex, ever injected drugs or ever had sex in any part of the world where HIV/AIDS is very common

of death (providing that there were no medical contraindications to donation), an intra-aortic catheter was inserted and ice-cold perfusion of the kidneys commenced. Such perfusion reduces the warm ischaemic damage and allows time for medical/nursing colleagues to approach the family and the coroner for permission to proceed to donation. If permission was granted the kidneys had to be removed within 40–45 min of asystole in order to avoid irreversible renal damage.

Ethical concerns about the insertion of the catheter before consent has been given by the family were widely discussed during the planning of this programme and health personnel, the coroner and the general public groups that were consulted gave consent to this initiative. However, following the widely reported problems with organ retention after postmortem without family consent that occurred at Alder Hey and other hospitals, it was decided by the Leicester group that they must obtain consent before insertion of the intra-aortic catheter. This decision undoubtedly affected the length of time between asystole and cold perfusion of the kidneys. However, the Human Tissue Act (2004) made the wishes of the potential donor central to any decision to proceed.

Interestingly, results suggest a marginally higher rate of relative consent in asystolic donation than is usually achieved in brain-stem death donation. This may be due to the skill of the staff requesting and also the fact that with asystole the patient appears 'dead' in the conventional sense (cold, pale and cyanosed), thus there may be less psychological denial for the family.

Several other centres have introduced asystolic donation programmes and they are providing a useful additional supply of kidneys. However, the limiting factors will be the need for a rapid response time from the retrieval teams and the need for catheter insertion expertise. Such factors may preclude donation from hospitals that are some distance away from the transplant centre.

Requesting donation

In the United Kingdom, the legal requirements for organ donation are laid down in the Human Tissue Act (2004). This Act established the Human Tissue Authority (HTA) as the regulatory body for all matters concerning the removal, storage, use and disposal of human tissues (except gametes and embryos) for scheduled purposes, and includes responsibilty for living donor transplantation. The HTA's code of practice on consent sets out guidance on how the law should be applied, encompassing issues of consent.

In practice, it is the next of kin or the patient's executor who is usually approached to give permission for donation. If the patient has signed a donor card there is no statutory requirement to approach the family, but in practice the views of the family are always sought and if objections are raised donation does not occur.

If the next of kin cannot be notified, the body remains in the possession of the hospital. In such cases the hospital manager can give permission for donation as long as reasonable enquiries have been made and that there is no reason to believe that the deceased had expressed objections.

Religious beliefs

As far as it is known, no major religious groups in the United Kingdom object to the principles of organ donation and transplantation. Some groups feel that it is only permissible if donors themselves had requested donation. These groups include, in particular, Orthodox Jews, Christian Scientists and some Hindu groups. Jehovah's Witnesses have religious objections to blood transfusions, but feel that donating or receiving organs is a matter for all Jehovah's Witnesses to decide for themselves.

It is often thought that the Muslim faith does not support donation and anecdotal evidence suggests that British Muslims are, in general, reluctant to donate organs. However, recent legislation has approved donation and transplantation in Muslim countries such as Saudi Arabia. Also, a fatwa issued by the Muslim Law Council has stated that Muslims may donate organs. They may carry donor cards and their next of kin may give permission for donating. Previous reluctance to donate may have been cultural rather than religious and therefore information and liaison with Muslims will be vital in order to encourage donation.

Roderick *et al.* (2009) states that there is a documented fourfold increased prevalence of ERF in the black and south-Asian patient groups. Major causes are the higher incidence of hypertension and diabetes combined with other reasons that are, as yet, unknown. Although none of the major religions forbids organ donation, there are fewer deceased organ donations from this community. The reasons for this are complex but include mistrust of the NHS, lack of available culturally sensitive information and lack of engagement with the community in general (Department of Health 2010). Language and cultural barriers seem to have inhibited the uptake of public health messages pertinent to organ donation and transplantation.

The Organ Donor Task Force (ODTF) was set up in 2006 by the UK government with the aim of increasing donation rates in the United Kingdom. The ODTF recommended the need to engage with black and minority ethnic groups in order to address the shortage of donor organs from this group.

Other issues may also be adversely affecting the deceased donation rate from within *all* groups, particularly aspects relating to gaining consent from the bereaved.

Fear of increasing the distress of the family

Critical care staff have expressed fears that offering donation may increase the distress of the bereaved; however, experience suggests that offering the choice to donate, if performed with empathy, does not increase distress (Simpkin *et al.* 2009). Indeed, donor families report that the act of donation brings comfort and something positive in an otherwise negative situation. One American study found that families were more likely to consent to donation when hospital staff mentioned that by donating they would offer help to others (Siminoff *et al.* 2001). In the presence of a diagnosis of brain stem death there can be no hope for the patient but donation can be an option offering hope of life for others.

Acceptance that death has occurred

It is crucial that the bereaved family have accepted the fact that death has occurred before donation is requested. In the case of brain stem death the acceptance of death is more difficult for the family as they are asked to accept a 'new concept of death'. The accepted concept and image of death involves a cold, lifeless body without a heartbeat; however, in the case of brain stem death the family are presented with an image of a warm patient with a heart beat who appears (due to the ventilator) to be breathing. Therefore, the visual message is one of life but the verbal message is one of death. In such cases denial is often enhanced and relatives must struggle to understand and accept the situation. Denial may be particularly acute in the case of an intracerebral bleed where there is no outward sign of injury or trauma.

Clear communications must ensue, the core message being that there is no hope of recovery. Irreparable damage has occurred and, in the case of brain stem death, the brain has died – death of the brain stem is death of the person.

When to offer donation

It is damaging to approach the family too early, as trust may be lost. Several studies examined the reasons for relatives' refusal (for example, Simpkin *et al.* 2009) and noted that refusal could be attributed to several reasons, including concern about protecting the dead body, perceived quality of care during the current episode, timing of the request and a limited understanding of brain death. It was recognised as being important for the family to have accepted that death has occurred before donation is offered, so to inform the family of the death and to request donation at separate meetings. The timing of the request and the skill of the person making the request were seen to have the greatest positive impact on gaining consent for donation.

Who should offer donation?

All studies report that the person who has established a trusting relationship with the family is the most appropriate person to offer donation. It is important that the requestee has a positive view of donation and can offer it in a positive way.

How to offer donation

There are no 'right' words; each situation is unique and families will have their own individual responses. The family should be asked if they have any objection to donation rather than for permission to proceed. Some families will require time to consider their decision. Many relatives will have additional questions concerning the process of donation and its implications at this time. The family may require reassurance on the following issues:

- The donor will feel no pain.
- There will be dignity and respect throughout the donor surgery.
- The body will not be grossly mutilated or disfigured.
- The surgical wound will be sutured.
- They can view the body after surgery and the funeral will not be delayed.

The specialist nurse for organ donation works closely with other healthcare professionals to answer further questions and to facilitate the wishes of the family. It can be reassuring to the family that he or she will be present throughout the surgery and at the end to oversee and continue care. They will also ensure that the bereaved can see the deceased after surgery in the chapel of rest if this is their wish.

Unconditional gift

It is important to stress that organ donation is a voluntary 'unconditional gift'. One case, much publicised, reported that the bereaved had stated that the organs 'must only be given to white recipients'. Such a condition is totally unacceptable and there is now legislation that prohibits the placing of any conditions when agreeing to organ donations.

Continuing care after donation

Letters of thanks containing brief anonymous information concerning the transplant recipients are given or sent to the donor family after the donation. Further help and

support are also offered. Many families state that the news of the successful transplants is a source of comfort. More recently, transplant coordinators have arranged meetings between donor families and recipients. Such meetings have been requested by both parties and have followed careful counselling and preparation to ensure the willingness of all individuals involved.

Refusal to donate

As part of recent measures to improve organ donation rates in the United Kingdom, an audit of potential donors in all UK intensive care units and emergency departments commenced in 2003 and was updated in 2009. The aim of the audit is to determine the number of potential organ donors. Results from the report for 1 April 2011 to 31 March 2012 indicate that 91% of patients who met the criteria for donation after brain death (DBD) were referred as potential donors, however only 53% of patients meeting the criteria for donation after circulatory death (DCD) were referred. Of the families approached regarding potential organ donation the report cites the following as the main reasons for refusal of consent:

- Patient stated in the past they did not wish to be a donor (16.4%).
- Family were not sure the patient would have agreed to donation (16.2%).
- Family did not want surgery to the body (11.9%).
- Family felt it was against their religious/cultural beliefs (9.1%).

Further analysis of the results of the audit show that the age and gender of the potential donor has little impact on the refusal rate, but relatives of ethnic minority groups are more than twice as likely to deny consent than those of white potential donors (NHSBT 2012).

Refusal rates at this level represent a desperate lost potential. Therefore, it is vital that information programmes to allay fears and to present the successes of transplantation continue. It is also helpful to implement education for healthcare staff to examine the issue of requesting donation so that personnel will feel comfortable when offering this option of hope to the family.

Transplant coordinator groups have introduced workshops on breaking bad news and the approach for donation for nursing and medical colleagues working in intensive care and emergency departments. Such workshops use informed actors and provide a forum and a safe environment for staff to examine sudden traumatic death, the reactions of relatives and responses that will facilitate the approach for donation.

If the family agree to donation, the ventilation continues and the preparations for the donor surgery are made, but if the family refuse donation then ventilation will cease.

It is always helpful for the family if the deceased carried a donor card, was registered as a donor on the National Register or had discussed the issue with them. Most families want to fulfil the wishes of their loved one and if they know the thoughts of the deceased with regard to donation, then the question and decision are no longer difficult for them.

Clinical care of a potential organ donor

Brain-stem death results in changes to normal homeostatic mechanisms; such changes will ultimately result in cardiac arrest. Once permission has been given for donation it is important to stabilise the condition of the donor to ensure optimal condition of the organs for transplantation. The care can be very complex and is outside the scope of this book; but further reading can be found in ICS (2004).

The role of the specialist nurse for organ donation

All renal transplant centres depend on local organ donation specialist nurses. They are senior practitioners who offer a 24-hour service to intensive care units with regard to organ donation. The role of the specialist nurse at the time of donation is to offer:

- advice regarding suitability of a potential organ donor;
- advice regarding donor clinical care;
- advice and/or help with the approach to relatives;
- organisation of the organ donation procedure and surgery;
- support of the family and staff.

Organisation of the organ donation procedure and surgery

The specialist nurse will usually attend at the donor hospital to offer advice and support to the donor family and critical care staff. Organisation of the organ donation is complex and the specialist nurse will attempt to make all arrangements with a minimum of distress to the donor family and the critical care staff. The majority of organ donations today are multiple donations and it is the specialist nurse who organises the necessary blood and clinical tests, liaises with the heart, liver, renal and ophthalmic teams and arranges the donor surgery (Box 10.7).

Permission from the coroner

If the case comes under the jurisdiction of the coroner (or Procurator Fiscal in Scotland), then permission must be obtained to proceed to organ donation. Cases usually requiring the coroner's permission include:

- road traffic accident;
- suspicious deaths/suicide;
- deaths less than 12 h after surgery;
- traumatic deaths.

It is unusual for permission to be withheld except in the case of suspected murder.

Removal of kidneys from a multiorgan donor

It is most common now for kidneys to be taken out as part of an operation from a multiorgan donor. This requires careful coordination between the liver, renal and thoracic teams involved to make sure that there is no compromise to viability in any of the transplanted organs.

The exact details of the operation vary from centre to centre, but the principles include a generous incision giving good exposure to the organs of interest with the heart still beating, and placement of cannulae for in situ perfusion and cooling:

- A bilateral subcostal incision with a midline sternotomy is a common approach to the chest. The heart and lungs are inspected and mobilised first to allow rapid removal at a later stage.
- A careful laparotomy is carried out before dissection of the major blood supply to the liver. The common bile duct is transected and the gall bladder incised and flushed to prevent biliary autolysis.
- Cannulae are placed into the aorta and portal vein via the mesenteric vein for perfusion. The distal inferior vena cava is cannulated and used for vascular drainage.

BOX 10.7

Organ Donation: Role of the Specialist Nurse for Organ Donation

Arrival at donor hospital.

Meet with critical care staff.

Assess potential donor suitability.

Advice regarding donor clinical care (if requested).

Meet with donor family; offer advice and support (if requested).

Permission from the coroner or coroner's officer.

Organise clinical tests and blood tests:

Clinical tests	*Blood tests*
12-lead ECG	ABO blood group
Chest X-ray	Biochemistry
Approx. size and weight of donor	Urea and electrolytes
Arterial blood gases	• Liver function tests
	• Full blood count
	Virology screen
	• HIV
	• Hepatitis B and C
	• Cytomegalovirus
	• Toxoplasmosis
	• Syphilis

Contact NHSBT about superurgent cases.

Liaise with heart, liver, renal and ophthalmic teams.

Liaise with theatre staff and obtain theatre time:
- Accompany donor to theatre.
- Assist surgical teams.
- Support theatre personnel.

Final care of donor

Contact with donor family offering information and/or support.

Information and thanks to donor hospital personnel.

Ventilation ceases when the aorta is cross-clamped. Perfusion starts simultaneously to minimise warm ischaemia.

- The organs are removed; first, heart and lungs, followed by the liver and then the kidneys. Careful cooperation between teams is required to minimise damage to the various organs. The pancreas is used for transplantation with increasing success; concurrent retrieval with the above organs has not been associated with adverse outcome.

Before closure of the abdominal incisions, specimens of donor lymph nodes and spleen are removed for histocompatibility and tissue typing.

Surgical technique for deceased donor nephrectomy

If the kidneys are to be removed alone, bilateral nephrectomy is accomplished through a long midline incision or a bilateral subcostal incision. The kidneys are either taken

out *en bloc* or individually on patches of inferior vena cava and aorta. The technique preferred in this centre entails the removal of an individual kidney on a patch of aorta and inferior vena cava. The technique is as follows:

- Abdominal incision and laparotomy are performed as for multiorgan retrieval.
- The aorta is dissected up to the superior mesenteric artery and the inferior vena cava dissected above the renal veins.
- Slings are placed around the aorta and the inferior vena cava above the bifurcation ready for tying at a later stage.
- A catheter is passed into the aorta through an incision just above the bifurcation. The balloon of the catheter is distended with fluid and ties placed around the aorta distal to the balloon to hold it in place. Care must be taken not to overdistend catheter balloons as this can obstruct the lumen of the catheter.
- A similar procedure is carried out with the inferior vena cava just above the confluence of the right and left common iliac veins, and the aorta and inferior vena cava below the catheters are tied off.
- The aorta is tied off in the upper abdomen and perfusion is started through the Foley catheter (Figure 10.3). As perfusion starts, ventilation is discontinued.
- The kidneys begin to get cold at this stage and, while the perfusion fluid is running through into the kidneys and out through the renal veins, the kidneys should be surrounded by ice to assist cooling and prevent rewarming from the adjacent tissues.
- The inferior vena cava above the renal veins is ligated and the blood from the kidneys drains out through the catheter in the inferior vena cava.
- After 2 L of perfusion fluid has flushed through the kidneys and the kidneys are cold, they can be mobilised and the cannulae removed.
- The inferior vena cava is split up the middle and along the back, taking care not to divide the right renal artery. The aorta is also divided anteriorly and posteriorly, taking care to avoid damaging the left renal vein which crosses in front of the aorta.

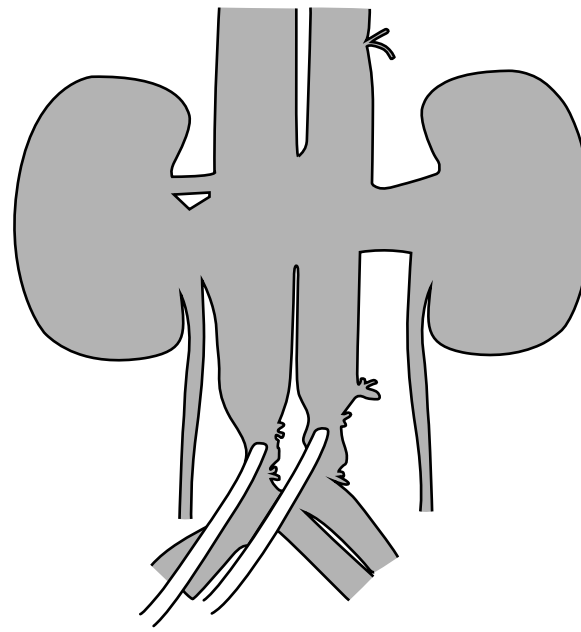


Figure 10.3 Perfusion catheters in situ for deceased donor nephrectomy.

Having done this, each kidney is taken out with a section of aorta, inferior vena cava and long length of ureter and placed in iced saline, where it is reflushed with preservation fluid.

- Normally, no further dissection is done at this stage, but the kidney is placed in sterile bags and sent at 4 °C to the receiving centre. Further dissection of the kidney is performed immediately before subsequent transplantation into the recipient.

Following removal, each kidney is examined for any surgical injury and unusual anatomy and is placed in a sterile bag with a small amount of perfusion fluid. This bag is then placed inside two further polythene bags to ensure sterility. The kidney is finally packed into a transport container with ice.

Organ preservation

The aim of preservation is to maintain the organ in an optimal condition until transplantation can occur. All living cells require oxygen to survive. Once the blood supply to the organ ceases, the lack of oxygen will result in cellular ischaemia. Cooling the organ will reduce the cellular metabolism and thus help to minimise subsequent damage. Ischaemia that occurs before the organ is cooled is termed warm ischaemia.

Warm ischaemia

If the blood supply to the kidneys is interrupted without cooling, the tubular cells suffer warm ischaemia resulting in acute tubular necrosis (ATN). Acute tubular necrosis may be reversible if the warm ischaemia time is limited (approximately 45 min). However, should the warm ischaemia extend longer than one hour the glomeruli are likely to suffer irreversible damage and the kidney may not regain function. During DBD donation the ventilation and blood supply continue until the perfusion system is in place. As perfusion with cooled fluid commences, the ventilation ceases. Thus, the kidney is immediately cooled and the warm ischaemia is limited to approximately 1–2 min only.

Cold ischaemia

The ice should maintain the kidney at approximately 4 °C, thus minimizing ischaemic damage and enabling transport to the transplant centre. The time from the beginning of cooling to reperfusion and rewarming at the time of transplantation is termed the cold ischaemia time. Most kidneys can be stored for 24–48 h if necessary. However, recent studies suggest that prolonged cold ischaemia does reduce the function of the transplant, with a 4% increased risk of graft failure for every hour after 21 hours of cold ischaemia (Johnson *et al.* 2010).

Donation after circulatory death

Donation after circulatory death can take place when death occurs as a result of irreversible cardio-respiratory arrest. Such donation may be 'controlled', that is where life-sustaining support is withdrawn and death takes place, or 'uncontrolled' where death is sudden and unexpected. Relative and absolute contraindications for donation are the same as for DBD donation. To establish death the patient must be observed by the clinician for at least five minutes to ensure that irreversible cardio-respiratory arrest has occurred. Following this a double balloon triple lumen catheter is inserted into

the femoral artery, the catheter is guided into the aorta and the top balloon inflated to occlude the aorta. The lower balloon is then inflated and cold perfusion fluid is flushed through the catheter and into the kidneys. A further catheter is inserted into the femoral vein to allow the perfusion fluid to drain. This procedure allows the kidneys to be perfused with cold solution prior to removal, allowing time for the patient to be moved to the operating theatre whilst minimizing warm ischaemic time.

Prior to the introduction of brain stem death criteria in 1976 all organ donations came from donors who had suffered circulatory death, the introduction of this criteria and the ability to maintain potential donors on artificial ventilation led to the reduction in this practice. However, the lack of suitable organ donors in the last ten years has led to the increasing use of DCD donors, with good success rates for kidneys transplanted from this group. DCD donor kidneys accounted for 37.6% of all deceased donor transplants carried out in the UK in 2011 (NHSBT 2012), a 17% increase since 2010. However, the National Potential Donor Audit carried out by NHSBT has identified large numbers of patients in intensive care units and emergency departments who meet the criteria for DCD donation but who are not referred to the Specialist Nurse for Organ Donation. This indicates potential to further increase the numbers of such donations in the UK.

The issue of gaining consent can be problematic, it is unlikely the donor will be able to give consent so the family will be approached. The Organ Donor Register (ODR) can be accessed to give an indication of the patients wishes. The time between referral for donation and actual donation can be distressing for the family and friends of the patient. The Specialist Nurse-Organ Donation (SN-OD) will assume the same role as in DBD donation and will provide support and assistance to both the donor's family and to the team providing care to the patient.

A consensus group meeting in 2010 (ICS 2010) recognised a wide variation across the United Kingdom in the care of potential DCD donors and the retrieval and transplant of organs. The consensus group report recommended that all intensive care units and emergency departments have clear local policies based on national guidelines to assist clinicians in this area. The decision to withdraw life sustaining treatment must be based on the best interests of the patient with no regard to the potential for organ donation. Only after this decision has been made can treatment aimed at preserving organs for transplantation be commenced. There are ethical and legal questions to consider with the practice of DCD donation, for example, to what extent should clinical interventions be undertaken in the dying patient in order to facilitate organ donation, such as, admission to intensive care, arterial and venous catheterisation, inotropic support? The Department of Health set out to clarify the legal position regarding DCD donation in 2009 (Department of Health 2009). This guidance should be used as a basis for local DCD donation protocols. The increase in the number of DCD donor kidneys for transplantation is related to the development of more extensive DCD programmes in the UK and there is potential for these numbers to increase further.

Living Relation Donation

In the early days of transplantation, live related transplants were the only possible option but, with the advent of deceased donation and improved immunosuppression regimes, most centres concentrated, in the main, on deceased donation with fewer live donor transplants. This was due, in part, to the fact that some clinicians struggled with the ethical issue of subjecting a healthy and fit person to the risks of major surgery that had no personal benefit for them, albeit there would be benefit to their family member.

Ethical issues

The core factors of the living donation debate involve the critical issue of a balance between 'doing good without doing harm' and the concept of altruism.

Physical wellbeing – doing good without doing harm

The donation will most certainly 'do good' in benefiting the recipient but may also 'do harm' to the donor, as the surgical procedure exposes the living donor to major clinical risks. Mortality from living donor surgery is low, however, donor deaths have been reported. A figure of 1 in 3000 is suggested in UK guidelines on living kidney donation. The risk of death is comparable with that of dying in a road traffic accident. Early postoperative complications may occur including chest infection, deep vein thrombosis, wound infection and postsurgical depression amongst others. Long-term complications have not been demonstrated, with follow-up studies of living related donors, over at least 20 years, finding no functional abnormalities. A major study of 3698 donors undertaken by Ibrahim *et al.* (2009) demonstrated no difference in survival of donors when compared to matched controls.

Psychological wellbeing – doing good without doing harm

Undoubtedly, many living donors gain psychologically from the act of giving. Studies suggest that donors describe the act 'as one of the most meaningful experiences in their lives' (Fellner and Marshall 1968) and 'view themselves as more worthwhile because of donation' (Simmons *et al.* 1971). The satisfaction of helping a 'loved one' return to a normal lifestyle is very rewarding for many. Indeed, it has been suggested that there may be psychological harm if a donor is prevented from giving (Simmons *et al.* 1977). Thus, living donation presents physical risks but psychological gain for most donors (Thiel *et al.* 2005).

Altruism

Altruism – the act of unselfishness – means giving freely without thought of reward. Much debate has surrounded this concept, with writers in the 1960s and 70s questioning the fundamental reasons for giving. Kemph (1966) reported that although donors were 'consciously altruistic' there was 'considerable unconscious resentment' towards the recipient and towards hospital personnel who requested or encouraged the donation. Other studies suggested the presence of a degree of coercion or subtle familial pressure. There were also reports of financial incentives or other 'material rewards' offered by recipients to donors to encourage donation. Although many of these early studies involved small numbers of donors and recipients, the negative findings led many centres to pursue deceased donor options.

Later studies in the 1970s and the 1980s reported more positive psychological findings (Smith *et al.* 1986) and this led to the development of more extensive live donor transplant programmes in many UK centres. Some centres however continued with a strong stance against living donation, mainly because of the physical risks to the donor. However, a study by Levey *et al.* (1986) noted that the physical risks to the donor were 'minimal' and that the benefits to the donor were 'considerable' with regard to self-esteem and self-worth. Surman (1989) stated that 'kidney donation has a favourable outcome for both donor and recipient and that the participation of living related donors in kidney transplantation was now widely accepted'.

Recent studies have been supportive of live donation but have also noted psychological issues that may need to be addressed. Scheper-Hughes (2007) identified hidden pressures from within families where patients may have an expectation that a certain family member will donate. A study of 262 live kidney donors found that 40% felt pressure to donate, with this most likely where there was a family relationship to the patient (Valapour *et al.* 2011).

Further studies have also reported positive findings. Fournier *et al.* (2012) investigated follow-up of 398 living donors who had donated between 1952 and 2008. The study concluded that there were no negative psychological effects on the donors in the long term.

Benefits for the transplant recipient

Although the ethical issues have been recognised and much debated, the decision to continue with living donation has usually been based upon the very real benefits that ensue for the recipient. Living donation has always demonstrated higher graft survival rates than deceased donation, regardless of genetic relationship or tissue matching. Although recent advances in immunosuppression have narrowed the gap between the two groups, in most cases the living donor grafts still have a better survival rate at one year and a significantly higher probability of function in the long term. The recipient benefits from a reduction in the time on dialysis, which is recognised as contributing to an improved outcome following transplantation.

The living donation can be planned to take place at the most suitable time (medically and socially) for the recipient and donor. As renal function deteriorates, transplantation can be planned for the predialysis phase, thus avoiding the physical and psychological stress of dialysis adjustments. Studies have shown an improved outcome for recipients transplanted in the predialysis phase. Such benefits have encouraged the expansion of living donor programmes.

Transplant rates

Living donor programmes vary throughout the world but most European countries have a substantial live donor programme. In the countries covered by Eurotransplant, in 2011, nearly 37% of kidney transplants were from living donors (Eurotransplant 2011). Sweden, the United States, Denmark and Greece also have relatively high rates. Until recently, the United Kingdom had a low rate with only 5% of the total transplant programme resulting from living donation in 1981, now increased to 36% in 2011 (Figure 10.4).

Living unrelated donation (genetically unrelated – emotionally related)

In Norway in the early 1990s, parents, siblings, adult children, uncles, aunts, grandparents and spouses were accepted as donors. Spouses are, of course, genetically unrelated but were recognised as 'emotionally related'. The Norwegian experience showed that transplantation between spouses (partners) could achieve graft survival rates equal to the best achieved with cadaveric organs. Similar results for transplantation between partners were reported in the United States (Terasaki *et al.* 1995). Centres across the world are now utilising spousal/partner donors and also other donors, who have a demonstrable long-term relationship with the recipient, such as close friends. However, all centres stress that the donor must be well motivated and well informed and that the offer must be 'altruistic' and come from within a 'stable relationship'.

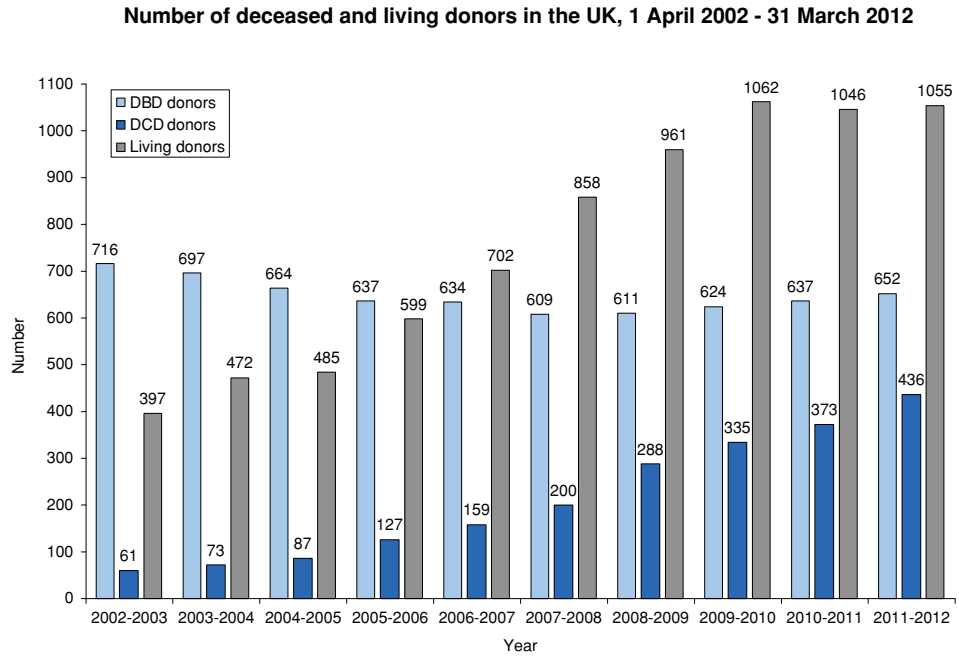


Figure 10.4 Number of deceased and living donors in UK, 1 April 2002 - 31 March 2012.
Source: from *Transplant Activity in the UK 2011–2012.* NHS Blood and Transplant.

Buying and selling of organs

Living donor transplantation in the United Kingdom is controlled by strict laws to prevent the possibility of illegal practices such as financial payments and coercion. In the United Kingdom the Human Tissue Act 2004 came into place in 2006. This Act placed the principle of consent at the centre of living donation, and indeed to all issues relating to donation and the taking of, storage and use of human tissues and organs. It covers England, Wales, Northern Ireland with the Human Tissue (Scotland) Act 2006 covering Scotland. The Human Tissue Authority (HTA), established in 2005, implemented the provisions of the Act and the EU Tissue and Cells Directive which also came into force in 2006. Under the Act, the approval process is the same for directed genetically or emotionally related organ donation. Local independent assessors, trained and accredited by the HTA, assess all donor/recipient pairs, and where the requirements are met, give approval to proceed. Prior to 2006, legislation precluded the use of altruistic donors who wish to give anonymously to the donor pool, however it is now possible for nondirected altruistic donation to take place, with the donor kidney being utilised in the same way as a deceased donor kidney. The new Act has also allowed the development of the National Living Donor Kidney Sharing Scheme.

The buying and selling of organs does occur in some of the developing countries and is an accepted practice. Indeed, some clinicians have suggested that a similar system, strictly controlled by legislation, could be introduced in the UK to increase transplant rates. The ethical and moral ramifications would be immense and at present such a concept is illegal and totally unacceptable to most.

National Living Donor Kidney Sharing Scheme

This system was introduced to allow donor and recipient pairs who were incompatible for transplantation to be matched with other donors and recipients in the same situation and the donors to be effectively 'swapped'. This procedure can be carried out between more than two pairs, known as pooled donation. This scheme is administered by NHSBT and individual units are responsible for donor and recipient work-up prior to registering for the scheme. Matching runs are carried out on a three monthly basis and the units involved informed of any matches thereafter. Once units are informed of a match a cross-match blood test is arranged between relevant donors and recipients. Once results of the cross-match confirm that the transplant can proceed, the donor and recipient are interviewed by their local Independent Assessor (IA) and a report submitted to the HTA. Once HTA approval is given the transplant must take place within six months, otherwise re-assessment by an IA will be required. The transplant operations take place simultanously at each centre with kidneys travelling from the donating unit to the receiving unit. Anonymity between donor and recipient is maintained in the same way as for deceased donation.

A review of the living donor kidney transplant programme in the UK was undertaken in 2010 by NHSBT. The findings of this review led to the development of the UK Strategy for Living Donor Kidney Transplantation (NHSBT 2011). The aims of the strategy are to:

- Increase the number of living donor transplants, especially pre-emptive, paired/pooled and altruistic transplants.
- Promote best practice to ensure donor safety.
- Ensure equity of access and maximise the opportunity for donors to access national living kidney donor schemes.
- Set up a steering group with key stakeholders, including patient representation, from across the transplant community to develop an implementation plan for the strategy.
- Work with the Department of Health to develop robust and transparent commissioning arrangements to facilitate and develop living donor kidney transplantation.

Donor and recipient matching

Individual tissue type is inherited as half from each parent. Therefore, matching within a nuclear family unit will usually result in a potential donor who is HLA-identical, a one-haplotype match or a mismatch.

Immunological aspects (example as for donor-related (DR) matching)

Matching for the major histocompatibility complex (MHC) will take place, however. Figure 10.5 demonstrates tissue-type inheritance using the DR locus.

Therefore, potential donors may be:

- HLA-identical, as with DR1:3 (siblings);
- a one-haplotype match, as with DR1:3 and DR1:8 (siblings);
- DR1:4 and DR1:3 (parent–child);
- unmatched, as with DR1:3 and DR4:8 (siblings).

The long-term graft survival rates are better with better matching, but a mismatched living donor kidney transplant gives better results overall than well matched deceased donor transplants.

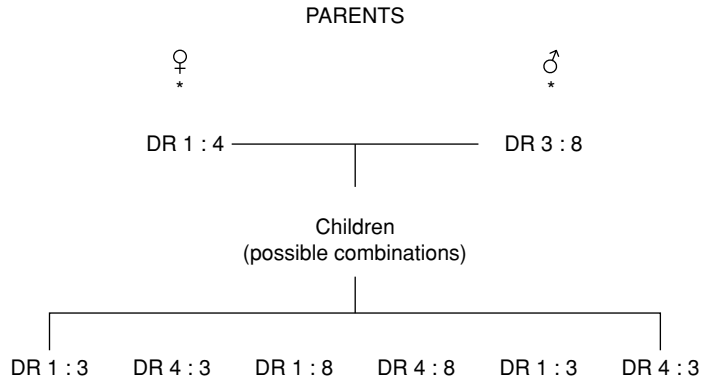


Figure 10.5 An example of tissue-type inheritance.

Psychological issues

The question of the possibility of living related donation may bring unity to a family group but it may also bring conflict. Parents will often offer to donate early in the disease process and are extremely well motivated, but problems can arise if one parent is 'more suitable' due to tissue matching or physical constraints. The 'less suitable' parent may feel rejected and excluded from the donation and transplant process.

Siblings may be willing or ambivalent and it may be difficult to express ambivalent feelings because of societal concepts of family loyalty and love. A sibling of a patient has expressed the wish that 'the request had never been made, as once verbalised it was impossible to refuse without feeling enormous guilt'. Married siblings may wish to donate but may encounter hostility from their partner who feels that the risks are too great and that responsibilities to the family of marriage are more important than loyalty to the family of birth.

Ongoing psychological support is a necessary part of a living donor programme. Donor and recipient must be well informed concerning the risks and benefits and also the psychological difficulties that may develop. Separate meetings, both for the donor and the recipient, with medical staff and nurse/counsellor should be planned so that feelings, fears and anxieties can be discussed with honesty. The motivation to donate should be explored and, if appropriate, the donor offered the opportunity to withdraw without guilt or family conflict.

Similarly, the decision to receive should be explored and the recipient offered the opportunity to refuse. Some patients have refused living donation, preferring to wait for cadaveric grafts so as not to 'inflict my disease on my family'. The dynamics of the donor and recipient relationship must be well understood so that help and advice may be offered if difficulties arise.

Assessment and preparation of donors

The living donor must be:

- well motivated;
- in excellent health with two normal kidneys and normal renal function;
- ideally compatible for blood group and crossmatch with the recipient, although ABOi and HLAi transplantation is now possible

BOX 10.8

Initial Donor Assessment

- Donor previous medical history.
- Blood group.
- Tissue typing.
- Urinalysis (urine microscopy, culture and sensitivity, albumin/protein:creatinine ratio).
- Blood pressure, pulse, weight and height.

The aim is to identify unsuitable donors early in the process. If there are no contraindications at this point the donor will move on to the next stage of assessment.

The assessment and preparation for living donation are extensive and normally carried out in stages over several weeks or months. Different centres will conduct tests at different stages but most units complete the same catalogue of tests in order to ensure that the criteria are fulfilled. The British Transplant Society and Renal Association have produced guidelines on this. It is recommended that the potential recipient should be evaluated for suitablility for transplantation as early as possible, to avoid any unnecessary delay. Donor assessment should be organised in a way that is acceptable to the potential donor, avoiding the need for repeated visits and inconvenience to home and work life as far as possible. Grouping tests and investigations together can minimise extra visits to hospital and an organised and focused approach to the process is good practice (see Box 10.8 and 10.9). This is best organised and monitored by the living

BOX 10.9

Medical Assessment and Further Investigations see British Transplantation Society (2011) for detailed information on donor assessment.

- Full medical history and physical examination.
- History in relation to transmissible infection.
- Repeat urea, electrolytes, creatinine.
- Liver function tests, fasting glucose, bone profile.
- Haemoglobin, blood count and coagulation screen.
- Viral screen.
- Repeat urinalysis (urine microscopy, culture and sensitivity, albumin/protein:creatinine ratio).
- Measurement of glomerular filtration rate (GFR) – see British Transplantation Society (2011) guidelines for acceptable GFR based on donor age.

Clinical tests

- Chest X-ray.
- Electrocardiogram.
- Imaging of kidneys to determine renal anatomy, initially by ultrasound (less invasive) and progress to preferred method of assessment of vessels, which may be by catheter angiography, digital subtraction angiography (DSA), computed tomography (CT), magnetic resonance angiography (MRA).

Other tests as indicated, depending on family history and/or results of physical examination, for example glucose tolerance test, thyroid function, echocardiogram. The donor assessment procedure aims to ensure the suitability of the donor, to minimise the risks of donation and to ensure suitability of the donor kidney for the recipient. Donor confidentiality should be maintained at all times. Donor assessment is generally carried out by medical and surgical teams that are not also caring for the recipient, this ensures separation of interest. The donor assessment process should be designed in such a way that straightforward noninvasive tests are carried out first, therefore, if donors are later found to be unsuitable they avoid the need to undergo invasive testing.

donor co-ordinator who becomes the point of contact for potential donors and liaises between the various members of the multidisciplinary team (MDT).

Throughout the assessment programme the donor is assured that it is possible to retract the offer to donate at any time. Such a decision will be strictly confidential and support and advice will be available. If the donor wishes, a medical reason not to donate can be provided. This medical reason is seen within the context of a 'benevolent decision' to enable the donor to retract without family conflict or distress, thus promoting full altruism.

Preoperative care for the donor

Two separate surgical teams are usually involved with a living related donation. The donor team assumes responsibility for donor care and the transplant team takes responsibility for recipient care. The donor and recipient are usually both nursed within the transplant centre in separate rooms. However, they may be nursed together if they so wish, if there are language or other difficulties.

The donor and recipient are usually admitted on the day before transplant and at this stage a further medical history and physical examination will be performed, along with an anaesthetic and physiotherapist assessment (see Box 10.10).

The immediate preoperative care for the living donor will be similar to that given to patients undergoing conventional nephrectomy. However, particular attention is paid to informed consent, preoperative hygienic care and premedication.

Surgical technique of nephrectomy

Living donor nephrectomy is always emotionally taxing surgery and can be technically difficult. The estimated mortality from living donor nephrectomy is 1 in 3000. Thus, while very rare, the risks are certainly not negligible and major morbidity or death is very traumatic not only for the relatives but for the members of the surgical team themselves.

The traditional approaches for removing a kidney from a live donor are either transabdominal, intraperitoneal, or via the loin over the 11th or 12th rib, either spreading or removing the 11th or 12th rib. The intraabdominal approach is usually through a transverse incision in the right or left upper quadrant. Laparoscopic nephrectomy, either

BOX 10.10

Donor Preoperative Assessment Investigations

- Electrocardiogram.
- Chest X-ray.

Blood tests

- Final cross match.
- Meticillin-resistant *Staphylococcus aureus* screening swabs (throat, nose, axilla, groin).
- Urinalysis, urine for microscopy, culture and sensitivity.
- Biochemistry.
- Liver function tests.
- Haematology and clotting screen.
- Baseline measurement of blood pressure, pulse, respiration rate, temperature and weight and nursing admission procedure.

hand assisted or totally laporascopic is the most common surgical technique used in the United Kingdom and may be transperitoneal or retroperitoneal in approach. The technique requires a high degree of training of surgeons. The donor is placed in the flank position and the abdomen insufflated with carbon dioxide gas. Entry ports are made into the abdomen for the camera and instruments. After isolating the kidney it is enclosed by a bag to aid removal through another incision. The hand-assisted laparoscopic technique entails an incision large enough to allow insertion of the surgeon's hand to assist with the laparoscopic procedure.

Generally the left kidney is preferred due to the longer left renal vein, however the right kidney may be used succesfully if preferred and if there are extra arteries on the left. The presence of more than one artery can make the surgery more complicated and it is important that this is established pretransplant and the donor counselled of the relevant risks.

The kidney is carefully exposed and meticulous dissection is carried out with careful handling of the kidney and careful exposure of the renal vein and artery. The gonadal and adrenal tributaries of the renal vein are ligated and divided and often a posterior lumbar vein needs ligating and dividing as well. The renal artery is cleaned and exposed at its junction with the aorta and the ureter is identified and dissected down to the pelvic brim or just below, where it is ligated and divided. It is very important to avoid too much dissection in the hilum of the kidney and it is also essential to avoid stripping the ureter of its adventitia. The blood supply to the ureter normally comes from the renal artery, branches from the gonadal vessels and the external iliac artery and branches of the superior vesicle artery. In a transplant kidney the blood supply to the ureter is entirely dependent on the renal artery and it is essential to keep a good amount of adventitia around the ureter to allow the blood to reach the distal ureter. One of the major complications after transplantation is ischaemia of the lower end of the ureter and this is normally due to stripping of the ureter or loss of a lower pole artery at the time of the donor surgery.

When the kidney is free and attached just by the artery and the vein, the artery is ligated and divided first, followed by the vein. The kidney is removed and placed in iced saline where perfusion is started immediately and, after careful inspection, any further dissection is carried out and a renal biopsy is taken.

Postoperative management: living donor

The postoperative care for the living donor is similar to the care given for a conventional nephrectomy. Laparoscopic nephrectomy is associated with a shorter hospital stay, reduced pain and quicker recovery time than standard nephrectomy. In most centres, patient-controlled analgesia using an opiate is utilised.

Hydration: fluid and electrolyte balance

Paralytic ileus may occur as a result of the retroperitoneal dissection and the handling of the bowel. Therefore, the intake of oral fluids must commence slowly and only increase as ileus resolves and bowel sounds are evident. In practice, hydration is maintained by intravenous infusion until oral intake is sufficient. Close monitoring of fluid and electrolyte balance is necessary until dietary intake is adequate.

The passing of urine may prove difficult due to the pain of movement and anxiety, so often a urinary catheter is inserted under anaesthetic so that urinary output can be closely monitored and pain minimised. The catheter is usually removed on the

second postoperative day. Regular midstream urine specimens should be obtained for microscopy, culture and sensitivity during hospitalisation. Monitoring of urine output is important to determine the function of the remaining kidney.

Wound management

Wound management should include regular inspection to exclude complications of bleeding and infection.

Emotional support

During the early postoperative period, emotional support should be offered, as should frequent information regarding the progress of the recipient. Donor and recipient should be reunited at the earliest opportunity and encouraged to spend time together. The donor may experience a feeling of anticlimax after the surgery due to a release of the preoperative tension and anticipation. Such anticlimax may combine with postanaesthetic 'blues' to form a mild depression with emotional lability. Staff should recognise the altruism of the act and offer understanding and reassurance.

Discharge

The majority of living donors will be discharged between the third and fourth postoperative day. It is recommended that they continue their postoperative recovery at home for approximately 6 weeks to 2 months. Return to work will be variable depending on type of employment and its physical and psychological demands. Physical monitoring may include one or two further assessments by the surgical team.

Most centres now monitor donors annually, although this may be done by the General Practitioner. Annual follow-up is recommended in the British Transplant Society/Renal Association Guidelines on Living Kidney Donation (2011), and NHSBT gather data from these annual follow-ups. Emotional support should continue as appropriate, with help available if difficulties arise.

Reimbursment for loss of earnings and travel expenses can be payed by the recipient's local Clinical Commissioning Group if authorised by the Specialist Health Care Commissioners. Donors should be made aware of this at an early stage in the work-up process. Reimbursement is not obligatory and depends on circumstances and locally agreed guidelines. It can often be a time consuming and slow process with no uniformity between different geographical areas. This situation is currently under review with the aim of standardizing donor reimbursement across all areas.

Increasing Donor Organ Supply

As stated earlier, deceased organ donor rates and kidney transplant rates in the United Kingdom have remained fairly constant since the early 2000s. Such rates are insufficient to meet demand and the renal transplant waiting list continues to rise. If the renal transplant rate continues at the same level,, many hopeful patients on dialysis will be denied their 'treatment of choice'. Extending living donor programmes has increased the supply of kidneys, livers and in some cases lungs for transplantation but it is crucial that the United Kingdom continues to explore and introduce initiatives to increase deceased donor organ supply.

The Organ Donation Taskforce was formed by the Department of Health to look at ways to increase organ donation. The United Kingdom has the eight lowest rate of organ donation in Europe (16.4 donors per million population in 2010) compared with 32.0 in Spain, the highest rate in Europe (see Table 10.2). 'Organs for Transplants' a report of the taskforce published in 2008, made fourteen recommendations and aimed to increase donor numbers by 50%, an achievable goal based on their research. These suggested changes were, in part, based upon the very successful Spanish organ donation system.

The recommendations included:

- Identification and referral of donors, facilitated by specialist donor transplant co-ordinators.
- Expansion of the donor transplant co-ordinator network, strengthening of the role nationally.
- Co-ordination of donor care by increasing the remit of NHSBT.
- Self-sufficient, UK wide organ retrieval teams, with provision to attend to more than one donor at a time.
- Local donation champions within hospital trusts.
- Mandatory training on donation for all members of the MDT.
- Reimbursement of costs incurred for donor care to participating hospitals.

Figures released annually by NHSBT have indicated the number of organ donors is increasing, in no small part due to the initiatives implemented following the taskforce report. However the work must continue if the target of a 50% increase in donor numbers is to be achieved by 2013.

Table 10.2 Actual deceased organ donors across Europe in 2010.

Country	Cadaveric donors pmp in 2010
Greece	3.9
Switzerland	12.6
Sweden	12.6
Republic of Ireland	12.6
Poland	13.3
Holland	13.7
Germany	15.8
United Kingdom	16.4
Slovakia	16.8
Finland	17.0
Czech Republic	19.6
Belgium	20.5
Norway	20.8
Italy	21.6
Austria	23.3
France	23.8
Portugal	30.2
Spain	32.0

Source: from the Council of Europe (2012).

Opting in/opting out

Within the United Kingdom the general public are encouraged to 'opt in' by making the voluntary decision to donate organs. This decision is supported by carrying a donor card or joining the organ donor register and informing relatives of this wish. Thus, donation is a voluntary gift.

Research suggests that approximately 75% of the general public support donation and about 30% had joined the NHS Organ Donor register by 2012; over 18 million people. More people who have not registered will carry an organ donor card, however problems with this system are that in practice, the donor card may not be available at the time of death, or relatives may either be unaware of the donor's wishes or may choose to ignore them. Several patient groups, and the British Medical Association, have pressed for the introduction of an 'opting-out' system, whereby everyone is deemed to wish to donate unless they have registered an objection. The opting-out system has been introduced in Europe (namely Austria and Belgium), and appears to be successful. However, with a true opting-out system the wishes of the family are not considered. At present it is felt by the major health groups in the UK that the denial of the family's wishes is unacceptable practice. Therefore, the government has decided to continue to support opting-in with the introduction of the national registry, whereby those wishing to donate can register their wishes on to the national computer. The computer can be accessed by critical care staff should death occur. However, relatives will still be asked for consent.

The British Medical Association suggests that by adopting a presumed consent (softer opt-out option), close relatives would not be asked to give permission but rather informed that the individual had not registered an objection. Unless the family object, the donation will proceed and this donation becomes a default position. This issue is a source of continued debate. In July 2013 Wales became the first UK country to adopt a process where individuals will be presumed to have consented for their organs to be donated unless they opt out.

Conclusions

It is hoped that the recommendations of the ODTF will continue to increase donation rates and achieve the target of a 50% increase in organ donors. It is possible, however, that with growing waiting lists the demand may always outstrip supply. The solution in the long term may be the introduction of xenotransplantation.

Xenotransplantation

Xenotransplantation covers any procedure that involves the transplantation, implantation, or infusion into a human recipient of live tissues or organs retrieved from an animal. A xenograft is use of an organ from an animal, whilst an allograft is the use of a human organ for transplantation. The issue of xenotransplantation is complex, with potential benefits in the form of increased availability of organs for transplantation compared with the ethical issues regarding animal welfare and wider public health. To date, in the United Kingdom, there have been no transplants of animal organs into humans and there are strict guidelines set by the Department of Health to regulate research in this area. The main barriers to xenotransplantation, apart from the ethical considerations, are the problems of rejection of the organ and transmission of infection.

From a biological viewpoint, closely related nonhuman primates such as chimpanzees would be the most suitable for transplantation, because there is no hyperacute rejection problem. However, it has been universally agreed that such species would be ethically unacceptable and impractical since they are endangered. For practicality, the acceptable

species would be those in current large-scale usage for food production, such as the pig. The problem of rejection of the xenograft however is difficult to overcome. The only instances of such transplants in the past (in the United States) have resulted in either immediate rejection of the graft or death of the recipient due to extremely high doses of immunosuppression. The most obvious and immediate problem confronting the use of xenografts is the problem of hyperacute rejection. Connection of a suitably prepared pig kidney to the blood circulation of a dialysis patient initially results in normal perfusion of the kidney, which becomes pulsatile and pink and may even briefly produce urine. However, within minutes the pulsatility of the kidney lessens, and then ceases, the kidney becoming initially blue and finally almost black as the circulation ceases due to thrombosis. This typical pattern of rapid graft failure was initially described in human kidney allografts and was termed hyperacute rejection. The cause was subsequently shown to be the presence in the recipient of high-titre antibody against the donor tissue, binding the antibody causing complement activation and subsequent activation of the clotting cascade. Blood group ABO incompatibility was a potent source of antidonor antibody that was easily avoided, but some cases of hyperacute rejection still occurred, even after blood group matching. In the case of human allografts it was possible to avoid this fairly rare occurrence by testing for the presence of antidonor antibody and avoiding transplantation when antibody was detected. However, in the case of xenotransplantation between distantly related species, antibody is always detectable despite matching for blood groups, and this antibody came to be known as heterophile or natural antibody.

Two fundamental recent discoveries are the basis for a number of new approaches to prevent xenograft hyperacute rejection, for example by blocking or removing the natural antibody or infusing human complement regulatory proteins. The recent advent of transgenic manipulation has also allowed the concept of developing herds of animals which express high levels of human complement regulatory proteins on their cells.

It is possible that combinations of the above approaches will eventually allow transplantation of organs between species such as pigs and humans, avoiding destruction of the graft by hyperacute rejection. However, this is likely to be only the first of several barriers to successful xenograft usage. Other barriers include the processes of cellular rejection that may well be entirely different to those seen in allograft rejection, the problem of species compatibility for crucial molecular and biochemical pathways.

Infection transmission between species is a major concern. The US Food and Drug Administration (FDA) recognises the risk of infection with known and unknown agents, transmitted through a xenograft, with the possibility of subsequent transmission into the general population with unknown consequences to human health. Of particular concern are retroviruses, harmless to animals but with unknown effects on humans, with the potential for such viruses to remain latent for long periods of time before activation.

In theory, xenotransplantation has the potential to solve the problem of the shortage of organs for transplantation and research into this emerging area of transplantation is likely to continue. It is vital, however, that debate regarding the moral and ethical aspects of this practice continue.

Preoperative Management for a Recipient of a Renal Transplant

The transplant call

Transplant recipients report mixed reactions of relief, excitement, anxiety and sadness when they receive the transplant phone call – relief that the waiting time may be over; excitement for the new life ahead; anxiety that the surgery may be difficult or that the

transplant may fail; and sadness that a family elsewhere has experienced tragedy in order for the kidney to become available.

During the telephone conversation the recipient is informed that a transplant may be possible and to travel to the transplant centre and have nothing further to eat or drink. Brief questions are also asked to clarify current health status and to exclude any infections or other problems that may prevent transplantation.

Some centres contact two recipients for each transplant so that should a positive cross-match occur for one, a second recipient is already prepared, thus minimizing the cold ischaemia time. It has been found that contacting two recipients can lead to repeated disappointments, anger and depression, therefore it is preferable to only call one recipient to the transplant centre in the first instance.

Nursing admission

Upon arrival, the recipient and family are welcomed by the nursing team and helped to familiarise themselves with the unit. Brief information is given regarding the forthcoming blood and clinical tests; questions are answered and anxieties explored during the nursing admission procedure (Box 10.11).

Medical assessment

Immediate medical assessment and blood tests are required to assess fluid and electrolyte status (as dialysis may be needed prior to surgery), also to complete the final tissue typing cross-match test, if required, and therefore the medical assessment immediately follows the nursing admission procedure (Box 10.12).

Preoperative dialysis

The results of the medical assessment and blood tests will determine the need for dialysis. Fluid overload and electrolyte imbalance (particularly hyperkalaemia) must be corrected, as they represent an anaesthetic risk and may enhance posttransplantation difficulties.

Haemodialysis with minimal or no heparinisation is often necessary to ensure optimal weight and to reduce fluid overload and serum potassium levels.

Peritoneal dialysis patients may require rapid exchanges to achieve optimal fluid and electrolyte status. The peritoneal catheter exit site should be examined for any signs of infection and a swab taken for culture and sensitivity. Also, following the necessary exchanges, the catheter should be drained and a fluid specimen sent for microscopy, culture and sensitivity and then the catheter capped, leaving the patient empty of fluid.

BOX 10.11

Nursing Admission Procedure

- Blood pressure, pulse, temperature, respirations.
- Current weight: dry weight.
- Past medical history – renal disease.
- Dialysis history – current practice and date and time of last dialysis.
- Current health status – recent relevant health events (i.e. blood transfusion/ infections).
- Normal urine output, if any.
- Social information.
- Allergies.
- Name band applied.

BOX 10.12

Medical Assessment Procedure

- Medical history.
- Renal disease history.
- Dialysis history.
- Current health status – recent relevant events.
- Allergies.
- Medical examination.
- Blood tests:
  - Urea and electrolytes
  - Liver function tests
  - Tissue typing cross-match
  - Viral screen (as in pretransplant assessment)
  - Cross-match for 2–4 units of blood available for transplant surgery
- Clinical tests:
  - Chest X-ray
  - Electrocardiogram
  - Midstream specimen of urine, urinalysis

Information and emotional support

During the dialysis time, it is often possible to explore individual fears and anxieties and offer emotional support and information regarding postoperative medications and procedures. Recipients are often emotionally labile at this time ('tears and laughter') and require much emotional understanding and support.

Immediate preoperative care

It is usual for the physiotherapist to visit to commence chest physiotherapy and advise regarding postoperative mobility and for the anaesthetist to perform an assessment. Once the tissue typing cross-match has proved negative, the final preoperative preparation begins (Box 10.13).

BOX 10.13

Preoperative Preparation

- Skin swabs/nose, throat, axilla and groin swabs – for meticillin-resistant *Staphylococcus aureus* screening
- Swabs and dressings to other dialysis lines (i.e. permanent central venous catheters)
- Suppositories (if required)
- Bath/shower/hair wash
- Operation gown
- Marking and dressing (to protect) arteriovenous fistula from inadvertent use of invasive monitoring (e.g. intravenous lines, blood pressure cuffs) and to maintain warmth, thus avoiding clotting
- Antithrombosis stockings

Preoperative medications such as immunosuppression, aspirin
Note: Transplant centres may use differing combinations of immunosuppressive medications.
Medications given immediately preoperatively

- Premedication
- Diabetes mellitus: sliding-scale insulin as appropriate

Surgical Technique for Renal Transplantation

Before transplantation begins, a catheter is placed into the bladder. This allows drainage of the bladder during the transplant operation and also allows the bladder to be filled with solution containing antibiotics to facilitate later identification of the bladder for reimplantation of the ureter. The right or left iliac fossa is the normal site for the transplant (Figure 10.6).

- An incision is made curving from just above the pubic symphysis to just above the iliac crest.
- The inferior epigastric vessels are ligated and divided and an extraperitoneal approach is made down on to the iliac vessels.
- The external iliac artery and vein are freed and small branches or overlying lymphatics are ligated and divided.
- Clamps are applied to the external iliac vein and the renal vein is anastomosed to the external iliac vein with continuous 5.0 Prolene sutures.
- Clamps are then applied to the external iliac artery and the renal artery on its patch (known as the Carrell patch) is anastomosed with continuous 5.0 Prolene to the external iliac artery (Figure 10.7). Sometimes the internal iliac artery is used and an end-to-end anastomosis is performed.
- Once the anastomoses are complete, the clamps are released, taking the venous clamps off first. The kidney normally perfuses quickly and one is often able to see immediate urine production.
- The bladder is then filled through the catheter and the ureter put into the bladder and then tunnelled submucosally to prevent urinary ureteric reflux (the Leadbetter–Politano

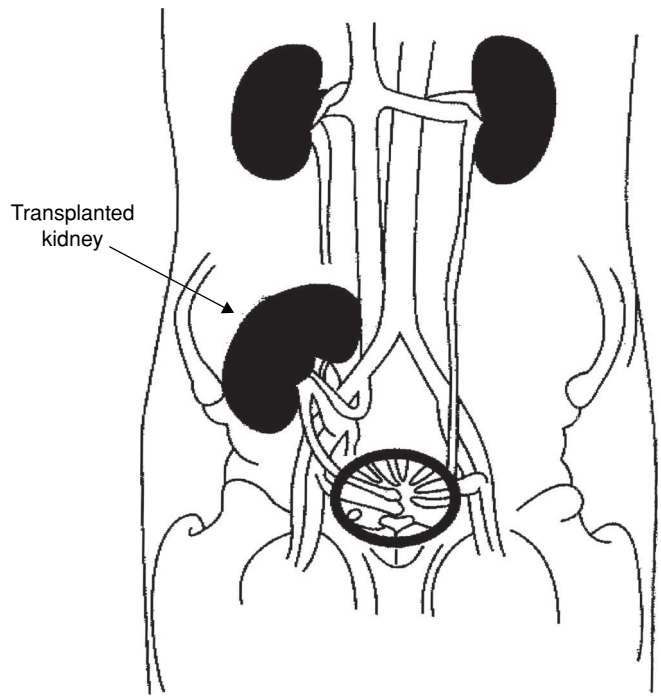


Figure 10.6 Position of the transplanted kidney.

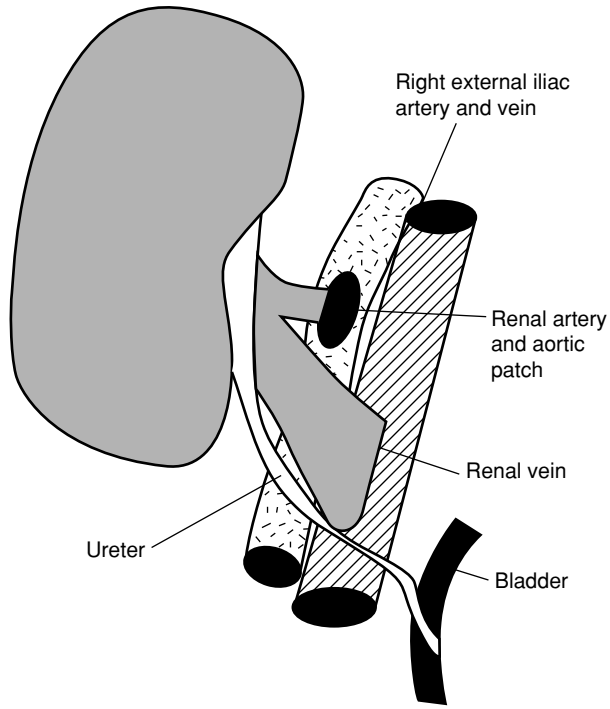


Figure 10.7 The surgical technique for renal transplantation.

technique). Most centres may use an extra vesicle technique which involves splitting the muscle, laying the ureter just above the bladder mucosa and so into the bladder, and closing the muscle over the top. If the bladder has been opened it is closed with two layers of Vicryl. A ureteric stent is placed in the ureter and left *in situ* for 4 to 6 weeks. This reduces the risk of ureteric stenosis.

- The wound is closed in the usual fashion and the bladder washed out at the end of the procedure.

Immunosuppression

Immunosuppression regimes

Until 1997, the most commonly used immunosuppression was a 'triple-therapy' regime involving ciclosporin (Sandimmun/Neoral), azathioprine (Imuran) and prednisolone. The advent of newer drugs has allowed centres to use differing combinations to 'tailor' immunosuppressive medications to individual recipients based on their risk of potential problems post transplant, such as rejection, diabetes, nonadherence and cancer. Immunosuppressive regimes are generally divided into induction (given at the time of transplant) and maintenance, with maintenance immunosuppression divided further to the early (less than 3–6 months) and late (more than 6 months) postoperative period. The aim of all immunosuppression protocols is to reduce rejection, maximise patient and graft survival and to minimise adverse side effects. The early postoperative period is when the risk of rejection is highest, therefore this is the time of maximum immunosuppression. Combinations of immunosuppressive medications are given in order to

minimise side effects of one particular drug whilst gaining adequate immunosuppressive effect. See Dudley and Harden (2011) for examples of risk stratification.

National Institute for Health and Clinical Excellence (NICE) (now called National Institute for Health and Care Excellence)

The National Institute for Health and Clinical Excellence (NICE 2004) issued guidance to the NHS in England and Wales on the use of immunosuppressive therapy for renal transplantation in adults. The guidance recommended: interleukin-2 receptor antagonist (IL2-RA, basiliximab or daclizumab) for induction treatment. These drugs should be used with a combination of other drugs including a calcineurin inhibitor (CNI). The cheapest one of the two (basiliximab or daclizumab) should be used.

Tacrolimus (a CNI) can be used instead of ciclosporin as maintenance immunosuppression. The drug (tacrolimus or ciclosporin) that is least likely to have serious side effects in that particular person should be used.

Mycophenolate mofetil as part of immunosuppressive treatment after kidney transplant only when a person has to stop taking a calcineurin inhibitor, or has to take a lower dose. This could be needed because the calcineurin inhibitor has already damaged the transplanted kidney.

Sirolimus can be used as one of a combination of immunosuppressive drugs, but only for people who cannot use calcineurin inhibitors because of their side effects.

This guidance represents the views of NICE, and health professionals are expected to take it into account when exercising clinical judgement. However, it does not overide the individual responsibility of health professionals to make appropriate decisions for patients.

More recent guidance, based on evaluation of up to date evidence, by Dudley and Harden (2011) recommend immunosuppressive regimens dependent on immunological risk (risk of rejection). Broad guidelines are as follows:

- Induction therapy should be given to all recipients, IL2-RA for those in the low risk group, T-cell depleting antibody (TDA) to be considered for those in the high risk group.
- Maintenance immunosuppression with a CNI, an antiproliferative agent (mycophenolate/azathioprine) plus or minus steroids for low and medium risk.
- Mycophenolic acid (MPA) based drugs given in preference to azathioprine as an antiproliferative agent.
- Steroid avoidance/withdrawal can be used in the first post operative week in low risk recipients.

Induction immunosuppression

Interleukin-2 receptor antagonists (IL2-RA): Basiliximab (Simulect), Daclizumab (Zenepax)

Action Basiliximab and Daclizimab work by binding specifically to part of the interleukin-2 receptor, which is only expressed on activated T lymphocytes. Therefore, they help to prevent proliferation of antigen-stimulated T cells. They are used in combination with other immunosuppressives to form a baseline therapy.

Side effects None have been reported.

T-cell depleting antibodies (TDA)

Action Inhibit and destroy circulatory lymphocytes through antibody action. TDAs are used as induction immunosuppression in high immunological risk recipients and as a treatment for rejection.

Muromab-CD3 (Orthoclone (OKT3)) monoclonal antibody

Side effects

- Chest pain.
- Pulmonary oedema.
- Gastrointestinal disturbances.
- Fever.
- Chills.
- Dyspnoea.
- Infections.

This drug can cause rapid pulmonary oedema and therefore it is essential that the patient is evaluated for volume overload and given treatment if necessary prior to administration of the drug.

Antilymphocyte globulin (ALG), Antithymocyte globulin (ATG) – polyclonal antibodies

Side effects

- Rash.
- Fever/chills.
- Anaphylaxis.
- Thrombocytopenia/leukopenia.
- Myalgia.

Maintenance immunosuppression

Calcineurin inhibitors.

Ciclosporin (Neoral/Sandimmune).

Ciclosporin is a natural peptide found in two strains of fungi. It was first introduced into clinical immunosuppression in 1983 and is a calcineurin inhibitor. Neoral ciclosporin is in a microemulsion and is more reliably absorbed.

Action Ciclosporin inhibits interleukin-2 and interferes with the growth and activation of T lymphocytes.

Side effects Usually side effects are dose dependent and responsive to dose reduction. The commonest side effects include:

- nephrotoxicity – decreased GFR;
- hypertension;
- hepatic dysfunction;
- hirsutism;
- hyperlipidaemia;
- hyperkalaemia;
- hyperuricaemia;
- gum hypertrophy;
- hypomagnesaemia;
- hypertrichosis.

Other less common side effects include:

- muscle weakness;
- thrombocytopenia.

Absorption Ciclosporin is absorbed with variable efficiency by different individuals; therefore, regular monitoring of whole blood levels is necessary. The usual therapeutic range may be higher during the early post transplant period, with maintenance doses aimed at lower levels. Therapeutic monitoring is usually by twelve hour post dose trough levels. It may take up to one month to stabilise levels post transplant and continual monitoring is necessary at every clinic visit thereafter.

Some units perform C2 monitoring, i.e. measuring blood concentrations 2 hour postdose. C2 is thought to predict more accurately individual patient absorptions than traditional trough monitoring and potentially results in a reduced incidence of acute rejection episodes and acute renal dysfunction. However this method can be difficult to organise, relying on accurate timing of dose administration and sample collection to ensure accuracy.

Tacrolimus (FK506)

Tacrolimus is another calcineurin inhibitor that, like ciclosporin, works early in T-cell activations. Its action inhibits interleukin-2 and other cytokines that cause early T-cell activation.

Absorption As with ciclosporin, regular monitoring of whole blood levels is necessary.

Side effects The commonest side effects include:

- visual and neurological disturbances;
- hypertension;
- tremor, headache, insomnia;
- raised blood sugar level;
- leukopenia.

Antiproliferative agents

Azathioprine

Azathioprine is a derivative of the anticancer drug 6-mercaptopurine and was introduced into clinical practice in 1962.

Action Azathioprine inhibits both DNA and RNA synthesis and prevents growth of lymphocytes.

Side effects The main side effect is neutropenia. If the white cell count (WBC) drops to below 3.5×10^9/l the dose should be reduced. If the WBC continues to fall the drug should be stopped temporarily.

Other side effects include:

- alopecia;
- general malaise;
- muscular pains;
- malignancy;
- pancreatitis (rare);
- altered liver function;
- cholestatic jaundice (rare).

Because of the risk of neutropenia, blood counts must be checked at intervals of not longer than 3 months.

Mycophenolate mofetil

Mycophenolate mofetil was licensed in 1995, it is metabolised to mycophenolic acid (MPA). MPA is similar in effect to azathioprine but has a more selective action.

Action Mycophenolate mofetil acts by preventing activated lymphocytes from differentiating and proliferating and thereby limiting clonal expansion. In the United Kingdom, this drug was previously used in preference to azathioprine in selected patients who were considered to be at a higher risk of rejection than average, however, it is now routinely used as part of maintenance immunosuppression.

Side effects
- gastro-intestinal effects including: diarrhoea, constipation, nausea, vomiting,
- blood disorders: leukopenia, anaemia, pancytopaenia

A formulation of mycophenolic acid (Myfortic) is available with an enteric coating that some patients may find reduces gastro-intestinal side effects.

Corticosteroids

Prednisolone

Action The action of corticosteroid preparations is complex and involves anti-inflammatory responses with blocking of T cells and interleukin-1.

Side effects
- cushingoid appearance;
- fluid retention;
- glaucoma;
- increased appetite;
- hypertension;
- psychosis;
- peptic ulceration;
- increase in blood sugar levels.

Side effects with long-term treatment:

- subcapsular cataract;
- pancreatitis;
- skin thinning;
- osteoporosis.

Many centres start steroid reduction at one month after transplant and aim to remove steroid therapy at 1 year after transplant because of the long-term side effects.

Mamalian target of rapamycin inhibitor (m-TORi)

Sirolimus (Rapamycin)

Sirolimus acts later in the T-cell activation than CNIs. It inhibits interleukin-2-mediated signal transduction pathways. Sirolimus is not nephrotoxic, which gives it an advantage over CNIs. It was licensed for use in the UK in 2001. Due to its potential to delay healing, sirolimus is rarely used in the early post transplant peroid.

Side effects
- Delayed healing (lymphocoele).
- Hypercholesterolaemia.
- Hypertriglyceridaemia.
- Thrombocytopaenia.
- Increased blood levels of MPA.
- Nose bleeds.

Belatacept

Action Belatacept is a fusion protein that works by selectively blocking the process of T-cell activation. Licenced in the United Kingdom in 2011 for use in combination with corticosteroids and mycophenolate in maintenance immunosuppression, Belatacept is given by intravenous infusion according to a dosing schedule commencing on the day of transplant, then on day 5, week 2, 4, 8 and 12. Subsequent maintenance regime comprises monthly infusions. Studies have shown a reduction in cardiovascular and metabolic risk factors when compared to standard CNI-based immunosuppressive regimes (Vanrenterghem *et al.* 2011). Data are not yet available for long-term side effects but there is a potential increased risk for post transplant lymphoproliferative disorder (PTLD). Depending on the long-term effects of this medication it may offer potential benefits for patients particularly with regard to the convenience of dosing and freedom from side effects of CNIs.

Side effects

- Anaemia.
- Diarrhoea, constipation, nausea, vomiting.
- Urinary tract infection.
- Peripheral oedema.
- Hypertension.
- Headache.
- Electrolyte disturbance.
- Leukopenia.

Renal Transplant Rejection

There are three types of renal transplant rejection:

- hyperacute rejection;
- acute rejection;
- chronic rejection or chronic allograft nephropathy (CAN).

Hyperacute rejection

Hyperacute rejection (Figure 10.8) occurs rapidly, within minutes or hours of revascularisation of the transplant. It is caused by:

- the presence of preformed cytotoxic antibodies in the recipient's blood (resulting from previous failed transplants, blood transfusions or pregnancies) reacting against the donor's histocompatibility antigens
- ABO incompatibility between the donor and the recipient.

The final lymphocytotoxic cross-match prior to transplant should demonstrate that cytotoxic antibodies are present and transplantation should not take place, thus a hyperacute rejection is a very rare phenomenon today.

Hyperacute rejection may be observed during the transplant surgery. Instead of the kidney becoming distended and pink as the arterial and venous clamps are released, as is usual, with hyperacute rejection the kidney will remain flaccid and become blue. Damage is almost always irreversible and the graft is lost.

Acute rejection

Acute rejection (Figure 10.9) can be cellular and/or antibody-mediated rejection (ABMR) which commonly occurs between 4 days and 2 months after transplantation.

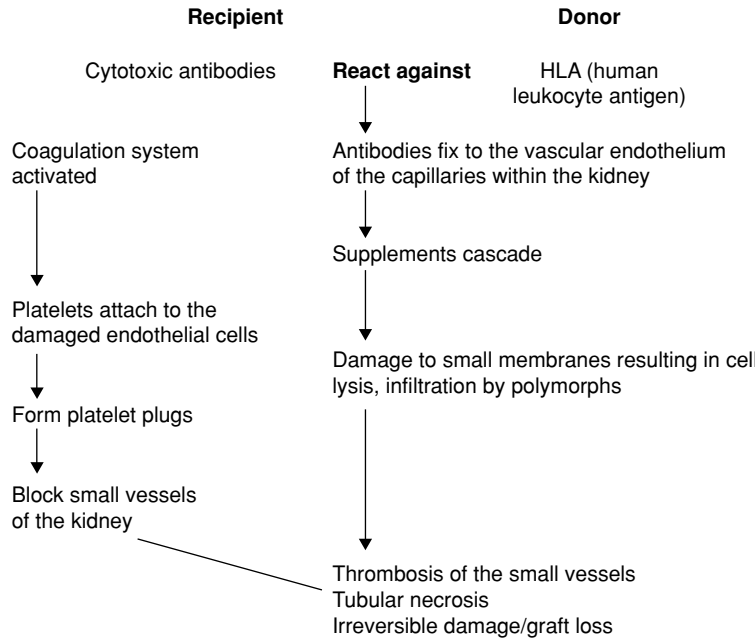


Figure 10.8 Histopathology of hyperacute rejection.

Rejection is ideally diagnosed by biopsy of the graft in order to differentiate from other causes of graft dysfunction such as CNI toxicity or BK virus nephropathy. Acute cellular rejection is usually treated initially with corticosteroids, usual practice is to administer daily bolus doses of 500 mg intravenous methylprednisolone over a 3-day period (one bolus each day). Cellular rejection that does not respond to treatment with high dose steroids and rejection that is antibody mediated is treated with a course of TDA. Rejection often responds to treatment, however, a severe rejection episode may result in some loss of overall graft function. It is usual to increase the level of maintenance immunosuppression following an episode of rejection unless non adherence or another reason for reduced levels of immunosuppression can be confirmed.

Transplant biopsy

A percutaneous biopsy of the transplant kidney is often the only reliable way to diagnose accurately the cause of graft dysfunction. Many patients are anxious about the biopsy procedure and the effect on the transplanted kidney and will require reassurance and explanation of the rationale for the procedure and the procedure itself. Many centres now perform biopsies as day case procedures, minimizing hospital stay and disruption for the patient.

It is recommended practice to send serum samples at the time of biopsy to check for the presence of HLA specific antibodies. This can aid the diagnosis of ABMR and ensure the correct treatment is given. Biopsy samples should be routinely stained for C4d deposition (to indicate ABMR) and SV40 antigen (BK virus), as appearances can be similar on histological examination.

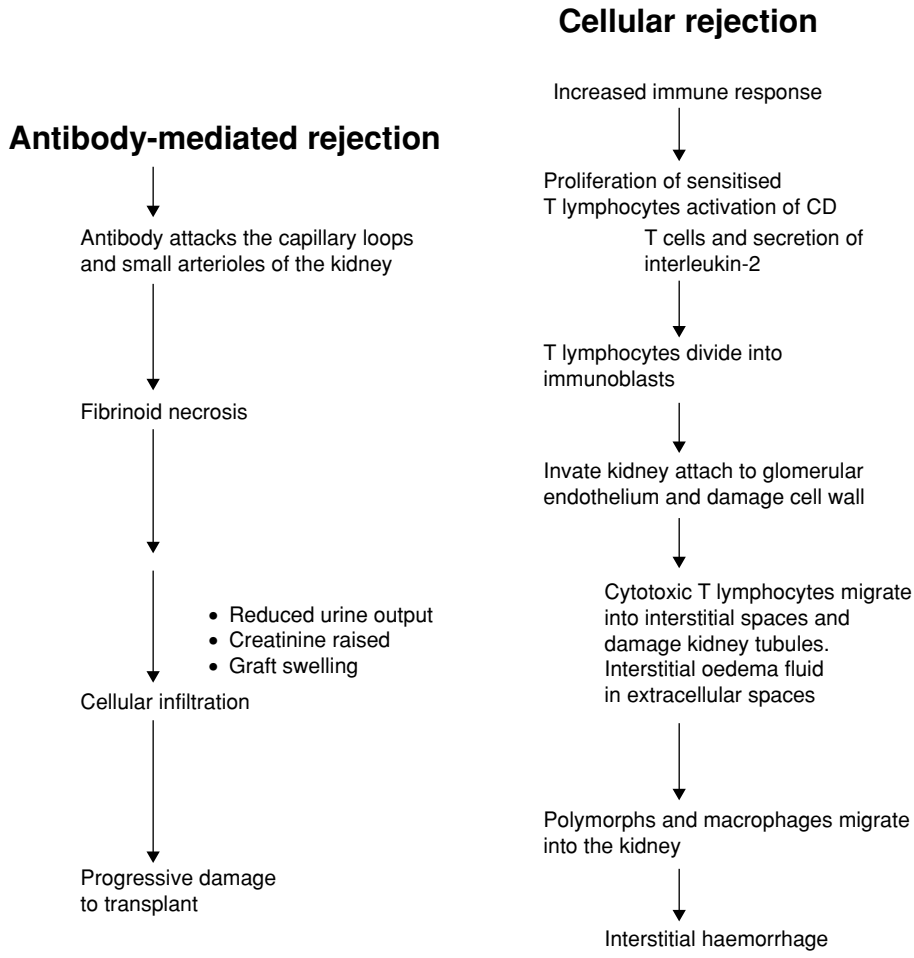


Figure 10.9 Histopathology of acute rejection.

Some centres perform 'protocol biopsies' that is, routine biopsies at set time periods post transplant (eg at 3, 6 or 12 months) with the aim of optimizing immunosuppressive regimes based on the results.

Chronic allograft injury

Chronic allograft injury (CAI) usually occurs over months or years but may occur much earlier. It is dificult to separate out the contribution of rejection from other factors detrimental to the kidney. The term chronic allograft injury encompasses all of these; meaning that permanent damage is seen on biopsy. There is a gradual occlusion of the lumen of the arteries of the kidney with interstitial fibrosis which destroys the graft. The exact mechanisms involved in CAI are still unclear and may be immunological or nonimmunological. Other factors include donor history and delayed graft function, acute rejection episodes, hypertension, CNI toxicity and infection. The first signs of CAI are usually a gradual worsening of renal function with proteinuria.

Postoperative Care and Complications for the Renal Transplant Recipient

Aims of care

The aim of postoperative management is to provide the appropriate care to support primary transplant function and to aid optimal recovery. Initial care involves close monitoring of physical and psychological health, with frequent assessments and adjustments in response to changes in health status.

Immediate postoperative care

In most cases the anaesthetist will insert a triple-lumen central venous line via the internal jugular vein immediately prior to surgery. This line facilitates monitoring of fluid status and central venous pressure (CVP) and allows infusion of fluids and medications during surgery and the early postoperative phase.

Cardiorespiratory status

Immediate baseline observations should be recorded, including blood pressure, pulse, respirations and temperature. Such observations should continue every 30 min until stable and thereafter hourly or as appropriate. Twenty-four-hour ECG monitoring may be routine; however, in some centres such monitoring may only be used for patients in high-risk categories. Close monitoring of respiratory status is essential, as anaesthetic drugs and analgesia may be poorly excreted due to the reduced transplant function, thus depressing respiratory effort and increasing the risk of pulmonary complication. Early chest physiotherapy is essential.

Pain management

The experience of pain is unique to each individual and therefore the use of patient-controlled analgesia is a suitable therapy as it will provide satisfactory pain management, reduce recipient anxiety and facilitate deep breathing and movement. An opiate derivative, is commonly used. Pethidine is avoided because of the possible accumulation of metabolites in the presence of reduced renal function. Recipients often report that the presence of the urinary catheter causes the greatest discomfort. Severe pain in the graft in the early post-operative period may be indicative of swelling of the kidney as a result of venous thrombosis.

Hydration: fluid and electrolyte balance

Inadequate hydration may adversely affect transplant function; therefore, the maintenance of an acceptable venous pressure without the complication of fluid overload is an integral element of care. Fluid intake is usually administered through the central venous line. CVP measurements, recorded hourly, and urinary output measurements, recorded hourly, are used as a guide to appropriate fluid intake.

Fluid intake protocol usually involves fluids being administered through an infusion pump with hourly intake equal to the previous hour's output plus 50 ml, with the aim of achieving a CVP level of approximately 10–15 cm H_2O.

Peripheral line perfusion must also be included in the intake total. Infusion of dopamine may be introduced to help maintain pressure and improve transplant perfusion

by reducing vasoconstriction of the smaller renal vessels. Monitoring of serum biochemistry and haemoglobin levels is ongoing and the results will determine the type of intravenous fluid given. Often 5% dextrose is alternated with normal saline. Blood transfusion is occasionally required.

Oral fluids are usually introduced within the early postoperative phase (as paralytic ileus is rare) and are gradually increased as appropriate. In uncomplicated cases the CVP line is removed after twenty-four hours and nutrition introduced.

Urine output: catheter care

A urinary catheter will be *in situ* following the transplant surgery, and the urine may be blood-stained due to the surgical procedures to the bladder and ureter. Clot formation may occur, resulting in pain and anuria. Gentle sterile bladder washouts can be performed to alleviate the problem and re-establish urine flow.

Twenty-four-hour urine output should be recorded and it is, of course, important to note the volume of urine passed from the native kidneys pretransplantation when assessing urinary totals. Daily urine analysis and biochemistry should be noted and daily catheter specimens obtained for microscopy, culture and sensitivity. The catheter is usually removed on the fifth postoperative day. Some recipients may experience difficulty with voiding and also may have very limited bladder capacity due to pretransplant bladder atrophy. Reassurance and bladder retraining strategies usually help to solve these problems.

Wound management

A wound drain may be present and drainage should be monitored. Observation and aseptic dressing of the wound will be given as appropriate and the sutures removed when healing has occurred. The immunosuppression regime and other contributory factors such as diabetes or malnutrition may impede the healing process.

Infection control

Recipients are immunocompromised and therefore infection control procedures should be strictly followed. Handwashing should take place before and after each nursing and medical procedure and visitors should be monitored for infections. Medications should include prophylaxis against infection and additional treatments should be commenced if infection is suspected.

The recipient should be helped to achieve personal and oral hygiene of a high standard and aseptic techniques utilised with regard to wound, peritoneal catheter site, urinary catheter and CVC care. Catheter tips should be cultured for microscopy and sensitivity when removed.

Postoperative medications

In addition to immunosuppressive medications other medications are required post transplant:

- antibiotic prophylaxis – particularly to prevent infection with *pneumocystis carinii;*
- PPI;
- nystatin to prevent oral candidiasis;

- aspirin, to minimise long term cardiovascular risk;
- statin, to minimise cardiovascular risk;
- calcium supplements, to limit side effects of corticosteroids on bone mineral density;
- isoniazid, for prophylaxis against TB if required;
- valganciclovir, for prophylaxis against CMV infection if required;

Continuing care

Recipients usually recover quickly from the anaesthetic and begin early mobilisation to prevent complications. A light diet is introduced on day 1. Constipation may be a problem due to anaesthetic, immobility and analgesia, and gentle laxatives or suppositories may be needed. Self-care is usually achieved by the fifth postoperative day.

Sadness may be linked to thoughts of the donor family and grief and guilt may be expressed that the transplant has resulted from 'another's tragedy'. It is often helpful to give recipients anonymous details such as age, sex and cause of death of the donor, and to offer them the opportunity to write a letter of thanks to the donor family. The expression of thanks usually enables recipients to accept the gift of the organ and to move forward to their new lifestyle.

Anxiety is usually linked to the fear of complications such as rejection, infection and graft loss. Recipients and their families require considerable support, understanding and indepth information during the early postoperative phase, particularly if difficulties occur.

Complications of renal transplantation

Renal dysfunction – acute tubular necrosis (ATN)

The most common cause of delayed graft function after renal transplantation is ATN, which may be due to prolonged hypotension in the donor or prolonged ischaemia during the donor or recipient surgery. Dialysis support may be required until adequate transplant function is achieved. Haemodialysis, with reduced heparinisation, can be undertaken as necessary (a frequent clotting screen will be required), and peritoneal dialysis recommenced as long as the peritoneum has not been breached by surgery.

CNIs (ciclosporin, tacrolimus) are known to be nephrotoxic and may therefore prolong ATN.

Acute rejection

Many transplant recipients will experience at least one episode of acute rejection. Acute rejection may not present with overt symptoms, a mild increase in creatinine, indicating graft dysfunction may be the only symptom, often picked up following a routine visit to the transplant clinic.

The clinical signs of acute rejection may include:

- renal dysfunction;
- pyrexia;
- reduced urine output;
- swelling and tenderness of the transplant;
- ankle oedema, weight gain;
- flu-like symptoms.

Vascular complications

Transplant renal artery and renal vein thrombosis Thrombosis of the renal artery or renal vein is a rare complication. Clinical signs of graft thrombosis usually include pain

in the graft, renal dysfunction, anuria and hypotension. Diagnosis may be confirmed by ultrasound scanning (see Chapter 7). Immediate surgical exploration should be undertaken. In the majority of cases the transplant will be lost.

Transplant renal artery stenosis Renal artery stenosis usually occurs between 6 and 12 months after transplantation. Signs include graft dysfunction and severe hypertension with a bruit on auscultation over the transplant. Diagnosis is confirmed by doppler ultrasound or angiography. In severe cases intervention may be required either by percutaneous transluminal angioplasty or surgery.

Urological complications

A major urological complication which may occur is avascular necrosis of the distal end of the transplant ureter, resulting in leakage of urine. Surgical reimplantation of the ureter will be required in most cases. This complication has become less common recently due to the use of a ureteric stent.

Infections

Bacterial infection

The clinical signs of infection are similar to those of rejection (pyrexia, tachycardia, flulike illness), therefore it is important that both possibilities are considered and investigations undertaken to exclude either cause. Transplant recipients are at increased risk of rejection due to immunosuppression however, due to their impaired immune respone, they may not display overt signs of infection until the infection has become more serious. It is therfore vital to monitor transplant recipients closely for signs and symptoms of infection and to investigate even seemingly innocuous symptoms. Infections in this group of patients can be life threatening if not treated appropriately and adequately.

Chest infections may result from *Pneumococcus*, *Haemophilus influenzae, Klebsiella* and *Pneumocystis*. Infection may develop rapidly, resulting in the need for ventilation. Early treatment with appropriate antibiotic therapies is essential.

Fungal infections

Oral *Candida* is common and many centres give antifungal prophylaxis for a short time following transplantation. Oral hygiene of a high standard should be encouraged. Genital *Candida* may also occur and recipients may be reluctant to report this problem. Recipients should be informed that *Candida* is a potential problem and that treatment will be required.

Transplant recipients are at increased risk of serious fungal infections such as *Aspergillus, Cryptococcus* and *Pneumocystis carinii.*

Viral infections

Cytomegalovirus

Cytomegalovirus (CMV) infection is usually acquired during childhood and early adulthood and is a minor flu-like illness. However, this minor illness can cause major complications in the immunosuppressed transplant recipient. CMV disease, after transplantation, may occur because of:

- Reactivation of latent disease in a CMV-positive recipient. Such reactivation is generally classed as ‘secondary CMV’.

- Transmission of CMV from a CMV-positive donor to a CMV-negative recipient through the transplanted organ, or community acquired infection after the transplant. This is classed as 'primary CMV'.

Cytomegalovirus may also be transmitted through whole blood transfusions, hence many centres require that all patients receive CMV-negative blood.

Cytomegalovirus vaccinations for all transplant recipients in the pretransplant phase would be an ideal solution to this problem but, as yet, no clinically acceptable vaccines have been formulated. Also matching so that CMV-negative recipients receive CMV-negative grafts would help to minimise the difficulties experienced, but such matching is not always possible in practice. Therefore, primary CMV disease does occur and can cause significant morbidity and mortality.

The usual time for manifestation of CMV disease is 4–8 weeks posttransplantation. Clinical signs include swinging pyrexia, rigors, malaise and, in extreme cases, pneumonitis, retinitis, gastroenteritis and encephalitis.

Valganciclovir is widely used as prophylaxis in high-risk recipients (such as CMV-negative recipients receiving CMV-positive grafts, or CMV-positive recipients receiving ATG).

Recipients are monitored for serological evidence of CMV activity and treated according to local guidelines. Oral valganciclovir has been used for treatment, although it is licensed only for prophylaxis, however, if the patient is unwell, admission to hospital and treatment with IV ganciclovir may be necessary.

Herpes simplex and varicella zoster virus

Herpes simplex (type I and type II) can cause problems following transplantation. Oral and anogenital lesions may occur. Recipients may be reluctant to report such problems due to anxiety and embarrassment. Therefore, recipients should be aware that these lesions may arise and that they occur because of reduced immunity, not because of other social issues. Sympathetic and understanding care should be offered and antiviral treatment commenced.

Reactivation of latent varicella zoster virus (VZV) may also occur and present as classical 'shingle' lesions. Antiviral treatment is necessary to prevent systemic complications. Disseminated VZV (chickenpox) is dangerous in immunosuppressed patients, resulting in some cases of life-threatening illness with encephalitis, pneumonitis and meningitis. Recipients must be aware of the problems associated with such viral infections and should be encouraged to report signs and symptoms or contact with infected others.

BK (Polyoma) virus

Most BK virus infections are asymptomatic but it is implicated in ureteric stenoses, late haemorrhagic cystitis and deteriorating graft function.Two factors may account for the increase in BK nephropathy: improvements in biopsy interpretation and the newer immunosuppressants now widely used. Presence of BK virus in biopsy samples can be confirmed by testing with SV40 staining. Infection is associated with deteriorating renal function but can often be controlled by reducing immunosuppression. BK virus is often detected during routine urinalysis, haematuria can be a sign of BK infection and urine should be sent to the laboratory for cytological examination. This will detect the presence of viral cells. This does not always indicate the presence of active virus in the graft and a serum sample tested for BK virus load can indicate the presence and the activity of the virus. Serological testing of viral counts is a useful tool to monitor the effect of reduction in immunosuppression following a diagnosis of BK virus nephropathy at biopsy.

Discharge of the Recipient from Hospital and Continuing Care

If recovery has been uncomplicated the transplant recipient may be discharged home on about the seventh to tenth postoperative day.

The educative and developmental intervention is very important for recipients of transplants. They must have sufficient knowledge to monitor their health status, be understanding of medication regimes and report problems if they arise. Assessment of learning difficulties should be completed soon after transplant so that relevant interventions may be implemented to aid learning, knowledge and eventual independence. Physical barriers such as impaired sight and hearing can be aided by electronic blood pressure monitoring equipment. Language and literacy difficulties can be resolved with diagrammatic information, translations and medication presented in daily dosette boxes, all promoting personal independence, although family members may be included in teaching sessions as appropriate.

The nurse may assess learning abilities (with an informal, nonthreatening discussion) posttransplant and plan a teaching information programme, implement this programme and evaluate progress. Information is given as appropriate both verbally and in the form of a written information booklet. At the time of discharge the recipient should have the following knowledge (Box 10.14).

Drug charts and monitoring booklets should be utilised as part of a self-medication programme introduced as recovery allows or on the second postoperative day.

Immediately after discharge, recipients will be seen very frequently in the outpatient clinic and it is important that nursing intervention identifies developmental needs so that the recipient's knowledge base continues to expand and psychosocial care is offered. Reports suggest that some recipients feel that only the renal function and transplant progress is monitored, not the rehabilitation of the 'whole person'. Therefore, holistic care is essential, addressing psychosocial needs with physical needs; such care may be most appropriately offered by a transplant nurse practitioner who can offer continuity of care as well as understanding and support.

The aim of ongoing care is to empower the recipient to achieve optimal individual rehabilitation. It is essential to help the recipient achieve a balance between monitoring health and gaining normality. One of the most important posttransplant psychosocial tasks that the recipient needs to accomplish is the gradual relinquishing of the sick role and the eventual return to nonpatient status. Medical and nursing staff can give a confusing message by referring to recipients as patients and demanding strict adherence to rigid health protocols, whilst at the same time insisting that transplantation offers a return to 'normality'.

Flexibility of care, understanding and encouragement are required to enable recipients to take control of their lives and achieve the highest quality of life possible. Ongoing health monitoring will continue and problems may occur, but advice and support should be available throughout the complete transplant experience.

BOX 10.14

Recipient Predischarge Knowledge

- Understand the action, dosage and side effects of medication and the need for adherence
- Awareness of how and where to obtain repeat prescription for all medications
- Recognise the signs of potential complications such as rejection and infection and ensure awareness of how and when to alert transplant personnel in the light of any of these changes
- Have telephone numbers of the transplant centre and know how to contact staff
- Ensure aware of arrangements for follow-up and the importance of regular attendance

Ongoing care: information and support for transplant recipients

- Peritoneal dialysis catheter: if transplant function is satisfactory, the peritoneal dialysis catheter is removed at 3 months after transplant, although there is evidence that removal at time of transplant is advantageous (Warren *et al.* 2012). The ureteric stent is usually removed endoscopically four to six weeks after transplant, although many transplant surgeons attach the stent to the urinary catheter at the time of surgery allowing the stent to be removed with the catheter. This practice may reduce the incidence of post transplant urinary tract infection due to early removal of the stent and avoidance of the need for an invasive procedure.
- Diet: follow a normal diet, but taking care with weight gain due to increased appetite and freedom from the renal diet. If cholesterol or lipid levels are raised, dietary restrictions may be necessary. See Chapter 13.
- Vaccinations and travel: transplant recipients should not receive live vaccines. Therefore, it is important to consult the transplant centre before travel immunisations are given. Foreign travel is encouraged but recognition of possible infection sources is necessary so that suitable precautions may be taken.
- Skin care: immunosuppression predisposes recipients to skin damage from trauma and sun and increases the risk of skin malignancies. Therefore, dermatological monitoring and advice should be given and recipients should use factor 25–30 sun block during sun exposure and report any skin lesions. Many centres refer their patients for a baseline dermatological assessment after transplantation.
- Fertility: female patients should be aware of fertility issues and be given advice with regard to birth control measures. Condoms or the mini-pill are the most appropriate therapies but intrauterine devices can be useful. Recipients of both sexes should, ideally, wait at least 1 year before considering pregnancy. Advice should be available with regard to pregnancy risks in individual cases. Patients of both sexes must be told that they should inform the clinic if they have any plans for pregnancy, so that any medical issues or drug changes can be discussed. Recipients cannot breast feed after delivery as the immunosuppression may transfer to the baby.
- Employment: recipients may return to work as soon as they feel able as long as graft function and health are satisfactory and employment does not put either at risk. Help should be available for those recipients seeking employment.
- Health education: smoking is discouraged due to the risk of enhanced cardiorespiratory and vascular complications. Exercise and activity are encouraged, although contact sports such as rugby or martial arts may put the graft at risk. Female patients should have regular cervical smears and breast examinations due to the increased risk of malignancy. Male patients should be monitored for potential malignancies and encouraged to perform testicular self-examination.
- Psychological health: psychological support should be available to help with sexual problems, body image problems and marital problems.
- Social needs: help and advice should be available for social needs such as benefits, housing and return to work.

Pancreas-Kidney Transplantation

Pancreatic transplantation is of proven clinical benefit for patients with type-1 diabetes who are undergoing renal transplantation, and is usually carried out at the same time, as simultaneous pancreas-kidney transplant (SPK). The procedure has a slightly increased mortality and morbidity risk due to the complexity of the surgery and the

additional immunosuppression, but the long-term benefits outweigh these risks (Friedman *et al.* 2001). SPK transplantation increases ten year survival in those with diabetes compared to cadaveric renal transplant alone (Sollinger *et al.* 1998). Pancreatic transplantation enables discontinuation of insulin and retardation of the complications of diabetes. Immunosuppression for kidney-pancreas transplantation is similar to that for kidney alone. Islet cell transplantation is yet to be established as a routine practice.

Figure 10.10 shows pancreatic transplant activity. The number of patients registered on the SPK waiting list in 2012 was 253, a significant increase from the 90 patients registered in 2003. A new national pancreas allocation scheme was introduced in 2010. The scheme introduced a points system based on clinical factors and the pancreas is allocated to the patient with the most number of points. Prior to introduction of the scheme organs were allocated to specific transplant centres and recipients were then selected locally. The new scheme aims to improve equity for patients regardless of geographical location.

The pancreas is a fragile gland and easily damaged by trauma, poor perfusion or duct obstruction. Complications include pancreatitis, pseudocyst and leakage of digestive pancreatic enzymes.

Surgical placement of the pancreas is determined by the need to allow drainage of the pancreatic enzymes. This may be either into the bladder, with vascular connections to the external iliac artery and vein, or into the duodenum. Enteric drainage appears to confer a long-term benefit over bladder drainage, avoiding the problems associated with bladder drainage such as dysuria, haematuria, metabolic acidosis (Lo *et al.* 2001). The major advantage of urinary drainage however is the ability to detect pancreas rejection early by monitoring amylase excretion in the urine, and rejection is the most

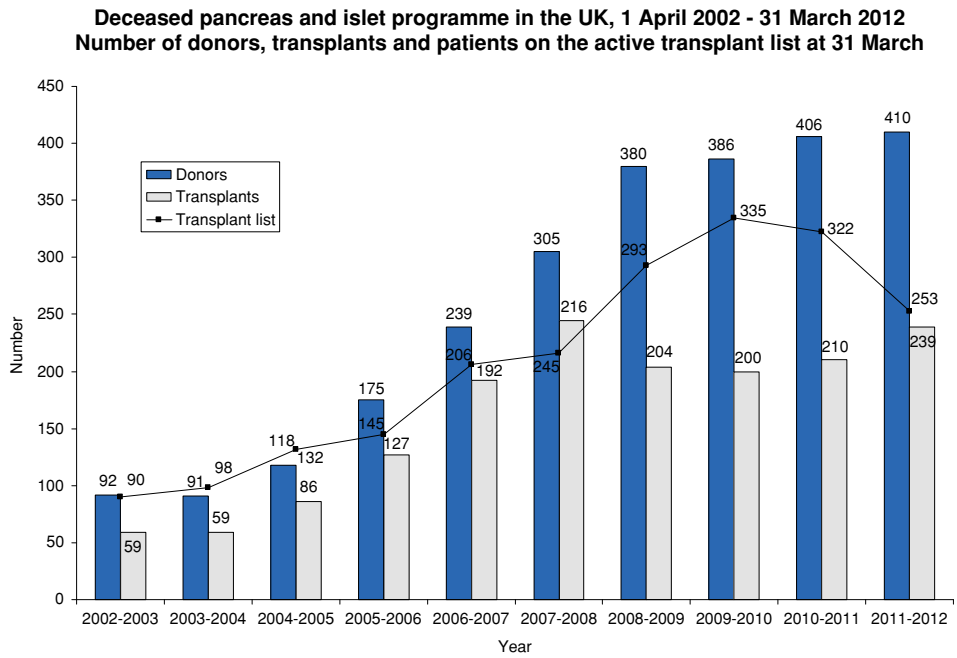


Figure 10.10 Deceased pancreas and islet programme in the United Kingdom, 1 April 2002–31 March 2012.

Source: from: *Transplant Activity in the UK 2011–2012.* NHS Blood and Transplant.

common cause of graft loss. Transplantation of a pancreas and a kidney from the same donor allows manifestations of kidney allograft rejection to guide treatment as kidney graft rejection is believed to precede or parallel pancreas rejection. Other causes of pancreas graft loss include vascular thrombosis, pancreatitis, and infection. Vascular thrombosis may occur, in part, because of the low circulatory flow through the pancreas but can also accompany pancreatitis or rejection. Hyperamylasaemia is common after transplantation and may be either asymptomatic or indicative of symptomatic pancreatitis. Patients with a neurogenic bladder can develop 'reflux pancreatitis' from inadequate bladder emptying. Surgical problems related to exocrine pancreatic drainage and allograft pancreatitis are usually due to leakage or fistula formation leading to fluid collections, pseudocysts or abscesses surrounding the pancreatic graft.

In the post-transplant period, urinary tract infections are common and pancreatic enzyme activation can lead to 'chemical' cystitis or urethritis. In several cases, patients may develop urethral stricture or disruption, haematuria, or perforation of the bladder or duodenum.

Finally, because of the loss of pancreatic secretions rich in sodium and bicarbonate into the urinary tract, pancreas transplant recipients are susceptible to metabolic acidosis and dehydration. All recipients must increase fluid and salt intake, but may require additional oral bicarbonate supplementation (Hakim 2013).

In addition to freeing the recipient from insulin therapy, the complications of diabetes are stabilised. Patients with type-2 diabetes have relative contraindications for pancreatic transplant – they are usually older by the time end-organ damage develops, and by this time usually have significant vasculopathy. Obesity is also strongly associated with increased morbidity and mortality after pancreas transplantation (Odorico *et al.* 1998). Additionally, insulin resistance is thought to lead to overstimulation of the pancreas resulting in loss of function (Sasaki *et al.* 1998).

Summary

A successful renal transplant can provide the best quality of life for those with ERF. As one patient, who received a transplant in 1972, said: 'It is amazing that the special gift from the donor has enabled me to achieve my career and personal goals and has resulted in the creation of a new family – a gift for generations to come'.

References

Academy of Medical Royal Colleges (2008). A Code of Practice for the Diagnosis and Confirmation of Death. [Online]. Available at http://www.aomrc.org.uk/publications/statements/doc_details/42-a-code-of-practice-for-the-diagnosis-and-confirmation-of-death.html (Accessed 18th June 2013).

Bryan, C.F., Nelson, P.W., Shield, C.F. *et al.* (2007) Long-term survival of kidneys transplanted from live A2 donors to O and B recipients. *American Journal of Transplantation* **7** (7), 1181.

Buckley PE. (1989) The delicate question of the donor family. Transplant Proceedings. 21:1411–1412.

Carlisle D. (1995) Life-giving FATWA. Nursing Times. 91:2.

Chadban S. (2001) Glomerulonephritis recurrence in the renal graft. *Journal of the American Society of Nephrology* **12** (2), 394–402.

Collaborative Transport Study (2012) *Collaborative Transplant Study,* www.ctstransplant.org/ (accessed 20 May 2013).

Department of Health (2009) *Legal Issues Relevant to Non-Heartbeating Organ Donation,* www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_108825 (accessed 20 May 2013).

Department of Health (2010) *Organ Donor Campaign Report: Faith and Organ Donation,* Department of Health, London.

Department of Health (2011) *Guidance on the Microbiological Safety of Human Organs, Tissues and Cells used in Transplantation,* www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_121497?ssSourceSiteId=ab (accessed 20 May 2013).

Dew, M., DiMartini, A., De Vito Dabbs, A. ***et al.*** (2007) Rates and risk factors for nonadherence to the medical regimen after adult solid organ transplantation. *Transplantation* **83,** 858–873.

Dudley, C. and Harden, P. (2011) Assessment of the Potential Kidney Transplant Recipient. Renal Association http://www.renal.org/Clinical/GuidelinesSection/AssessmentforRenalTransplantation.aspx [accessed 21st August 2012].

Dudley, C. and Harden, P. (2011) *Assessment of the Potential Kidney Transplant Recipient. Renal Association,* www.renal.org/Clinical/GuidelinesSection/AssessmentforRenalTransplantation.aspx (accessed 20 May 2013).

Eurotransplant (2011). Statistics 2011. Available at http://www.eurotransplant.org/cms/index.php?page=yearlystats (Accessed 18th June 2012).

Fellner CH, Marshall JR. (1968) Twelve kidney donors. JAMA. 206:2703.

Fournier, C., Pallet, N., Cherqaoui, Z. ***et al.*** (2012) Very long-term follow-up of living kidney donors. *Transplant International* **25** (4), 385–390.

Friedman EA, Friedman AL, Sommer BG. Pancreas Transplantation. (2001) In Kidney Transplantation (5thEdition). Morris PJ (Ed) WB Saunders, London.

Hakim NS. (2013) Pancreatic Transplantation. [Online]. Available at http://www.endocrinesurgeon.co.uk/index.php/pancreatic-transplantation (Accessed 18th June 2013).

Harvard Medical School (1968) Report of the ad hoc committee of Harvard Medical School to examine the definition of brain death. Definition of irreversible coma. *JAMA* **205,** 337.

Ibrahim HN, Foley R, Tan L, Rogers T, Bailey RF, Guo H, Gross CR, Matas AJ. (2009) New England Journal of Medicine. 360:459–469.

ICS (2004) Guidelines for Adult Organ and Tissue Donation: Clinical management of the potential heartbeating organ donor. Intensive Care Society, London.

ICS (2010) www.ics.ac.uk/professional/standards_and_guidelines/dcd (accessed 20 May 2013).

Johnson, R.J., Fuggle, S.V., O'Neill, J. ***et al.*** (2010). Factors influencing outcome after deceased heart beating donor kidney transplantation in the United Kingdom: an evidence base for a new national kidney allocation policy, on behalf of the Kidney Advisory Group of NHS Blood and Transplant. *Transplantation* **89** (4), 379–386.

Kemph JP. (1966) Renal failure, artifical kidney and kidney transplant. American Journal of Psychiatry. 122:1270.

Kovacs, A.Z., Molnar, M.Z., Szeifert, L. ***et al.*** (2011) Sleep disorders, depressive symptoms and health-related quality of life–a cross-sectional comparison between kidney transplant recipients and waitlisted patients on maintenance dialysis. *Nephrology Dialysis Transplantation* **26** (3), 1058–1065.

Levey AS, Hon S, Bush HL Jr. (1986) Kidney transplantation from unrelated living donors: time to reclaim a discarded opportunity. New England Journal of Medicine. 314:914.

Lo, A., Stratta, R.J., Hathaway, D.K. ***et al.*** (2001) Long-term outcomes in simultaneous kidney-pancreas transplant recipients with portal-enteric versus systemic-bladder drainage. *American Journal of Kidney Disease* **38** (1), 132–143

Martina, M.N., Cofan, F., Suarez, A. ***et al.*** (2011) Kidney transplantation and waiting list for renal transplantation for human immunodeficiency virus patients. *Transplantation Proceedings*. vol./is. 43/6(2179-81), 0041-1345;1873-2623.

NHSBT (2006) *Deceased Donor Kidney Allocation Scheme,* www.organdonation.nhs.uk/ukt/about_transplants/organ_allocation/kidney_%28renal%29/renal_organ_sharing_principles/kidney_organ_allocation_scheme_2006.asp (accessed 20 May 2013).

NHSBT (2012) *Organ Donation and Transplantation: Activity Report 2011–2012,* www.organdonation.nhs.uk/ukt/statistics/transplant_activity_report/ (accessed 20 May 2013).

NHSBT (2011) *UK Strategy for Living Donor Kidney Transplantation,* www.organdonation.nhs.uk/newsroom/news_releases/article.asp?releaseid=299 (accessed 20 May 2013).

Nobel Prize (2013) Blood Groups, Blood Typing and Blood Transfusions. [Online]. Available at http://www.nobelprize.org/educational/medicine/landsteiner/readmore.html (Accessed 18th June 2013).

Odorico JS, Becker YT, Van der Werf W *et al*. (1998) Advances in pancreatic transplantation: the University of Wisconsin experience. In Clinical Transplants 1997 (Cecka JM, Teresaki PI, eds) UCLA Tissue Typing Laboratory; Los Angeles

Penn I. (1997) Evaluation of transplant candidates with pre-existing malignancies. Annals of Transplantation. 2(4):14–7.

Pinsky, B.W., Takemoto, S.K., Lentine, K.L. ***et al.*** (2009) Transplant outcomes and economic costs associated with patient noncompliance to immunosuppression. *American Journal of Transplantation* **9,** 2597–2606.

Roderick, P., Byrne, C., Casula, A. ***et al.*** (2009) Survival of patients from South Asian and Black populations starting renal replacement therapy in England and Wales. *Nephrology Dialysis Transplant* **24,** 3774–3782.

Sasaki TM, Gray RS, Ratner RE, Currier C,; Aquino A, Barhyte DY, Light JA. (1998). Successful long-term kidney-pancreas transplants in diabetic patients with high C-peptide levels. Transplantation **65**(11):1510–1512.

Scheper-Hughes (2007) The Tyranny of the Gift: Sacrificial Violence in Living Donor Transplants. American Journal of Transplantation. **7**; 3: 507–511.

Siminoff, L.A., Gordon, N., Hewlett, J. and Arnold, R.M. (2001) Factors influencing families' consent for donation of solid organs for transplant. *JAMA* **286** (1), 71–77.

Simmons RG, Hickley K, Kjellstrand CM *et al*. (1971). Donors and non donors: the role of the family and the physician in kidney transplantation. Semin Psychiatr. 3:102.

Smith MD, Kappell DF, Province MA *et al*. (1986) Living related kidney donors: a multicentre study of donor education, socioeconomic adjustment and rehabilitation. American Journal of Kidney Diseases. 8:223.

Simpkin, A.L. Robertson, L.C., Barber, V.S. and Young, J.D. (2009) Modifiable factors influencing relatives' decision to offer organ donation: systematic review. *British Medical Journal* 338 (7702), 1061–1063.

Sollinger HW, Odorico J S, Knechtle, SJ, D'Alessandro A M, Kalayoglu, M,,Pirsch JD. (1998) Experience With 500 Simultaneous Pancreas-Kidney Transplants. Annals of Surgery. **228**(3):284–296.

Surman OS, (1989) Psychiatric aspects of organ transplantation. American Journal of Psychiatry. 146: 972.

Thiel GT, Nolte C, Tsinalis D. (2005) The Swiss Organ Living Donor Health Registry (SOL-DHR)] Ther Umsch. **62**(7):449–57

Valapour, M., Kahn, J.P., Bailey, R.F. and Matas, A.J. (2011) Assessing elements of informed consent among living donors. *Clinical Transplantation* **25** (2), 185–190.

Vanrenterghem ,Y., Bresnahan, B., Campistol, J. ***et al.*** (2011) Belatacept based regimens are associated with improved cardiovascular and metabolic risk factors compared with coclosporin in kidney transplant recipients (BENEFIT and BENEFIT-EXT studies). *Transplantation* **91** (9), 976–983.

Warren, J., Jones, E., Sener, A. ***et al.*** (2012) Should peritoneal dialysis catheters be removed at the time of kidney transplantation? *Canadian Urological Association Journal* **6** (5), 376–378.

White C, Gallagher P (2010) Effect of patient coping preferences on quality of life following renal transplantation. Journal of Advanced Nursing. **66**:11; 2550–2559.

CHAPTER 11

Nondialytic Options and the Role of Palliative Care

Fliss E.M. Murtagh
King's College London, Cicely Saunders Institute, UK

Learning Outcomes

- To describe the palliative care needs for patients with end-stage kidney disease (ESKD) who:
  - follow the non dialytic (conservative management) pathway;
  - withdraw from dialysis.
- To understand the range of symptoms patients with advanced ESKD experience, and how to assess and address them.
- To understand which patients require consideration of their end-of-life care needs.
- To analyse the role of the renal nurse when providing palliative and end-of-life care.

Introduction

This chapter considers the needs of patients with ESKD, their partners, carers and families at a sensitive time – when their health may be declining, and (for some) when the end of their life may be approaching. Both nephrology (Gunda *et al*., 2004) and palliative care specialists (Hobson *et al*. 2010) have identified the significant and growing need for palliative care within nephrology. The focus of the chapter is on those who choose not to dialyse and follow a conservative pathway, but the care of the smaller number of those who withdraw from dialysis is also discussed. Both groups of patients present specific challenges to the nurses caring for them. Renal nurses may also be asked to help patients and families as they consider the decision for or against dialysis. This is a challenging decision, particularly for those who have multiple comorbid conditions where the benefits of dialysis are less clear.

Numbers of Patients

Chronic kidney disease (CKD) is a disease that is found across the age spectrum but is more commonly seen in older people. The prevalence of Stage 3–5 CKD in the UK population is estimated to be between 5.4–8.5% (Evans and Taal 2011). While not all

Renal Nursing, Fourth Edition. Edited by Nicola Thomas. Published 2014 by John Wiley & Sons, Ltd.

of these will progress to end stage disease, the numbers requiring renal replacement therapy have been increasing steadily in recent years, as the population ages. Over the last 40 years there have also been many changes which have increased our understanding and improved life expectancy for people with ESKD. Medical and technological advances have led to increased availability of treatment for renal problems and an ability to treat older people who have other illnesses (Ansell *et al*. 2010). The Renal Registry report for 2010 suggests that the number of people on renal replacement therapy (RRT) is continuing to rise, with an annual growth rate of 4.4%, and that older patients treated by haemodialysis make up a disproportionate amount of the numbers accepted for RRT (Ansell *et al*. 2010). In the early 2010s, about 108 people per million population (pmp) are accepted for renal replacement, and in 2011 there were over 47 000 people receiving RRT in the United Kingdom.

The need for RRT is also being influenced by the ageing of the ethnic minority populations. These groups have a higher prevalence of renal problems; the Department of Health predicts that the numbers of those receiving treatment for established renal failure is increasing between 2005 to 2015, and that this increase will be particularly noticeable within the black and minority ethnic groups and older people (Department of Health 2005).

The Importance of Nondialytic (Conservative) Care

About half of all patients starting renal replacement therapy are over 65 years, and between 15–20% are over 75 years (Ansell *et al*. 2010). With increased age there is usually increased comorbidity; 67% of those over 65 have one or more comorbidities when commencing dialysis. For those over 85 years, about 10% die within the first 90 days of commencing dialysis (Ansell *et al*. 2010). There are many factors that can influence the treatment choices for these older patients, especially for those over 75 years. Dialysis has been shown to have very limited survival advantage in those with high levels of comorbidity (Murtagh *et al*. 2007b; Chandna *et al*. 2011) and this, combined with the high burden of treatment with dialysis, has led to the development of conservative management pathways (where dialysis is not commenced).

Unfortunately, the UK Renal Registry does not yet collect data on those managed without dialysis, so it is hard to know how many patients with ESKD opt to follow a nondialytic (conservative) pathway. Local data indicate it may be about 15–20% of those in managed nephrology care at Stage 5 CKD. Smith and colleagues (Smith *et al*. 2003) showed that approximately 20% of patients assessed were likely to follow a palliative (conservative) pathway. These patients were more likely to have diabetes and have higher comorbidity scores that those for whom dialysis or transplantation were recommended.

The Palliative Approach

Palliative care is a relatively new discipline, emerging in the 1960s, through the inspiration of Dame Cicely Saunders and others. The World Health Organisation definition of palliative care (World Health Organisation 2012) is widely accepted (see Box 11.1).

It is important to recognise that this definition is not disease orientated but patient focused, and also reflects changes made to move away from a disease-specific definition, such as cancer, to an understanding that palliative care should be available to all with a life threatening illness. It also encompasses early introduction of a palliative approach, while enabling a person to continue with life-prolonging therapies, such as dialysis.

BOX 11.1

Definition of Palliative Care (World Health Organisation 2012)

Palliative care is an approach that improves the quality of life of patients and their families facing the problem associated with life-threatening illness, through the prevention and relief of suffering by means of early identification and impeccable assessment and treatment of pain and other problems, physical, psychosocial and spiritual.

Palliative care:

provides relief from pain and other distressing symptoms;

affirms life and regards dying as a normal process;

intends neither to hasten or postpone death;

integrates the psychological and spiritual aspects of patient care;

offers a support system to help patients live as actively as possible until death;

offers a support system to help the family cope during the patients illness and in their own bereavement;

uses a team approach to address the needs of patients and their families, including bereavement counselling, if indicated;

will enhance quality of life, and may also positively influence the course of illness;

is applicable early in the course of illness, in conjunction with other therapies that are intended to prolong life, such as chemotherapy or radiation therapy, and includes those investigations needed to better understand and manage distressing clinical complications.

Source: WHO (2012).

Palliative care aims for an holistic approach to care of patients and families, in situations where the disease is advanced, progressive and incurable. It encompasses physical, psychological, practical, and spiritual aspects of care, and includes consideration of the needs of families and informal carers. For those with ESKD, it is not yet clear what model of palliative care provision should be adopted; whether palliative care should be provided predominantly by renal professionals, by specialist palliative care professionals, or by primary care professionals, or (most likely) by some combination of these three groups. Much will depend on the configuration and availability of local services. Palliative care has been, and still is, at different stages of development throughout the world, as Meghani indicates (Meghani 2004). She describes palliative care as a dynamic concept that all practitioners should be integrating into their daily practice. It may be inappropriate to move a person to a different group of health care professionals just because of their stage of life. One of the big influences on and challenges to practice therefore is the integration of the extensive knowledge and experience in palliative care from the specialist palliative care field into nephrology practice, for the benefit of patients and families.

Recent Government and Other Initiatives

Recent political and national developments in the United Kingdom have given considerable impetus to development of clinical services for those approaching the end of life. The National Service Framework for Renal Services gives the following as a quality requirement:

People with established renal failure receive timely evaluation of their prognosis, information about the choices available to them, and for those near the end of life a jointly agreed palliative care plan, built around individual needs and preferences ((Department of Health 2005).

This emphasis on palliative care in the National Service Framework help provide the impetus to incorporate a more patient-centred approach in advanced kidney disease. In the United Kingdom, nephrology was one of the first specialities to adapt the national End-of-life care Strategy (Department of Health 2011) and make specific recommendations for the ESKD population. A Framework for implementing End-of-life care in Advanced Kidney Disease was produced (NHS Kidney Care 2009). This has had an important impact within renal units, to ensure that improvements in palliative and end-of-life care for those with advanced kidney disease are achieved. Test projects were subsequently undertaken to uncover the best ways to implement the recommendations of the framework, and this led to the publication of a detailed 'roadmap' to help renal units implement best palliative and end-of-life care (NHS Kidney Care 2012).

It is important to distinguish between palliative and end-of-life care. Meghani (2004) cautions against using the terms synonymously; end-of-life care is palliative care, but not all palliative care will be end-of-life care. Palliative care interventions, which focus on a holistic approach, may be both appropriate and very helpful, up to two or three years or more before end of life, and can often markedly improve quality of life in a sustained way. If symptom burden is high and quality of life is poor, despite disease-based interventions, then this is the time to consider palliative care, whatever the expected prognosis.

Communication, Decision Making and Planning

Patient communication

As disease progressed and the end of life approaches, skilled communication becomes increasingly important in the delivery of effective patient care. Communication between patient and nurse is important; patients want to know what to expect as their illness advances, and they value professionals who can talk openly about death and dying (Davison and Simpson 2006). Contrary to the beliefs of many professionals, openness does not remove hope but helps to focus it in a more realistic way.

Information needs to be delivered in amounts, and at a pace, that each individual patient can cope with. It is important to ensure there is the time and conditions for difficult questions to be asked and answered, since many factors will prevent such questions being explored. Communication between the patient and their family also becomes increasingly important to patients as death approaches, and nurses have a key role in facilitating this. Sometimes, understandably, family members adopt a protective attitude towards each other, shielding each other from bad news, but this is not always helpful, particularly if the patient is seeking openness and honesty.

Information also needs to be carefully matched to each patient's preference for information and for involvement in decisions. In general, doctors and nurses tend not to raise their concerns about a patient's declining health and worsening prognosis unless a patient asks about this, and patients often wait for professionals to raise such matters. This can lead to a collusion of silence, where both continue to focus on other (often disease-related) issues, and do not address underlying concerns about declining health.

At the same time, the patient's choices about end-of-life care need to be explored. If open communication does not occur, choices are likely to be more limited. An example

BOX 11.2

Suggested questions to explore patient concerns

How do you think things are going with your health overall?
Have you any worries about your health?
What concerns you most at present?
Have you any worries about the future?
Do you want to know more about your illness and what to expect?
What is most important for you to achieve?
What are your most important hopes?
What are your biggest fears?
What would most improve your quality of life at present?
What is most important to you: quality or length of life?
How is your family handling your illness?
Have you given any thoughts to what treatments you might or might not want in the future?

of this is the preference to die at home if possible; this cannot be facilitated if initial communication and discussions about the implications of the illness have not taken place. Box 11.2 provides some suggestions of useful 'opening questions' that nurses can use to help enable a patient or their family to raise their concerns readily.

For patients with ESKD, some specific considerations are important. Firstly, some patients will be living with their renal condition over a long period of time. It can be more difficult, then, for both patient and professional to perceive the change from living with a long-term condition to a decline in health towards death. If health professionals do not see this change, they may well deny the patient and their family the opportunities they need to understand their illness and address and plan for their remaining time. Secondly, the pattern of decline may be more uncertain than for other terminal conditions such as cancer. The limited available evidence suggests that prognosis in conservatively managed patients varies considerably, depending partly on the underlying cause of the renal failure and on which other comorbid conditions coexist (Smith *et al*. 2003) (Chandna *et al*. 2011). Dealing with this uncertainty is hard for both patient and professional and it needs to be honestly acknowledged in any communication. Thirdly, renal professionals rightly focus on active disease management. End-of-life care requires a change of focus from a primarily disease-centred approach to a more patient-centred approach. Disease management takes a much lower priority, particularly as the end of life approaches. Controlling symptoms, attending to psychosocial and spiritual needs, and anticipating future care needs all become as important, or more important, than renal expertise. Nurses may feel uncertain about their skills in this area, particularly if they work with patients at the end of life infrequently.

Family communication

Effective end-of-life care cannot be delivered without good family communication. However, the ethical and legal responsibilities of the nurse are predominantly to the patient, so it is important to seek patient agreement *before* any communication with the family, particularly if that communication takes place away from the patient. In the final

days of life, increasing uraemia may mean that patients are confused, and increasingly lack the ability to make decisions for themselves. It is important, therefore, to ensure from the beginning that relevant family members are involved in any management decisions (if the patient wishes) and that they are aware of the patient's end-of-life preferences, before the patient becomes less well. Holley (2005) highlights the importance of the patient-family relationship, rather than the patient-professional relationship, as a better context for exploring preferences and undertaking advance care planning.

Communication within the team

A number of key decisions will be made with patients as they approach the end of their life. These include decisions around withholding or withdrawing dialysis, decisions around preferred place of care and death, and cardiopulmonary resuscitation (CPR) decisions, among others. Each of these needs to be communicated to the whole renal team. Patients will often see different professionals at each clinic visit or hospital admission, and it is important that patient and family are given clear and consistent messages.

A wide variety of nonrenal healthcare professionals may also be involved in end-of-life care, ranging from the general practitioner and district nurses to specialist palliative-care professionals (who may be community, hospital or hospice based). Time and energy therefore needs to be devoted to communicating any decisions made to *all* members of the team, including those providing care out of hours, and those who may be called in a crisis, both at home or in hospital.

Dialysis decision making

As disease advances, decisions may be made either to withdraw dialysis, or to follow a conservative pathway. This raises complex and challenging issues. These issues have been reviewed and guidelines have been developed in the United States to inform dialysis decision-making (Renal Physicians Association 2010). The guidelines are built on shared decision-making, recognising that patients are individuals and have their own history, perspectives, and preferences.

Renal patients are known to have widely differing preferences for involvement in decisions, but generally receive less information than they want and have less involvement in decisions than they prefer (Orsino *et al*. 2003). Some nephrologists feel that most, if not all, patients requiring renal replacement therapy should receive dialysis, but there is growing recognition that, for some patients, dialysis may not greatly increase survival while adding a considerable treatment burden. For these patients, conservative management (care without dialysis, but with management to minimise disease progression, and full supportive and palliative care) may be a better option, although any final decision will depend on patient preferences as well as professional advice. Work by Chandna *et al*. (2011) and others has shown that patients with poor functional status and high levels of comorbidity do not do well on dialysis. Carson *et al*. (2009) also describe poor survival in older patients on dialysis, but recognised that survival alone is an insufficient measure of outcome – they also recorded hospitalisations and time spent attending for dialysis.

Following a conservative management pathway sometimes demands especially difficult decision-making, since it requires weighing up patient preferences, estimated survival on or off dialysis, anticipated quality of life on or off dialysis, and the treatment burden with dialysis. Estimating survival and quality of life is difficult for the individual patient. These factors have been studied in patients on dialysis, but symptom burden, survival and quality of life have rarely been studied in patients who are managed conservatively.

Advance planning

Effective and appropriate care can only be delivered by planning ahead and anticipating future care needs. It is therefore important to explore sensitively with patients (and their family, if desired) what their wishes are for future care, or in the event of a sudden deterioration or crisis. Relatively few patients choose to write a formal advance directive, but all should be offered the chance to discuss preferences for future care and management. These discussions should be carefully documented and revisited regularly (since preferences may change).

Advance directives are written documents which specify a patient's preferences, in anticipation of loss of the capacity to make his or her own decisions, when they are less well. In the United Kingdom, the Mental Capacity Act (which became law in 2005) clarifies the legal status of such documents, and also makes provision for a person to be named to represent the patient's preferences in their place (known as Lasting Power of Attorney). The Mental Capacity Act is based on five principles designed to protect people who lack capacity to make particular decisions, but also to maximise their ability to make decisions, or to participate in decision-making, as far as they are able to do so. The principles are outlined in Box 11.3.

There are other ways to facilitate planning, including use of tools such as the Preferred Place of Care document (Pemberton *et al*. 2003). This was developed to promote discussion around patients' preferred place of care and death. It provides an accessible patient held record which records their preferred wishes, and has been recommended by the NSF for Renal Services (Department of Health 2005). Anticipating and planning for acute admissions is also particularly important for some renal patients, especially those with cardiac disease, who may be more liable to develop fluid overload or acute pulmonary oedema.

Whether specific documents or advance directives are used or not, every patient should, as their disease progresses have the chance to discuss their future care, concerns, hopes and preferences. The responsibility lies with the professional to ensure that these opportunities arise. These issues should be addressed early and systematically, remembering that both patients and professionals find it hard to introduce and address such matters.

Careful consideration should be given to resuscitation status, since this may be an issue during hospital admission. Cardio-pulmonary resuscitation (CPR) in this group of patients may be inappropriate, depending on prognosis and comorbidity. It is important to recognise that there is no ethical obligation to discuss CPR with terminally ill patients, if this treatment is judged to be futile and therefore would not be provided.

BOX 11.3

The principles underlying the UK Mental Capacity Act 2005

- A person must be assumed to have capacity unless it is established that he/she lacks capacity.
- A person is not to be treated as unable to make a decision unless all practicable steps to help him/her to do so have been taken without success.
- A person is not to be treated as unable to make a decision merely because he/she makes an unwise decision.
- An act done, or decision made, under this Act for or on behalf of a person who lacks capacity must be done, or made, in his/ her best interests.
- Before the act is done, or the decision is made, regard must be had to whether the purpose for which it is needed can be as effectively achieved in a way that is less restrictive of the person's rights and freedom of action.

Care of Patients Managed without Dialysis

Conservatively managed patients need much more than just symptom management (see Box 11.4). Achieving these goals requires a shift from a predominantly disease-focused approach towards more patient-centred management (the disease itself, while it must not be neglected, is less important than overall quality of life, and patients should be encouraged to decide what treatment they can or cannot tolerate as the illness progresses). Careful judgements need to be made as to when to discontinue onerous treatments; these will often depend on perceived burden and patient preference.

BOX 11.4

The needs of patients managed conservatively (Czapla 2003)

- Skilled communication to facilitate the 'not for dialysis' decision, to explain disease progression and prognosis, and to facilitate future management decisions, in accordance with the patient's information preferences.
- Regular review(s) of the 'not-for-dialysis' decision.
- Continuing disease management to maximise and maintain residual renal function.
- Continuing disease management to minimise symptoms.
- Regular and detailed assessment of symptoms.
- Proactive intervention to control symptoms
- Advance planning as the illness progresses, to:
  - avoid inappropriate acute admissions;
  - avoid inappropriate reversal of 'not for dialysis' decision;
  - enable place of care preferences to be met if possible.
- Ongoing psychological and social care.
- Involvement and support of family as appropriate.
- Spiritual care, especially as the end of life approaches.
- Detailed and expert end-of-life care in the final days or weeks.

Source: Czapla (2003).

Symptoms towards the End of Life

The most common physical symptoms that patients with CKD report are lack of energy or fatigue, itching (pruritus), pain, sleep disturbance and restless legs (see Box 11.5).

A number of studies report fatigue as extremely common (70–90%) (Murtagh *et al*. 2007c). Pruritus has been studied extensively; some of the larger studies suggest that 40–70% of patients may be troubled by this symptom. Pain has been infrequently studied but the few studies of it suggest more than 50% of patients have pain (Davison 2003). Sleep disturbance, and the related symptom of restless legs, has been studied more often, and appears to affect 30–52% of patients. Anxiety and depression may also be experienced by some patients. Reports of how common these problems are depend on how they are defined and sought. Screening questionnaires are positive in 26–58% of patients, but fewer patients (12–26%) have depression diagnosed at formal psychiatric interview (Murtagh *et al*. 2007c). A variety of other less common symptoms have been described, including anorexia, constipation, cough, dyspnoea, nausea and vomiting. Most evidence comes from patients on dialysis; some symptoms (such as muscle cramps, pruritus, restless legs) may be dialysis related, and will occur less often in conservatively managed patients, while other symptoms are disease related and will worsen with declining renal function.

BOX 11.5

Symptoms commonly experienced in Stage 5 CKD

- Fatigue or lack of energy.
- Itching (pruritus).
- Pain.
- Sleep disturbance.
- Restless legs.
- Anxiety and/or depression.
- Anorexia.
- Constipation.
- Cough and dyspnoea.
- Nausea and vomiting.

As the illness progresses, symptoms may worsen. Symptoms in the last days of life, in both the conservatively managed patient and the patient withdrawing from dialysis may follow different patterns but there have been very few studies of symptoms in either group at the end of life. Cohen *et al.* (2000) have carried out one of the few studies on dialysis withdrawal, and they describe pain, agitation, myoclonus (involuntary jerking of muscles), fatigue and dyspnoea each occurring in at least one in four patients in the last day of life.

Symptom assessment

The most important step is to identify symptoms when they are present. This is best done by asking the patient about potential symptoms, in a systematic way. Symptom questionnaires such as the Patient Outcome Scale symptom module (renal version) may be helpful (Murphy *et al.* 2009; Afshar *et al.* 2012) and are freely available at http://pos-pal.org/ (accessed 20 May 2013). There is evidence that symptoms may go unrecognised in ESKD (Weisbord *et al.* 2007). This may be partly because the focus has been on the disease itself and not the symptoms. Symptoms may also be related to other coexistent illnesses (comorbidity), not to the renal disease. Many of these patients will have several comorbid conditions and management of symptoms may fall to a variety of health professionals. However, these patients will have eGFR < 15 ml/minute, and nonrenal health professionals may be both unskilled and unconfident in, for example, using appropriate medications for symptom management. The key to good symptom control is proactive, detailed and thorough symptom assessment at regular intervals, without waiting for the patient to report a symptom.

Careful attention must be given to the underlying cause of each symptom. For example, pain may more likely to be due to comorbid conditions than the renal disease itself, with ischaemic pain from peripheral vascular disease, neuropathic pain from poly-neuropathy (often related to diabetes mellitus), bony pain from osteoporosis, or musculo-skeletal pains from a variety of causes, all common. There may less often be specific pains related to the renal disease, such as bone pain from renal osteodystrophy, cyst pain in polycystic kidney disease, or the infrequent but acute pain of calciphylaxis.

Symptom management

Management of symptoms in CKD is complex because of the altered pharmacology of drugs in advanced renal impairment, and high risk of toxicity and side effects. Symptoms are also commonly due to conditions other than the renal disease, although it is nevertheless important to recognise and treat them. A brief outline of the most frequent or challenging symptoms is given here, but more detail can be found elsewhere, such as in Chambers *et al*. (2010).

Constipation

This is common, and usually multifactorial. Fluid reductions, poor mobility, and drug side effects are common contributors. A stool softener such as lactulose or docusate often needs to be used in combination with a stimulant laxative such as senna or bisacodyl.

Fatigue or lack of energy

This is one of the commonest problems and difficult to help. Measures (such as erythropoietin replacement and iron supplementation) to maintain haemoglobin between 11 and 12 g/dl should be prescribed, and probably continued even when prognosis is short because of the symptom improvement they provide. Nutrition including dietician advice should be carefully considered.

Nausea and vomiting

It is important to try and identify the cause if effective management is to be achieved; history often provides the best clues. Gastroparesis (reduced gastric motility, usually presenting with early fullness, vomiting after eating, and relief of nausea with vomiting) responds to metoclopramide. Uraemic nausea is often more constant and less closely related to eating; haloperidol is a more appropriate treatment. Persistent nausea or vomiting near the very end of life can be treated with levomepromazine; this is very effective but doses may be limited by sedation. Ondansetron or granisetron may also be used, especially if nausea is drug-related, but severe constipation is a common side effect, and should be proactively managed by co-prescription of a laxative.

Pain

Pain management needs to be tailored, both to the individual patient, and to the specific cause of the pain. If the cause cannot be removed or reduced, then pain medication should be given according to the World Health Organisation 'analgesic ladder' (www.who.int/cancer/palliative/painladder/en/, accessed 20 May 2013). This consists of three steps:

Step 1: nonopioid, usually paracetamol.

Step 2: opioids for mild to moderate pain.

Step 3: opioids for moderate to severe pain.

Initial analgesia should start with the lowest appropriate step. It is important to understand that, if the full dose is insufficient for relief, then using another medication from the same 'step' does not usually provide any better relief, and it is better to move up to the next step. Tramadol is probably the optimal Step 2 opioid, although should be used at a reduced dose and at an increased dose interval in Stage 5 CKD (Broadbent *et al*. 2003). Use of Step 3 opioids in Stage 5 CKD is highly problematic: morphine and

diamorphine in particular accumulate and readily cause toxicity. Fentanyl is probably safer, although evidence is limited, and available formulations are restrictive (Murtagh *et al*. 2007a). According to the cause of the pain, additional (adjuvant) medication may need to be used alongside opioids. This is particularly true of neuropathic pain.

Pruritus

Dry skin is very commonly associated with pruritus, and should be actively managed with liberal regular emollients (such as aqueous cream). High serum levels of calcium, phosphate, magnesium, and parathyroid hormone have all been associated with pruritus to a greater or lesser extent (Lugon 2005), and should be sought and actively managed, if present. Oral antihistamines are often used, although there is little evidence for benefit. If pruritus disturbs sleep, a sedative antihistamine (such as chlorpheniramine) given at night may be useful. Other treatment options include naltrexone (not with opioids), capsaicin cream (especially if pruritus is localised) or thalidomide (caution with handling).

Restless legs and sleep disturbance

These two symptoms frequently co-exist. Simple measures, such as avoiding caffeine, avoiding alcohol in the evenings, and reducing daytime sleep, are important in facilitating sleep. Hypnotics, such as zolpidem, zopiclone or temazepam can be used, although doses should be reduced in Stage 5 CKD without dialysis, and risk of dependence should be considered carefully if prognosis is months or more.

Restless legs should be managed specifically with reduction in caffeine and any aggravating medications (such as tricyclics), and active treatment of anaemia and low ferritin (which are both associated with restless legs). Clonazepam or dopaminergic agents are most often prescribed, although if these are effective, then symptoms often recur after an interval. For this reason, lowest possible doses should be used, and intermittent rather than continuous use may be helpful.

Psychological, Social and Spiritual Issues

Palliative care considers the whole person and their family. It is important to consider all aspects, since psychological, social and spiritual issues are important. For example, as Davison (2005) identifies, unless the psychological, social, and spiritual components of pain are addressed, pain may not be relieved adequately.

There are many psychological and social implications of living and dying with CKD, many of which are similar to other life-threatening or chronic diseases. Both the patient and their carer or family face many potential changes and these can be related to, for example, role change, appearance, sexuality, financial challenges and becoming more physically dependent on someone. It is important that timely discussions occur to ensure that the patient and their family are prepared for potential changes and aware of services and benefits that may help. Psychological aspects of care are addressed more fully elsewhere (Chambers *et al*. 2010) but failure to address psychosocial issues can lead to 'technical' treatment without healing. It is also important to provide support to the family caregivers; by doing this the patient is also supported. The involvement of the multidisciplinary team is essential. The timely intervention of, for example, an occupational therapist can help promote independence and safety, which gives a boost to both patients and carers. The provision of a bereavement service is also seen as important. Some renal units offer an annual memorial service, as part of their bereavement care. Families of patients who have died in the previous

year are invited to the service, as well as renal professionals. It is an opportunity for all to acknowledge the loss, to continue to provide support, and often helps families progress in their bereavement journey.

Spiritual care

The term 'spiritual' is ill defined and can mean very different things to different people (Chambers *et al*. 2010). To add to the confusion, the terms 'spiritual' and 'religious' are frequently used interchangeably, which is unhelpful. Spirituality is to do with meaning, not necessarily through formal religious beliefs, while religion is an expression of spiritual beliefs through a more formal framework (Speck *et al*. 2004). Spiritual care should be integrated into practice to ensure that the whole person is considered within the context of their care. Illness, and the end of life in particular, involves mind and spirit, not just what happens to the body, and it is therefore important that care of mind and spirit are included in overall care. Spiritual care is often neglected until the end of life is perceived as being very near, leaving little time for spiritual care or resolution of issues. The closeness of death, and the prospect of facing mortality, can have significant effects on both patient and family, as well as on professionals. Sometimes people look for meaning in what is happening, or ask the question 'why me?' There may be issues of guilt, or some families may be facing multiple losses or another recent bereavement. Knowledge and discussion of spiritual needs should help addressing these issues as death approaches, although listening is frequently the most important skill in spiritual care.

Summary

The needs of patients with kidney disease (and their families) as they become less well and as they approach the end of life are complex. They need skilled and open communication from an early stage, advance planning, high quality symptom control, and good psychological and spiritual care. Their families may also need bereavement care. Effective delivery of such care also requires communication with, and co-ordination of, the network of professionals who may be involved, including primary care, renal, and specialist palliative care professionals, as well as families and informal carers.

It is imperative that nephrology nurses develop generic palliative-care skills to ensure that appropriate care, including good symptom relief, is given to patients and their families at all stages of their disease trajectory. In addition, partnerships with specialist palliative care providers need to be nurtured to ensure that their timely intervention can be of full benefit, and that there is maximum sharing of expertise and experience. The overall aim is to enable the last months and days of each patient's life to be lived as fully as possible, and for them to achieve a good death. It is a challenging area for nephrology nursing practice, but one that cannot and must not be ignored.

References

Afshar, M., Rebollo-Mesa, I., Murphy, E. *et al.* (2012) Symptom burden and associated factors in renal transplant patients in the UK. *Journal of Pain and Symptom Management* **44, 229–238**.

Ansell, D., Feehally, J., Fogarty, D. *et al.* (2010) Twelfth Annual Report of the Renal Association. *Nephron – Clinical Practice* **115** (suppl. **1**), c1–c366.

Broadbent, A., Khor, K. and Heaney, A. (2003) Palliation and chronic renal failure: opioid and other palliative medications – dosage guidelines. *Progress in Palliative Care* **11,** 183–190.

Carson, R. C., Juszczak, M., Davenport, A. and Burns, A. (2009) Is maximum conservative management an equivalent treatment option to dialysis for elderly patients with significant comorbid disease? *Clinical Journal of the American Society of Nephrology* **4**, 1611–1619.

Chambers, E. J., Germain, M. and Brown, E. (2010) *Supportive Care for the Renal Patient*, Oxford University Press, Oxford.

Chandna, S.M., Da Silva-Gane, M., Marshall, C. *et al.* (2011) Survival of elderly patients with stage 5 CKD: comparison of conservative management and renal replacement therapy. *Nephrology, Dialysis, Transplantation* **26**, 1608–1614.

Cohen, L.M., Germain, M., Poppel, D.M. *et al.* (2000) Dialysis discontinuation and palliative care. *American Journal of Kidney Diseases* **36**, 140–144.

Czapla, K. (2003) Management of chronic renal insufficiency in frail older patients who are unfit for renal replacement therapy. *Reviews in Clinical Gerontology* **13** (**1**), 25–37.

Davison, S.N. (2003) Pain in hemodialysis patients: prevalence, cause, severity, and management. *American Journal of Kidney Diseases* **42**, 1239–1247.

Davison, S.N. (2005) Chronic pain in end-stage renal disease. *Advances in Chronic Kidney Disease* **12**, 326–334.

Davison, S.N. and Simpson, C. (2006) Hope and advance care planning in patients with end stage renal disease: qualitative interview study. *British Medical Journal* **333**, 886.

Department of Health (2005) *National Service Framework for Renal Services – Part 2*, Department of Health, London.

Department of Health (2011) End-of-life Care Strategy, Third Annual Report. Department of Health, London.

Evans, P.D. and Taal, M.W. (2011) Epidemiology and causes of chronic kidney disease. *Medicine* **39**, 402–406.

Gunda, S., Smith, S. and Thomas, M. (2004) National survey of palliative care in end-stage renal disease in the United Kingdom. *Nephrology Dialysis Transplantation* **20**, 392–395.

Hobson, K., Gomm, S., Murtagh, F. and Caress, A.L. (2010) National survey of the current provision of specialist palliative care services for patients with end-stage renal disease. *Nephrology Dialysis Transplantation* **26** (**4**), 1275–1281.

Holley, J.L. (2005) Palliative care in end-stage renal disease: focus on advance care planning, hospice referral, and bereavement. *Seminars in Dialysis* **18**, 154–156.

Lugon, J.R. (2005) Uremic pruritus: a review. *Hemodialysis International* **9**, 180–188.

Meghani, S. (2004) A concept analysis of palliative care in the United States. *Journal of Advanced Nursing* **46**, 152–161.

Murphy, E.L., Murtagh, F.E., Carey, I. and Sheerin, N.S. (2009) Understanding symptoms in patients with advanced chronic kidney disease managed without dialysis: use of a short patient-completed assessment tool. *Nephron Clinical Practice* **111**, c74–c80.

Murtagh, F.E., Chai, M.O. and Donohoe, P. *et al.* (2007a) The use of opioid analgesia in end-stage renal disease patients managed without dialysis: recommendations for practice. *Journal of Pain and Palliative Care Pharmacotherapy* **21**, 5–16.

Murtagh, F. E., Marsh, J. E., Donohoe, P. *et al.* (2007b) Dialysis or not? A comparative survival study of patients over 75 years with chronic kidney disease stage 5. *Nephrology Dialysis Transplantation* **22**, 1955–1962.

Murtagh, F.E.M., Addington-Hall, J. and Higginson, I.J. (2007c) The prevalence of symptoms in end-stage renal disease: a systematic review. *Advances in Chronic Kidney Disease* **14**, 82–99.

NHS Kidney Care (2009) *End-of-life Care in Advanced Kidney Disease: A Framework for Implementation*, Department of Health, London.

NHS Kidney Care (2012) *Getting it Right: End-of-life Care in Advanced Kidney Disease*, Department of Health, London.

Orsino, A., Cameron, J.I., Seidl, M. *et al.* (2003) Medical decision-making and information needs in end-stage renal disease patients. *General Hospital Psychiatry* **25**, 324–331.

Pemberton, C., Storey, L. and Howard, A. (2003) The preferred place of care document: an opportunity for communication. *International Journal of Palliative Nursing* **9**, 439–441.

Renal Physicians Association (2010) *Guidelines on Shared Decison Making in Dialysis*, www.aahpm.org/uploads/files/rpaguidelines.pdf (accessed 20 May 2013).

Smith, C., Silva-Gane, M., Chandna, S., *et al.* (2003) Choosing not to dialyse: evaluation of planned non-dialytic management in a cohort of patients with end-stage renal failure. *Nephron Clinical Practice* **95**, c40–c46.

Speck, P., Higginson, I. and Addington-Hall, J. (2004) Spiritual needs in health care. *British Medical Journal* **329**, 123–124.

Weisbord, S.D., Fried, L., Mor, M.K. *et al.* (2007) Renal provider recognition of symptoms in patients on maintenance hemodialysis. *Clinical Journal of the American Society of Nephrologists* **2**, 960–967.

World Health Organisation (2012) *Definition of Palliative Care*, www.who.int/cancer/palliative/definition/en/ (accessed 20 May 2013).

CHAPTER 12

Renal Care in Infancy, Childhood and Early Adulthood

Diane Blyton and Shelley Jepson

Nottingham Children's Hospital, UK

Learning Outcomes

- To gain an understanding of the physiological differences between children and adults.
- To develop an appreciation of the psychosocial impact of chronic kidney disease and renal replacement therapies on children and their families.
- To identify the key differences in the management of chronic kidney disease, dialysis, transplantation and acute renal failure in children.
- To be able to identify important issues around transition, and the transfer of young people to adult services.

Introduction

The aim of this chapter is to address the unique needs of infants, children and young adults who have kidney damage. The challenge is to meet the needs of the patients and their parents within each of these age groups.

Infants and young children are dependent upon their parent/carer for their global needs, and as they mature, they are increasingly able to become self-caring. The Renal National Service Framework (NSF) for children and young people emphasised the need for families to be partners in their child's care (Department of Health 2006a). Therefore the approach taken with this client group needs to be flexible, and the multiprofessional team needs to be diverse to support this. Specialist units will commonly comprise not only medical staff and specialist nurses but also specialist dieticians, social workers, nursery nurses/hospital play specialists, hospital school teachers, psychologist and where possible youth workers.

Renal Nursing, Fourth Edition. Edited by Nicola Thomas. © 2014 John Wiley & Sons, Ltd. Published 2014 by John Wiley & Sons, Ltd.

Key concerns are the psychosocial impact of a condition, which will often be long-term, on both the child and their family (Department of Health 2006a). A recent study has reported poorer overall quality of life, and poorer physical, school, emotional, and social functioning in children with mild-to-moderate CKD compared with healthy children (Gerson *et al.* 2010). The prevention of complications that may have an impact on the health of the child throughout their future, on transfer to adult services, is also important.

The following sections will highlight both the physiological and psychosocial differences between children and adults, and how renal replacement therapies need to be adapted accordingly.

Physiology in Childhood – Impact on Renal Care

There are several key areas where physiology in childhood differs from adulthood.

Growth

A major difference is that children are continually growing, with accelerated growth spurts during infancy and adolescence.

Normal birth weight is 3.5 kg and during infancy growth varies between 50–200 g a week, with an expected 25 cm length increase in the first year. This gradually declines to 2 kg per year with 6 cm height increase until the pubertal growth spurt (Shaw and Lawson 2007). Body proportions also change. The head changes from a proportion of 1:4 to 1:8 in adulthood (MacGregor 2008).

Several factors have an influence in growth including diet, genetic inheritance and growth hormone production, which are discussed further below.

Fluid balance

Seventy to eighty percent of the body consists of water in infants, decreasing to 60% in adults. There is also a greater proportion of extracellular water in infants; therefore water is more easily lost, particularly during pyrexia (MacGregor 2008).

Renal anatomy

Neonates' kidneys are affected by the removal of blood flow from the placenta, leading to a reduction in glomerular filtration rate (GFR) and renal blood flow.

At birth, the kidneys have the correct number of nephrons but they are immature (Hockenberry and Wilson 2011). Newborns have small underdeveloped glomeruli, short loops of Henle and an under developed renal cortex. The main consequence of this is a reduced GFR of 30 ml/min/1.73 m^2 at birth reaching 100 ml/min/1.73 m^2 by 9 months of age.

There is a reduced ability to concentrate urine, and also to secrete hydrogen ions. This becomes particularly important if the infant enters into a state of metabolic acidosis.

There is rapid development particularly in the first 6 months of age, but still at 1–2 years of age the GFR is approximately 30–50% of adult values (MacGregor 2008).

Careful consideration is needed when monitoring children and that age-appropriate parameters are used. Infants, in particular, are expected to have higher levels for many electrolytes. They also have a reduced serum creatinine as a result of smaller muscle mass. Age appropriate reference ranges should be consulted for biochemistry results throughout childhood, as other variations are seen (see Table 12.1).

Table 12.1 Biochemistry reference ranges for children.

Sodium (mmol/l)		132–142
Potassium (mmol/l)	<1 month	3.0–6.6
	>1 month	3.0–5.6
Bicarbonate (mmol/l)		22–32
Urea (mmol/l)		2.5–6.5
Albumin (g/l)		34–45
Calcium (mmol/l)	<1 year	2.4–2.8
	1–2 years	2.3–2.7
	3–16 years	2.2–2.6
Phosphate (mmol/l)	<4 wks	1.2–3.1
	5 wks–6 mths	1.5–2.4
	6 mths–1 year	1.5–2.1
	1–3 years	1.2–2.0
	3–6 years	1.0–1.8
	6–15 years	1.0–1.7
	Adult	0.8–1.4
Creatinine (μmol/l)	<5 years	<44
	5–6 years	<53
	6–7 years	<62
	7–8 years	<71
	8–9 years	<80

Blood pressure increases with size/age. Height centile charts should be used to monitor blood pressure in children with short stature for accuracy. This will include many children with renal disease (National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents 2005)

Chronic Kidney Disease

The common causes of chronic kidney disease (CKD) in children are different from those experienced in later life, as indicated in Box 12.1. In comparison with the numbers seen in the adult population, it is difficult to gain accurate figures. In 2009 data suggested that the incidence of established renal disease (ERD) was 56.1 pmarp (per million age

BOX 12.1

Common causes of ERD in children

Renal dysplasia +/– reflux, 32.6%.

Glomerulopathies, 13.8%.

Obstructive uropathies, e.g. posterior urethral valves, 17.3%.

Source: UK Renal Registry (2012).

related population) and 9.6 pmp (per million population) as a whole. This rate was estimated to be 774 pmp in the adult population (UK Renal Registry 2012).
The presenting symptoms of CKD commonly seen in children are;

- Failure to thrive or anorexia.
- Nausea, vomiting and loss of appetite.
- Lethargy.
- Headaches and high blood pressure.
- Reduced urine output or polyuria/polydipsia, possibly wetting.

Children can present at any age and at different stages of renal disease. It is important that investigations are undertaken to determine cause and therefore the interventions required. Dialysis may be necessary in some cases, however many children can be treated conservatively.

Some conditions are familial and therefore siblings may also need to be assessed, even if they are asymptomatic. In rare cases a parent and one or more children may be dialysis dependent and a thorough plan of psychosocial support is a necessity in this situation.

Conservative Management

Providing the biochemistry is stable, children can be maintained without dialysis for some time. Several interventions can be incorporated into conservative management. These interventions continue into the established phase of chronic kidney disease, and may be temporarily used to support children in an acute phase of renal disease.

Diet (also see Chapter 13)

Poor appetite, gastro-intestinal reflux and vomiting are common problems seen in children and infants with chronic kidney disease. Parents often see feeding their child as an important aspect of their role, and therefore this is potentially an area of great stress (Royle 2007).

It is important that a paediatric renal dietitian is involved in the management of children with renal disorders, providing support in this area of anxiety (Department of Health 2006a). Dietary control can assist in delaying the need for dialysis and all of the medical and psychosocial problems associated with it, as discussed further below. Adequate nutrition is also important for growth and neurological development.

Energy requirements should be based upon EAR (estimated average requirement) for chronological age, or height age if the child falls below the second percentile (Royle 2007). Modified mild formulas may be necessary for infants, dependent upon biochemistry, as standard formulations may have inappropriate protein and electrolyte concentrations.

Individualised dietary guidance is needed for each family, based on the child's biochemistry. Negotiation with food allowances is often needed with older children, to improve adherence to the nutritional plan. Clear education is needed for the child and their parents, to ensure understanding of the necessity for restricting many favourite childhood foods, such as chips and pizza. Sodium, potassium and phosphate intakes often need to be altered. A small number of patients with tubular disorders may require supplementation (Rees and Shaw 2007). Protein intake may also need to be modified to balance growth requirements against potential uraemia (Royle 2007).

High-energy food and drinks are encouraged, as it can be difficult to achieve EAR when on an altered diet. Good nutrition is very important in reaching the minimum weight to be placed on the transplant list (commonly 10 kg).

It is common for younger children and infants, in particular, to refuse to eat, and enteral feeding via the nasogastric or gastrostomy route is often required. Gastrostomy feeding has been shown to be a valuable tool in nutritional support and has also been associated, with other factors, in improved growth of young children (Rees *et al.* 2011).

Socialisation with food is still important, with the end goal of transplantation in mind. Feeding problems can remain following a successful transplant and speech-and-language therapy can be required. Conversely, in older children, advice is often needed to prevent excessive weight gain, particularly when taking corticosteroids as immunosuppression.

Fluid management

The approach to fluid management will be dependent upon whether the child concerned has a reduced urine output or is polyuric.

Patients who have a reduced urine output will usually be given a fluid allowance, and placed on a diuretic regimen. The common guideline used is to add 400 ml/m^2 surface area/day to the average daily urine output, to allow for insensible losses (Royle 2007).

Some patients are polyuric and great care needs to be taken to ensure that fluid intake is sufficient to prevent dehydration.

Along with dietary changes, it is the reduction in fluid allowance that older children often find the most difficult to adhere to. It is important to give advice on ways of managing fluid. Fluid overload is a contributor to hypertension in many patients, and therefore can impact in cardiovascular health (Wright 2004).

Blood pressure

As with adults, hypertension is a complication that children with renal disease may experience. It is essential that accurate measurements are taken, to enable effective treatment of hypertension. Cardiovascular complications are a major cause of mortality and morbidity in adult patients (UK Renal Registry 2012). Slowing the progression of CKD, avoiding long-term dialysis and, if possible, conducting pre-emptive transplantation may represent the best strategies to decrease the risk of premature cardiac disease (Mitsnefes 2012).

Prevention of early complications is therefore essential, with hypertension being one of the most modifiable. Hypertension has also been associated with acceleration of renal disease and there is evidence that intensified blood-pressure control, with target 24-hour blood-pressure levels in the low range of normal, confers a substantial benefit in terms of slowing kidney disease progression (ESCAPE trial group *et al.* 2009).

Blood pressure decreases with age, and there are reference guidelines to assist in patient management. As children with renal insufficiency are often short in stature, their height should be used as a reference, rather than chronological age. It is recommended that systolic blood pressure should be maintained below the 90th percentile for height and sex (UK Renal Registry 2012). There are charts based upon gender, age and height, which should be used (National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents 2007).

The British Hypertension Society has guidelines on blood-pressure measurement, which include some guidance on children www.bhsoc.org/ (accessed 20 May 2013). Blood-pressure measurement in children is difficult and many inaccuracies are seen because of the method of measurement of the blood pressure cuff and the choice

BOX 12.2

Key principles in blood pressure measurement

- The bladder in the cuff should cover 80–100% of arm circumference.
- Doppler devices are the recommended method in children under 2 years.
- Inflate to 30 mmHg above the estimated systolic pressure.
- Deflate the cuff at 2–3 mmHg/s.
- Record the reading to the nearest 2 mmHg.
- Blood pressure should be compared to centile charts for height, age and gender.

of apparatus with which to measure the blood pressure See Box 12.2 for a summary of blood pressure measurement guidelines.

There are other issues to consider in very small children. Firstly they can be uncooperative. It can also be difficult to hear Korotkoff sounds in small children using a stethoscope. As a result, Doppler devices are recommended in children under 2 years of age. Single readings should not be used to direct management, because white-coat hypertension can be particularly problematic in children. Ambulatory blood-pressure monitoring is often used to assist in correct treatment of hypertension enabling monitoring away from the hospital environment (Flynn 2011).

Anaemia

Anaemia is also associated with an increased risk of cardiac morbidity and mortality, and also affects growth and development (Koshy and Geary 2008). Haemoglobin should be maintained above or equal to 11 g/dl, ferritin 100–500 ng/ml and TSATS (Transferrin Saturation Rate) >20%. Initially oral iron supplementation with nutritional management is sufficient in managing anaemia. However as renal function deteriorates erythropoietin stimulating agents may need to be introduced. Most children with established kidney disease require treatment.

Intravenous iron is beneficial in increasing ferritin, TSATS and haemoglobin (Albaramki *et al.* 2012). This is usually given on an as required basis, however weekly doses for children on haemodialysis can be effective in counteracting the blood loss experienced. Whenever possible, blood transfusions are to be avoided.

Growth and bone health

Growth problems are common in children with renal disease, and monitoring is essential. This becomes a particular issue when GFR decreases below 25% (Hodson *et al.* 2012). Height/length, weight and head circumference in the under 2s should be measured and recorded on a growth chart (Royle 2007).

Renal bone disease is a major contributor to growth problems (Wesseling *et al.* 2008). Close monitoring of phosphate levels and parathyroid hormone is essential. Nondominant hand and wrist x-ray is also used to monitor growth, enabling bone age to be compared with chronological age.

Diet has a major impact on growth, including control of calcium and phosphate levels. Phosphate binding medication is often required (Royle 2007). In infants and young children this is added as a suspension into feeds, whereas older children follow similar regimes to adults. Again adherence can be a problem, and education and negotiation is essential to identify a regime that is realistic.

Vitamin D analogue treatments may also be required. Combining these treatments can control serum calcium levels and prevent the development of hyperparathyroidism (Bacchetta *et al.* 2012). Progression to tertiary hyperparathyroidism can make long-term treatment very difficult, and may ultimately lead to the need for a parathyroidectomy. Vascular calcification is also a major concern, and can be a contributing factor in cardiovascular complications (Bacchetta *et al.* 2012).

Growth problems in children with renal disorders have been associated with deranged secretion of growth hormone and resistance. Recombinant growth hormone can be effective (Hodson *et al.* 2012) and this treatment should be considered. This should be carefully managed in conjunction with an endocrinologist to minimise complications.

Nephrotic Syndrome

Nephrotic syndrome is the most common glomerular disease in childhood. The disease is predominantly seen in preschool children with an incidence of 2–4 cases per 100 000 in the United Kingdom (Krishnan 2012). It is 4–6 times more common in the UK Asian population (Lennon *et al.* 2009).

Nephrotic syndrome is characterised by a triad of symptoms: proteinuria (early morning protein to creatinine ratio greater than 200 mg/mmol), hypoalbuminaemia (plasma albumin less than 25 g/L), and generalised oedema (Lennon *et al.* 2009). Oedema develops when a loss of plasma protein leads to a fall in oncotic pressure and water leaks into the interstitial space. Elevated plasma cholesterol frequently occurs.

Acquired nephrotic syndrome can be secondary to infection, allergic disorders or systemic disease such as Henoch–Schönlein purpura, however it is most commonly idiopathic. Ninety-five per cent of paediatric patients respond well to corticosteroid therapy and can be classed as having minimal change nephrotic syndrome (MCNS).

The treatment of MCNS is with prednisolone, 60 mg/m²/day for 28 days, followed by 40 mg/m²/day on alternate weeks for a further 28 days. The child is considered to be in remission when the urine has been negative of protein for three consecutive days. Relapse occurs when there is proteinuria of 3+ or more on dipstick for three consecutive days after remission (Krishnan 2012). Relapse occurs in approximately 70% of children, requiring high-dose steroid treatment, which is weaned after 4 weeks. In children who frequently relapse, long-term low dose steroids (15–20 mg/m²) are recommended.

Renal biopsy is only indicated if remission is not achieved within 28 days of commencing treatment.

Nursing care of children with nephrotic syndrome

Accurate monitoring of fluid balance is essential along with daily weight and regular blood pressure measurement. Frequent assessment of oedema is necessary and mobilisation should be encouraged to disperse oedema. In children with significant oedema, a fluid allowance of 750 ml daily for children under 5 years and 1000 ml daily for those over 5 years should be considered. Although oedema may be present, hypovolaemia may occur due to the shift of fluid into the interstitial space. Diuretics should therefore be used with extreme caution and daily monitoring of serum electrolytes is necessary. In severe cases of oedema or hypovolaemia, 20% albumin infusions may be prescribed. Albumin should be administered with caution and frequent observations made during and after the infusion.

Urine should be checked for protein daily and a teaching programme should be arranged for children and carers, so that they can continue with urinalysis following discharge.

Advice about steroid dosage and potential side effects should be given. Referral to a paediatric renal dietician is recommended. A healthy eating plan should be observed with a no-added salt diet. Monosaturated or polyunsaturated fats should be used to prevent hyperlipidaemia.

In cases of frequent relapse or steroid resistance, second-line nonsteroidal treatment is necessary. These children should be referred to a paediatric nephrologist. Minimal change nephrotic syndrome has a favourable prognosis. Children who present with this syndrome between one to eight years of age are likely to respond to steroid treatment. The disease usually burns out before childhood leaving no residual renal damage (Hodson *et al.* 2012).

Congenital nephrotic syndrome

This is a rare, inherited disorder, which usually presents in the antenatal stage or within the first three months of life (Jalanko 2009). It is characterised by heavy proteinuria, oedema and hypoalbuminaemia. Unlike childhood nephrotic syndrome, the disease cannot be controlled with the use of corticosteroids.

Daily albumin infusions are necessary and central venous line insertion is recommended to facilitate this. Ultimately, nephrectomy and renal replacement therapy is required. Early referral to a paediatric nephrology centre is crucial.

Renal Replacement Therapy

Transplantation

Transplantation is the treatment of choice for children with established renal disease. In 2009 it was reported that 76.7% of children with established renal disease were transplanted (UK Renal Registry 2012). Normal renal function provides children with better opportunities for growth and development. In addition, successful transplantation maximises the amount of education and normal childhood activities, which may be compromised during dialysis.

Allocation of deceased donor transplants currently gives priority to paediatric recipients (under 18 years of age) or young adults of 19 years of age who have been on the list since age 18 years. This was agreed as children are likely to require more than one kidney transplant in their life time and a good match at first transplant will mean less difficulty in finding a suitable donor in the future.

It is possible to transplant kidneys from adult donors depending on the size of the child's abdominal cavity. If the donor kidney is disproportionately large, it may be placed intraperitoneally. However the extraperitoneal position is preferable as this preserves the peritoneum for dialysis and avoids long term complications.

Transplantation into very small children is rarely successful. Most transplant surgeons require children to weigh approximately 10 kg or have reached at least 22 months of age before transplantation is considered. This is due to the risk of infarction in small vessels post operatively. Children receiving renal replacement therapy from birth therefore require the maintenance of dialysis access up until this time. This places a significant burden on the carers and a challenge for professionals.

Living donor transplantation

With the decrease in the number of deceased donors, living donor transplantation is on the increase and is now routinely considered as an early option. In children, the donor is

most frequently a parent, although donation from grandparents has been reported. UK law prohibits minors from donating a kidney and therefore siblings under 18 years are not considered. For children placed on the deceased donor waiting list, the avoidance of parental antigens will allow living related transplantation to be considered in the future.

Living related donation (LRD) is advantageous in that families are able to plan the timing of the transplant, which allows them to consider employment, education and family arrangements. It is recommended that children receiving kidney transplants must be cared for within a paediatric unit (Department of Health 2004) therefore there is the potential for the recipient and the donor to have surgery at different hospitals simultaneously. Professionals need to pay attention to the psychosocial needs of the family during this time, as often the nondonating parent must divide his or her time between the two sites. Supportive care could be provided in terms of video links and assistance with transport.

Pre-emptive transplantation

Transplantation prior to the need for dialysis is considered to be the gold standard for treatment of ERF and is achieved in up to 30% of transplanted children in the United Kingdom and United States (Williams 2012). The benefits of transplant before dialysis include: less interruption of schooling and family life, preservation of the peritoneum and vessels for future dialysis treatments, improved growth and development, and reduction in the symptoms of established renal failure

A child is generally considered for transplantation once the glomerular filtration rate has fallen below 10–15 ml/min/1.73 m^2 and dialysis is anticipated within 12–24 months and/or a significant complication of growth failure is present (Webb 2003). In addition, pre-emptive transplantation should be considered if the child exhibits symptoms of established renal disease, i.e. renal bone disease, poor growth, fatigue and inability to take part in normal childhood activities.

Care of the child after kidney transplantation

Nursing care of the child following renal transplant must be in a designated high dependency nursing area in order to ensure close monitoring. Postoperative complications include bleeding, vascular thrombosis and delayed graft function (Williams 2012). After the first 48 h recovery is generally fast and, if there are no complications, children can be discharged 7–10 days following transplant.

Careful attention to kidney function and immunosuppression levels is necessary, and children are usually seen as an outpatient several times a week in the first four weeks. Due to the long travelling distances to the specialist centre for paediatric patients, close collaboration with local health centres and district hospitals is encouraged so that blood tests can be taken locally and results sent to the tertiary centre.

Children should be encouraged to return to school within 4–6 weeks of a successful transplant. School liaison is recommended in order to reassure teaching staff (Royal College of Nursing 2000).

Immunosuppression

There is currently no standard immunosuppression regimen for children and young people undergoing renal transplantation. However most children in the United Kingdom receive triple therapy with a calcineurin inhibitor (tacrolimus), a DNA proliferation inhibitor (azathioprine, mycophenolate mofetil) and a corticosteroid (NICE 2006). There are newer immunosuppressant agents targeting different sites in immune activation pathways, such as sirolimus and everolimus. Experience with these drugs in the paediatric population is evolving (Williams 2012) although potential nonadherence to

the immunosuppressive regimen can be prevalent resulting in serious clinical consequences (Dobbels *et al*. 2010).

Complications

There are several potential complications following paediatric renal transplant. Hypertension is recognised as an important risk factor for cardiovascular morbidity and graft survival in transplanted children, with post-transplant hypertension occurring in 60–90% of transplanted children (Seeman 2007). Causes include: immunosuppression therapy, graft dysfunction, stenosis and weight gain. Ideally, hypertension should be confirmed using 24-hour automated blood pressure monitoring. The systolic blood pressure should be maintained at <90th percentile for age, gender and height. (+1.28SD = 90th percentile) or 130/– mmHg, whichever is lower.

Other complications include urinary-tract infection, rejection and recurrence of primary disease. Regular follow up and 24 hour access to the nephrology centre is essential.

Preparation for dialysis and transplant

Prior to commencing renal replacement therapy children, young people and their carers need to be given information regarding treatment options. In order for them to make an informed choice, information that is appropriate to age and understanding must be available. Hospital play specialists, trained to prepare children for procedures, are invaluable members of the paediatric multiprofessional team. Evidence shows that appropriate preparation for family members prior to treatment may prevent trauma later (Waby *et al*. 2005). Consideration must also be given to siblings who may feel distressed by the treatment and are concerned about family separation (Batte *et al*. 2006).

There are a number of investigations that are required within the preparation period. These are summarised in Box 12.3.

Immunisation

Live vaccines should not be given in children who are immunosuppressed. In order to receive optimal protection against infectious diseases children should be given a full course of primary immunisations prior to transplant listing. In addition to routine

BOX 12.3

Investigations required prior to renal replacement therapy

- Blood group
- Tissue type
- Cytotoxic antibodies
- Parental cross-match (if requested)
- Immunisations (see below)
- 24-hour urine collection
- ECG
- Urological opinion
- Urodynamics, if indicated

childhood immunisation, hepatitis B, BCG and varicella zoster vaccine should be given to nonimmune children. The quadrivalenthuman papillomavirus (HPV4) is recommended (Neu 2012).

Dialysis

Although every attempt is made to transplant pre-emptively and hold off dialysis, and this is not always possible. Peritoneal dialysis is often the dialysis of choice if a transplant is not available, however some families prefer haemodialysis. It is important that children and their families are aware of all of the options available, and that they are actively involved in the decision-making process.

Other professionals also often require information when children progress onto dialysis. General practitioners and community health staff should be informed of changes in the child's treatment.

School and nursery visits are also often required to inform teaching staff about the impact dialysis has on the child, and also for health and safety reasons (RCN **2000**).

Peritoneal dialysis (PD)

In 2010, 14.3% of children with ERD were on PD. One benefit of peritoneal dialysis in paediatric patients is the reduced disruption to normal life. It is the recommended therapy in children under the age of two (National Institute for Health and Clinical Excellence 2011). In many paediatric units automated PD is the most frequent mode of delivery. This is usually carried out overnight reducing the impact on schooling in particular. Machines can deliver fill volumes as low of 60 ml with reduced recirculation of fluid using specialised sets, therefore enabling most infants to be dialysed this way. Infants requiring lower volumes are usually hospitalised following transfer from Neonatal Services.

Another advantage of this method is the reduction in times the catheter is accessed, reducing the potential for contamination and therefore infection. Fill volumes are usually calculated based on surface area (1.2–1.4 litres/m^2) (British Association Paediatric Nephrology 2008), or weight 30–50 ml/kg.

Ambulatory peritoneal dialysis is less frequently used for younger patients. Young adults may choose this method, as it gives them more freedom during the evenings and it is estimated that less than 30% of paediatric patients use this mode of PD.

It is proposed that peritoneal membrane permeability changes with age, and mode of delivery should be modified accordingly (Mendley and Majkowski 1995). However it is suggested that, as in adults, the best way to identify the optimum treatment is to perform peritoneal equilibrium tests (PET) (Warady *et al.* 1996). There are two main problems experienced with peritoneal dialysis:

- Parental/carer burnout is always an issue. Whenever possible young adults are taught to undertake their own dialysis, with the support of another family member. However, with young patients there is a reliance on their relatives to provide this treatment. Where possible, respite care provision should be made available.
- Infection is a major concern in the paediatric population. Peritonitis can quickly lead to systemic illness in very young children. There is also the long-term treatment of the child/young person to consider and they may sometimes face a return to dialysis at a later date. Therefore it is very important to prevent sclerosis of the peritoneum due to either repeated or single severe peritonitis episodes, increasing the longevity

of this type of dialysis. Changes in treatment modality may be required if a child has repeated peritonitis episodes (Warady *et al.* 2012). Research into prevention and treatment is ongoing as a result.

Periodic updating of families on technique is recommended as this may reduce the risk of infections from practices at home (Warady *et al.* 2012). Young people and their families are trained to recognise early symptoms of infection to enable prompt treatment (Royal College of Nursing 2000).

A great difficulty can be in maintaining hygiene in infants wearing nappies and who do not understand that their catheter/line should be kept clean. Therefore fasten-through vests and tubigrip can be useful tools in preventing them from tampering with any type of access.

Haemodialysis

Haemodialysis is often the second choice of dialysis in children, because of the disruption it causes. Nine per cent of children in the United Kingdom with ERD were treated with haemodialysis in 2010 (UK Renal Registry 2012). Children should be cared for in a specialist paediatric renal unit. However, because of the very small numbers of children requiring this treatment there are only 13 paediatric renal units in the United Kingdom. This inevitably leads to children travelling to receive this treatment. As a result the psychosocial impact of haemodialysis can be considerable for children and their families.

Older children and young adults who dialyse three to four times a week are unable to attend school with their peers on dialysis days. Therefore, schooling should be provided for them whilst on dialysis. Preschool children need distraction as well as play programmes to promote their global development.

Families need support, particularly those with children under 16, who must be transported with an escort each time they attend the hospital.

There can also be technical difficulties when children require haemodialysis.

Venous access

Central lines are frequently used as a form of chronic access, particularly in children awaiting transplantation, for which dialysis will hopefully be a relatively short-term treatment. A range of sizes is required for the patient group cared for in paediatric renal units. As with PD catheters these lines can become infected (Shroff *et al.* 2003) they can also become thrombosed.

Arteriovenous fistulae are used, more for older patients with a longer term need for dialysis. Play preparation and the use of anaesthetic creams are very important in these patients, as this is a painful procedure (Wright 2004). However, patient choice is important. Grafts are rarely used in paediatric patients in the United Kingdom.

The challenge in children is maintaining access sites for the future, which can become very problematic in children receiving renal replacement therapies from a very early age. Prevention of complications is therefore very important, as indicated in the Renal NSF for children and young people (Department of Health 2006a).

Prescribing dialysis and adequacy

Standardised treatment regimens cannot be used in patients on paediatric programmes. Guidelines on prescribing haemodialysis safely must be adhered to, to ensure adequate dialysis whilst preventing complications of over-efficient dialysis such as disequilibrium. Common guidelines are a pump speed of 6–8 ml/min/kg. It is also important to use a

BOX 12.4

Blood volume calculation

Neonates	90 ml/kg
Infants and children	80 ml/kg
Adults	65 ml/kg

Source: from Willock and Jewkes (2000).

circuit less than a maximum of 10% (ideally 8%) of the child's total circulating volume (see Box 12.4). Therefore a variety of line volumes and dialysers need to be available to meet these requirements.

Guidelines recommend initial treatment should use a dialyser with a surface area no more than 75% of the child's own surface area (Wright 2004). This is usually increased in size to achieve a urea reduction rate (URR) of at least 65%.

An equilibrated Kt/V of >1.2 can be used, but is generally a less popular measure of dialysis efficiency.

Careful consideration is also needed in guiding fluid removal on dialysis. 0.2 ml/min/kg of fluid is the upper limit commonly used for guiding fluid removal whilst dialysing (Royal College of Nursing 2000). Additional fluid removal is undertaken via isolated ultrafiltration, sequentially followed by the prescribed dialysis. However, greater than a 5% reduction in fluid in one session is not advised. Blood volume monitoring can be used to guide fluid removal and can be a useful tool in assessing dry weight (Michael *et al.* 2004). Due to the continual growth of children, it can be difficult to establish dry weight. Regular reviews are required to prevent frequent hypotensive episodes during dialysis.

Haemodiafiltration is increasingly being used in paediatric units, following reports of benefits from adult literature. Although benefits have been seen in young adults in paediatric units, it continues to be technically challenging in younger children. High flux dialysis remains the more common treatment in many units for these patients, and is recommended for any child on dialysis for extended periods due to the risk of amyloidosis (Fischbach *et al.* 2012).

Acute Kidney Injury

Acute kidney injury (AKI) is characterised by a reversible increase in plasma creatinine and urea and by the inability of the kidney to regulate fluid and electrolyte balance.

The management of AKI in children has improved with advances in treatment for infants and children (Goldstein 2011). Critically ill neonates and children with congenital cardiac disease and those receiving solid organ transplants are susceptible to AKI. There is also evidence of increased incidence of AKI in children with malignancy, sepsis and those receiving nephrotoxic medications (Goldstein 2011). There is increasing emphasis on calculating the risk of AKI and early treatment (KDIGO 2011, Akcan-Arikan *et al.* 2007). The paediatric RIFLE criteria stratify AKI in children into five groups (R = risk, I = injury, F = failure, L = loss of kidney function, E = end stage renal disease) enabling earlier recognition and intervention (Hayes and Christian 2012). It is suggested that up to 10% of all children treated in intensive care units suffer a

degree of kidney injury with sepsis and fluid overload now frequently treated with renal replacement therapy (Basu *et al.* 2011).

Cause

The causes of acute kidney injury in childhood are commonly divided into three groups: prerenal, intrinsic and postrenal. Prerenal injury occurs when blood flow to the kidney is reduced as in cardiac insufficiency, renal vein or renal artery thrombosis and hypovolaemia. In infants and small children hypovolaemia is commonly due to dehydration following gastro-intestinal losses. Studies have shown that AKI in childhood due to dehydration is largely preventable with early management (Andreoli 2009),

Intrinsic renal disorders are those that occur following damage to renal parenchymal cells. These include malignancy, congenital malformation, glomerulonephritis and haemolytic uraemic syndrome. There is evidence that these disorders can lead to chronic kidney disease in later life (Andreoli 2009). Long-term follow up is recommended.

Post-renal disorders include urethral obstruction (valves, phimosis), ureteral obstruction and neurogenic bladder. These conditions require intervention by a paediatric urologist with nephrology liaison.

Treatment

There is no evidence for the optimum level of renal function for starting dialysis in children with acute kidney injury, or for the optimum dialysis modality. The choice of renal replacement therapy depends on the circumstances, the skill of the nursing staff and the therapies available. Not all children with acute kidney injury are referred to a paediatric renal centre, but discussion with a paediatric nephrologist is recommended (Department of Health 2006a). Indications for referral include oliguria, anuria, hyperkalaemia, hyponatraemia, acidosis or the need for blood transfusion (Strazdins *et al.* 2004). Children with multiorgan failure should be transferred to a paediatric intensive care facility with nephrology support at the earliest opportunity.

Traditionally, peritoneal dialysis (PD) has been the treatment of choice for children with acute kidney injury in renal centres. The advantage of PD is that it can be provided as a continuous therapy, which does not require vascular access. In addition, PD does not rely on specialist nursing expertise although prior experience with this therapy is advisable if using an automated machine. For units without this expertise, manual peritoneal dialysis sets for infants and children are available. Bicarbonate dialysis solutions should be considered for use in infants or children who have lactate intolerance.

Peritoneal dialysis in acute kidney injury must be commenced as soon as possible and there is therefore a risk of leakage. Small volumes of 10–20 ml per kg (300–600 ml/m^2) of continuous cycling therapy are recommended to prevent complications.

Haemodialysis is commonly used to treat children with acute kidney injury cared for within paediatric renal centres, when peritoneal dialysis has failed or is contraindicated. Haemodialysis is suitable for rapid fluid and toxin removal. The disadvantages of this therapy are the need for vascular access, a water supply that is often only available within paediatric nephrology units, and the need for specialist nurses.

Continuous renal replacement therapy (CRRT) in the form of continuous haemofiltration or continuous haemodiafiltration is increasingly seen as the preferred modality for the treatment of AKI in paediatric intensive care units (Goldstein 2011). CRRT is often used in critically ill patients on PICU as it minimises haemodynamic perturbations

associated with intermittent haemodialyis (Hayes and Christian 2012). Children require vascular access of a sufficient size to deliver appropriate blood flow through the filter. A dual lumen central venous line of a minimum 6.5 fg is recommended. Equipment must be calibrated to deliver blood pump speeds as low as 20 ml/minute. Recommended fluid removal should not exceed 0.02 ml/kg/min. As in haemodialysis the extra-corporeal circuit size should not exceed 10% of the child's circulating blood volume. In infants, regular blood priming is necessary if the line volume exceeds the child's extra-corporeal volume.

Haemolytic Uraemic Syndrome (HUS)

This is a common cause of acute kidney injury in childhood. Haemolytic uraemic syndrome (HUS) is characterised by haemolytic anaemia, thrombocytopenia and acute kidney injury in the absence of disseminated intravascular coagulation (Inward 2008). The *E. coli* 0157 bacteria cause approximately 90% of HUS cases. Children usually present with bloody diarrhoea, nausea and vomiting. Consequently, children with HUS are often misdiagnosed with surgical problems. Early investigation of renal function and blood film is essential, and transfer to a tertiary referral centre is recommended (Inward 2008).

Approximately 60% of children with HUS require dialysis during the acute stage of the illness (Sheiring *et al.* 2010). Supportive treatment such as blood transfusion and treatment of hypertension is also required. 70% of children with HUS recover renal function. However, approximately 25% need treatment for high blood pressure and chronic kidney disease management.

Atypical HUS may occur during childhood. This is associated with factor H deficiency (Fremeaux-Bacchi *et al.* 2005). Children may present with the symptoms of renal failure but there is often no preceding diarrhoeal illness. Treatment is usually with regular plasma exchange or plasma infusion to prevent established kidney disease. Liver and kidney transplant is considered an option. Drug trials are currently being undertaken, and this may change the future management of these children (Sheiring *et al.* 2010).

Transition to Adult Services

Adolescence is recognised as a time of physiological, emotional and psychological change. Transfer from paediatric to adult renal services during this critical time can be stressful for young people, their carers, and health professionals. Poorly planned transition has been associated with an increased risk of nonadherence to treatment and serious consequences in terms of morbidity, mortality and social and educational outcomes (Department of Health 2006b). A reported 35% of young people lose their transplant within 36 months of transfer to adult services (Harden *et al.* 2012).

A seamless transition plan is essential. This should consider clinical, educational and social outcomes for young people. The transition process should start as early as 11 years of age with involvement from the young person, his or her carers, and health professionals from paediatric and adult teams. Flexibility of the time of transfer is important, and should depend on the individual young person's needs rather than a fixed age. An age range of 14–24 years should be considered (Webb *et al.* 2010).

A UK consensus statement (Webb *et al.* 2010) recommends that young people should be able to achieve specific competencies prior to transfer to an adult unit. Examples of such competencies are the ability to understand and organise medications, and to manage hospital appointments.

It is acknowledged that paediatric services differ in terms of staffing resources and patient numbers. The key to successful transition is to manage the expectations of young people and their carers. Preparation for change is essential and joint clinics with multi-professional adult and paediatric teams are recommended. Young people should be given choice as to whether parents and carers are present at clinic appointments. Specific young adult clinics where young people can receive support from peers are valuable. The participation of youth workers, trained to provide social and informal educational support is recommended and where possible the appointment of a hospital youth worker should be considered (Hilton and Jepson 2012).

Conclusion

As this chapter has highlighted, providing treatment for children with renal disorders has different challenges from the adult population. In addition to treating the renal-associated complications, there are the additional issues around growth, development and the psychosocial impact on the whole family (Marciano *et al*. 2011).

The British Association of Paediatric Nephrology (www.bapn.org/, accessed 20 May 2013) identifies standards for care, and markers for good practice in the service provision for children and young people. The challenge for all paediatric nephrology services is to ensure that these standards are achieved, and the highest quality care is provided for these children and young people.

References

Albaramki, J., Hodson, E.M., Craig, J.C. and Webster, A.C. (2012) Parenteral versus oral iron therapy for adults and children with chronic kidney disease. *Cochrane Database of Systematic Reviews* **1**.

Andreoli, S.P (2009) Acute kidney injury in children. *Pediatric Nephrology* **24** (2), 253–263.

Akcan-Arikan, A., Zappitelli, M., Loftis, L.L. *et al.* (2007) Modified RIFLE criteria in critically ill children with acute kidney injury. *Kidney International* **71,** 1028–1035.

Bacchetta, J., Harambat, J., Cochat, P. *et al.* (2012) The consequences of chronic kidney disease on bone metabolism and growth in children. *Nephrology Dialysis and Transplantation* **27,** 3063–3071.

Basu, R.K., Wheeler, D.S., Goldstein, S. and Doughty, L. (2011) Acute renal replacement therapy in paediatrics. *International Journal of Nephrology* DOI: 10.4061/2011/785392.

Batte, S., Watson, A.R. and Amess, K. (2006) The effects of chronic renal failure on siblings. *Paediatric Nephrology* **21,** 246–250.

Department of Health (2004) *Department for Education and Skills National Service Framework for Children, Young People and Maternity Services,* Core Standards, Stationery Office, London.

Department of Health (2006a) *The National Service Framework for Renal Services. Working for Children and Young People,* Department of Health, London.

Department of Health (2006b) *Transition: Getting it Right for Young People. Improving the Transition of Young People with Long-Term Conditions from Children's to Adult Health Services,* Department of Health. London

Dobbels, F., Ruppar, T., De Geest, S. *et al.* (2010) Adherence to the immunosuppressive regimen in pediatric kidney transplant recipients: a systematic review. *Pediatric Transplantation* **14** (5), 603–613.

ESCAPE trial group, Wuhl, E., Trivelli, A. *et al.* (2009) Strict blood-pressure control and progression of renal failure in children. *The New England Journal of Medicine* **361** (17), 1639–1650.

Fischbach, M. Fothergill, H., Zaloszyc, A. and Seuge, L. (2012) Hemodiafiltration: the addition of convective flow to hemodialysis. *Pediatric Nephrology* **27** (3), 351–356.

Flynn, J.T. (2011) Ambulatory blood pressure monitoring in children: imperfect yet essential. *Pediatric Nephrology* **26** (12), 2089–2094.

Fremeaux-Bacchi, V., Kemp, E., Goodship, J. *et al.* (2005) The development of atypical HUS is influenced by susceptibility factors in factor H and membrane cofactor protein- evidence from two independent cohorts. *JMG Online,* http://jmg.bmjjournals.com/cgi/content/abstract/jmg.2005.030783v1 (accessed 20 May 2013).

Gerson, A.C., Wentz, A., Abraham, A.G. *et al.* (2010) Health-related quality of life of children with mild to moderate chronic kidney disease. *Pediatrics,* **125** (2), e349–e357.
Goldstein, S. (2011) Advances in paediatric renal replacement therapy for acute kidney injury. *Seminars in Dialysis* **24,** 187–191.
Harden, P.N., Walsh, G., Bandler, N. *et al.* (2012) Bridging the gap: an integrated paediatric to adult clinical service for young adults with kidney failure. *British Medical Journal* **344,** e3718.
Hayes, W. and Christian, M. (2012) Acute kidney injury. *Paediatrics and Child Health* **22** (8), 341–345
Hodson, E.M., Knight, J.F., Willis, N.F. and Craig, J.C. (2002) Corticosteroid therapy for nephrotic syndrome in children. *Cochrane Database of Systematic Reviews* **3**. The Oxford Update.
Hockenberry, M.J. and Wilson, D. (2011) *Wong's Nursing Care of Infants and Children*, 9th edn, Elsevier Mosby, St Louis MO.
Hodson, E.M., Willis, N.S. and Craig, J.C. (2012) Growth hormone for children with kidney disease. *Cochrane Database of Systematic Reviews* **3**.
Hilton, D. and Jepson, S. (2012) Evolution of a youth work service in hospital. *Nursing Children and Young People* **24** (6), 14–28.
Inward, C. (2008) Haemolytic uraemic syndrome. *Paediatrics and Child Health* **18** (8), 364–368.
Jalanko, H. (2009) Congenital nephrotic syndrome. *Pediatric Nephrology* **24,** 2121–2128.
Koshy, S.M. and Geary, D.F. (2008) Anemia in children with chronic kidney disease. *Pediatric Nephrology,* **23**(2), 209–219.
KDIGO (2011) KDIGO clinical practice guideline for acute kidney injury. *Kidney International* **2** (suppl. 1), 124–138.
Krishnan, R. (2012) Nephrotic syndrome. *Paediatrics and Child Health* **22** (8), 337–340.
Lennon, R., Watson, L. and Webb, N. (2009) Nephrotic syndrome in children. *Paediatrics and Child Health* **20** (1), 36–42
MacGregor, J. (2008) *Introduction to the Anatomy and Physiology of Children,* 2nd edn, Routledge, London.
Marciano, R.C., Bouissou Soares, C.M., Diniz, J.S.S. *et al.* (2011) Behavioral disorders and low quality of life in children and adolescents with chronic kidney disease. *Pediatric Nephrology* **26** (2), 281–290.
Mendley, S.R. and Majkowski, N.L. (1995) Peritoneal Equilibrium Test results are different in infants, children, and adults. *Journal of the American Society of Nephrology* **6,** 1309–1312.
Michael, M. Brewer, E.D. and Goldstein, S.L. (2004) Blood volume monitoring to achieve target weight in pediatric hemodialysis patients. *Pediatric Nephrology* **19,** 432–437.
Mitsnefes, M.M. (2012) Cardiovascular disease in children with chronic kidney disease. *Journal of the American Society of Nephrology* **23** (4), 578–585.
National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents (2004) The fourth report on the diagnosis, evaluation and treatment of high blood pressure in children and adolescents. *Pediatrics* **114,** 555–576.
National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents (2005) The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents. National Heart, Lung, and Blood Institute, National Institute of Health, Bethesda MD. http://www.nhlbi.nih.gov/health/prof/heart/hbp/hbp_ped.pdf (accessed 13 June 2013).
National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents (2007) *A Pocket Guide to Blood Pressure Measurement in Children,* National Institutes of Health, Bethesda MD.
National Institute for Health and Clinical Excellence (NICE) (2006) *Final Appraisal Determination: Immunosuppressive Therapy for Renal Transplantation in Children and Adolescents*, NICE, London.
National Institute for Clinical Excellence (NICE) (2011) *Clinical Guideline 125 Peritoneal Dialysis: Peritoneal Dialysis in the Treatment of Stage 5 Chronic Kidney Disease*, NICE, London.
Neu, A. (2012) Immunizations in children with chronic kidney disease. *Pediatric Nephrology* **27,** 1257–1263.
Rees, L., Azocar, M., Borzych, D. *et al.* (2011) Growth in very young children undergoing chronic peritoneal dialysis. *Journal of the American Society of Nephrology* **22** (12), 2303–2312.
Rees, L. and Shaw, V. (2007) Nutrition in children with CRF and on dialysis. *Paediatric Nephrology* **22** (10), 1689–1702.
Royal College of Nursing (2000) *Paediatric Nephrology Nursing. Guidance for Nurses,* RCN, London.
Royle, J. (2007) The kidney. In *Clinical Paediatric Dietetics,* 3rd edn (eds Shaw, V. and Lawson, M.), Blackwell Science, Oxford, Ch. 12.
Sedman, A. Friedman, A., Boineau, F. *et al.* (1996) Nutritional management of the child with mild to moderate chronic renal failure. *Journal of Pediatrics* **129** (2), 14s–18s.
Seeman, T. (2007) Hypertension after renal transplantation. *Paediatric Nephrology* **24,** 959–972.
Shaw, V. and Lawson, M. (2007) Principles of paediatric dietetic. In Clinical Paediatric Dietetics, 3rd edn (eds Shaw, V. and Lawson, M.), Blackwell Science, Oxford, Ch. 1.
Sheiring, J., Rosales, A. and Zimmerhackl, L.B. (2010) Clinical practice. Today's understanding of the haemolytic uraemic syndrome. *European Journal of Pediatrics* **169** (1), 7–13.
Shroff, R., Wright, E., Ledermann, S. *et al.* (2003) Chronic hemodialysis in infants and children under two years of age. *Pediatric Nephrology* **18** (4), 378–383.

Strazdins, V., Watson, A.R. and Harvey, B. (2004) Replacement therapy for acute renal failure in children: European guidelines. *Pediatric Nephrology* **19** (2), 199–207.
UK Renal Registry (2012) *The Fifteenth Annual Report of the UK Renal Registry,* http://www.renalreg.com/Reports/2012.html (accessed 10 June 2012).
Waby, K., Helm, K. and Watson, A.R. (2005) Preparing children for kidney transplantation through play. *British Journal of Renal Medicine* **10** (4), 9–11.
Warady, B.A., Alexander, S.R., Hossli, S. *et al.* (1996) Peritoneal membrane transport function in children receiving long-term dialysis. *Journal of the American Society of Nephrology* **7** (11), 2385–2391.
Warady, B.A. Bakkalogu, S. Newland, J. *et al.* (2012) Consensus guidelines for the prevention of catheter related infections and peritonitis in pediatric patients receiving peritoneal dialysis: 2012 update. *Peritoneal Dialysis International* **32,** s29–s86
Webb, N., Harden, P., Lewis, C. *et al.* (2010) Building consensus on transition of transplant patients from paediatric to adult healthcare. *Archives of Disease in Childhood* **95,** 606–611.
Webb, N., Johnson, R. and Postlethwaite, R. (2003) Renal transplantation. *Archives of Disease in Childhood* **88,** 844–847.
Wesseling, K., Bakkaloglu, S. and Salusky, I. (2008) Chronic kidney disease mineral and bone disorder in children. *Pediatric Nephrology* **23** (2), 195–207.
Williams, A. (2012) Paediatric renal transplantation. *Paediatrics and Child Health* **22** (8), 346–350.
Willock J, Jewkes F (2000) Making sense of fluid balance in children. Paediatric Nursing, **12** (7), 37–42.
Wright, E. (2004) Assessment and management of the child requiring chronic haemodialysis. *Paediatric Nursing* **16** (7), 37–41.

CHAPTER 13

Renal Nutrition

Barbara Engel
Surrey University, UK

Learning Outcomes

- To describe the historical background to renal nutrition and dietetics.
- To evaluate nutritional management in the predialysis phase.
- To identify the dietary principles of haemodialysis (HD) peritoneal dialysis (PD) and transplantation.
- To discuss the role of the nurse in giving dietary advice.

Introduction

Dietary treatment has always been regarded as an important part of managing patients with established renal failure (ERF), before and during renal replacement therapy (RRT). During the 1960s many patients were treated with diet alone. The renal diet was adapted to dialysis and transplantation once these modes of RRT became available during the 1970s and early 1980s. Nowadays, chronic fluid overload, hyperphosphataemia and protein energy malnutrition are amongst the most common problems. These can lead to long term complications if not resolved and adversely affect outcome of treatment and the quality of life of patients with renal disease, who may require treatment for many decades. This chapter will address the important issues of dietary management and the role it plays in the overall treatment of ERF.

Historical Review of Dietary Management

Predialysis treatment (1960–2000)

Haemodialysis (HD) was only accepted as a regular form of RRT for selected patients at the end of the 1960s. Prior to this period, patients approaching ERF with gastrointestinal symptoms were advised to follow a very low protein diet (VLPD). The best known diet was the Giovanetti diet, containing 20 g protein of high biological value to cover essential amino acid requirements. An intake of 50 kcal/kg body weight (BW)

Renal Nursing, Fourth Edition. Edited by Nicola Thomas. Published 2014 by John Wiley & Sons, Ltd.

was recommended to prevent loss of muscle and maintain nitrogen balance. This diet was prescribed to selected patients with a creatinine clearance of 3 ml/min or a plasma urea level of 33 mmol/l (200 mg/d/l) and was the only treatment available to improve the well-being of patients, until regular HD treatment became available.

It became apparent in later years that a badly managed protein reduced diet contributed to malnutrition before patients started HD. This prolonged the rehabilitation period and also contributed to the outcome of treatment, with an increased morbidity and mortality (Ikizler and Hakim 1996).

During the 1980s there was a renewed interest in protein allowance as protein restriction in partially nephrectomised rats delayed the progression of renal disease. This was the hyperfiltration/hyperperfusion hypothesis (Brenner 1983). It was more difficult to prove the same effect in humans. High energy diets containing no more than 0.6 g protein/kg BW were prescribed during the early stages of chronic renal disease to asymptomatic patients, who not surprisingly found this difficult to follow for extended periods of time.

In the United States, the National Institutes of Health (NIH) stated in 1993 that the nutritional health of a patient prior to dialysis was an important indicator of outcome and that all patients were entitled to receive a nutritional assessment by a trained renal dietitian. In the absence of obvious malnutrition, a moderate low protein diet of up to 0.7–0.8 g protein/kg/BWday should be prescribed. When malnutrition was present, the amount of energy was increased and the amount of protein raised to 1.0 – 1.2g/kg to allow for nutritional repletion or to counter the catabolic effects of stress. Dietary prescriptions should also include guidelines for energy, fat and carbohydrate, fluid, sodium, phosphate and potassium as well as other nutrients and micronutrients (NIH 1993). The NIH had also commissioned a large multicentre study to ascertain once and for all the efficacy of low protein diets. The Modification of Diet in Renal Disease (MDRD) study compared diets with different levels of protein reduction at different levels of renal impairment. The diets ranged from usual intake to VLPD supplemented with ketoacids and combined with phosphorus restriction. The results of this 2-year study, which had been launched in 1985, were finally published in 1994 (Klahr *et al*. 1994).

The MDRD study showed that, in the absence of severe proteinuria and hypertension, a reduction of protein intake by 0.2 g/kg BW resulted in a modest reduction in the rate of progression. There appeared to be no further advantage in using a VLPD supplemented with essential amino acids. However, it did reveal that subjects accustomed to a 'Western' diet containing typically > 1.2 g protein/kg found it very difficult to achieve the designated protein restrictions of < 0.6 g protein/kg/day. The report cautioned that, while lowering blood pressure and protein intake appeared to be safe, both must be carefully monitored.

Several meta-analyses were subsequently conducted, which included studies such as the MDRD study. Fouque *et al*. (2000), Pedrini *et al*. (1996) and Ginn *et al*. (1999) concluded that dietary protein restriction effectively slows the progression of diabetic (DM) and nondiabetic renal disease (see also ongoing Cochrane Reviews: www.cochrane-renal.org, accessed 20 May 2013).

On the basis of these analyses as well as expert opinion, NKF/DOQI published the 'Clinical practice guidelines for nutrition in chronic renal failure' (Kopple *et al*. 2000) and the European Dialysis and Transplant Nurses Association/European Renal Care Association also published guidelines shortly afterwards. The suggested protein and energy requirements for patients with advanced CKD, not on dialysis, are summarised in Table 13.1. and take the patient's ideal body weight (IBW)[1] as well as the residual renal function into consideration.

[1]See Appendix 13.1 for calculation of IBW.

Table 13.1 Suggested protein and energy requirements versus degree of renal function.

GFR[a] (ml/min)	Protein (g/kg IBW)	Energy (kcal/kg IBW)
> 50	normalise	30–35
25–50	0.6–1.0[b]	30–35
< 25	0.6–0.75[b]	30–35
< 10 start dialysis		

Notes: [a]GFR – glomerular filtration rate; [b]Protein should contain at least 50% sources of high biological value. 35 kcal/kg IBW for active patients and 30 kcal/kg IBW for sedentary or older patients i.e. > 65 years of age.

The debate about whether to reduce protein (and how low to go) continues to this day. In support of protein reduction, a low-protein diet will reduce the burden of waste products that have to be removed: nitrogen compounds, acids, phosphate and also potassium. This potentially has beneficial effects on reducing symptoms of uraemia and controlling the development of problems such as acidosis and renal bone disease (Mandayam and Mitch 2006).

The main deleterious effect of the low protein diet is the risk of malnutrition; energy requirements are difficult to meet (although not impossible) without resorting to sources of carbohydrate and fat, which may have an impact on cardiovascular disease (CVD). Vitamin and mineral intakes also have to be monitored closely. Those clinicians not in favour of low-protein diets argue that the risk of malnutrition outweighs any benefits that may be gained from the (very moderate) reduction in the rate of decline in kidney function (Johnson 2006). Even the most recent Cochrane review concluded that the optimal level of protein prescription could still not be confirmed (Fouque *et al*. 2006).

As there are many different elements to patient care prior to starting dialysis, a more realistic approach to protein recommendations is usually taken which is described below.

Current Concepts of Predialysis Dietary Intervention

The nutritional content of the diet should be specifically adapted to each patient's individual needs and personal circumstances. This should result in the reduction of metabolic waste products, which can otherwise accumulate as chronic disease progresses. Most patients will receive some nutrition information in the predialysis phase, although it is very variable and dependent on dietetic staffing levels. The Renal Nutrition Group of the BDA has designed a flow diagram which outlines the nutritional care of a person with chronic kidney disease (Figure 13.1). In CKD stages 1–3 the focus is on weight management, diabetes control, hypertension and lipid management as described in the National Institute for Health and Clinical Excellence (2008) clinical guideline. This guideline also describes four points regarding lifestyle advice relevant to the management of chronic kidney disease:

- encourage exercise, achieve healthy weight and stop smoking;
- if appropriate, discuss the risks and benefits of protein reduction;
- ensure malnutrition is prevented;
- offer dietary advice to people with progressive CKD regarding potassium, phosphate, protein, calories and salt when indicated.

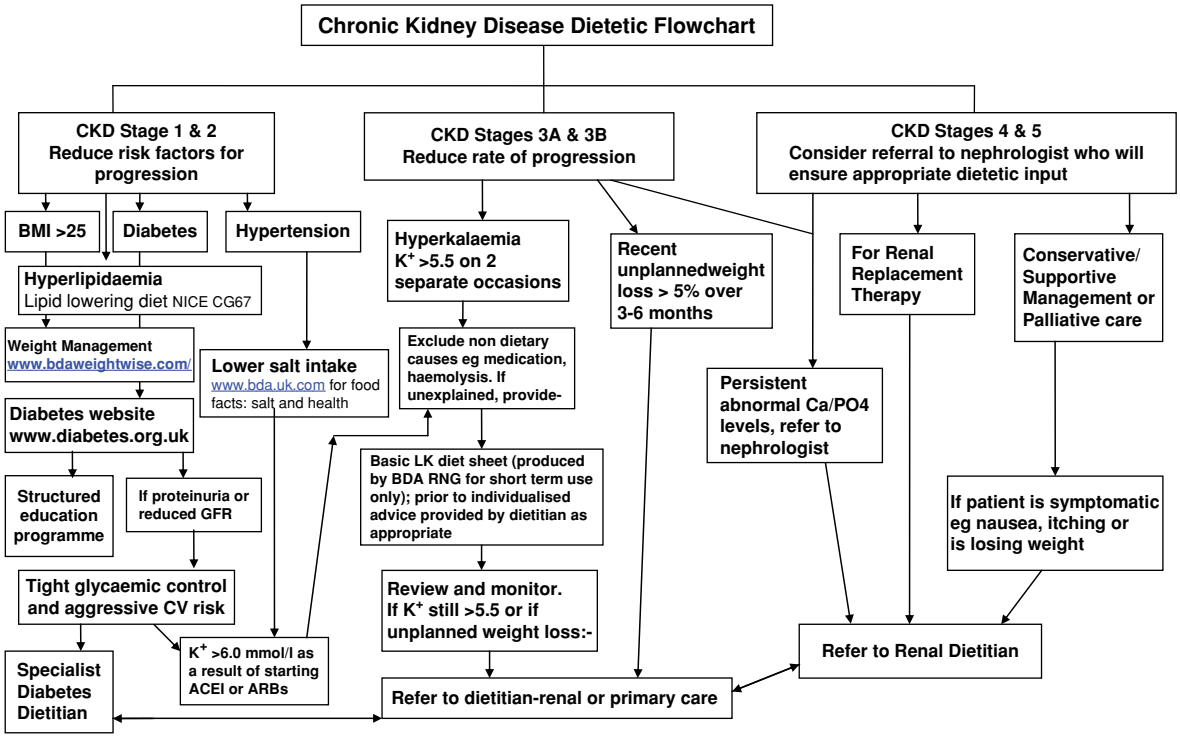


Figure 13.1 Flow chart for dietary treatment of Chronic Kidney Disease; stages 1–5.

The Renal Association concur with all of these points and they have produced specific clinical guidelines (5th edition, 2009–2012), which cover the key elements of care, many of which also have nutritional implications. A more detailed discussion of the nutritional implications follows and includes:

- Detection, monitoring and care of patients with CKD includes management of hypertension, diabetes and cardiovascular risk factors. It also discusses management of hyperphosphataemia and hyperkalaemia (MacGregor and Taal 2011).
- Cardiovascular disease in CKD (Holt and Goldsmith 2010).
- CKD mineral and Bone Disorders (Steddon and Sharples 2010).
- Anaemia in CKD (Mikhail, Shrivastava and Richardson 2010).
- Nutrition in CKD; focus is on malnutrition (Wright and Jones 2010).

In Stages 1–3 CKD, the dietetic treatment of hypertension, cardiovascular risk (obesity, hyperlipidaemia) and diabetes control takes precedence. From stage 3 (usually 3b) to stage 5, the problems of preventing and controlling renal bone disease, hyperkalaemia, anaemia and malnutrition come to the fore.

Hypertension

Sodium (Na) and fluid retention occur in most types of renal disease and contribute to high blood pressure. The National Institute for Health and Clinical Excellence (2008) guideline and the 'Kidney Disease Improving Global Outcomes' (KDIGO) guidelines recommend that, to improve blood pressure control, patients should be advised to reduce dietary salt and alcohol intake, stop smoking and take regular exercise.

A moderate salt-reduced diet (about 80–120 mmol Na) will facilitate the action of antihypertensive medication such as diuretics and the commonly used angiotensin converting enzyme (ACE) inhibitors. The Renal Association guidelines and also the current government Food Standards Agency (FSA) guidelines for the general population recommend a maximum salt intake of 6 g/day or 100 mmol sodium. However KDIGO recommend a sodium intake of 90 mmol, which is equivalent to a salt intake of 5 g/day. In practice this is not simple as many people rely on the purchase of processed foods (see Appendix 13.2). About 80% of our salt intake is hidden in processed foods, including staple food items such as bread and breakfast cereals. Patients should be advised as follows:

- Prepare meals using fresh ingredients.
- Use spices and herbs to add flavour to food.
- Only use a little salt in meal preparation.
- Avoid adding salt to food after preparation.
- Avoid excessive amounts of salty foods such as cured and processed foods: this includes takeaway meals.
- Avoid using salt substitutes containing potassium salts such as potassium chloride (KCl): see 'Hyperkalaemia' section.
- Avoid meals prepared with monosodium glutamate. This is added to enhance the taste of food in restaurants, take-away outlets and ready-to-eat meals sold in supermarkets.
- Read food labels and check for additives like monosodium glutamate and salt substitutes. Note that 1 mmol Na = 23 mg Na; 2 g (2000 mg) Na = 5 g NaCl = 90 mmol Na

A small proportion of patients are 'salt losers' (due to a specific renal pathology) and need to add salt to their meals and/or use salt supplements such as slow sodium.

The KDIGO guidelines for the management of blood pressure in renal disease also recommend the following:

- Maintaining a healthy body weight (BMI 20 – 25 kg m^{-2}).
- Undertaking exercise; compatible with cardiovascular health and tolerance. Aiming for 30 minutes, 5 times a week.
- Alcohol intake should be no more than 2 units per day for men and 1 unit per day for women.

Cardiovascular Risk and Hyperlipidaemia

The National Institute for Health and Clinical Excellence (2008) guidelines and the Renal Association guidelines recommend using the Joint British Societies (2005) guidelines to define cardiovascular risk; this risk assessor includes the traditional risk factors of age, gender, lipid levels and blood pressure. In patients with renal disease, other risk factors include calcium and phosphorus imbalance, hyperhomocysteinaemia, inflammation and possibly anaemia.

Recommendations from the K/DOQI (2003) guidelines were that CKD was a high risk factor for CVD and that 'major findings from randomised trials in the general population are applicable to patients with CKD, until proven otherwise'. More recent intervention trials in the renal population have now supported this statement and blood pressure and lipid levels should be well controlled using a combination of lifestyle changes and medication; including ACE inhibitors for blood pressure and statins for cholesterol. Lifestyle changes include; weight loss where necessary to achieve a healthier BMI, lower salt intake, stopping smoking, avoiding excess alcohol and taking regular exercise.

Recommended lipid and HbA1c levels are; LDL < 2 mmol/l or a 30% reduction from baseline, total cholesterol < 4 mmol/l or a 25% reduction from baseline, triglycerides < 1.7 mmol/l, HbA1c between 6.5% and 7.5% (48-58 mmol/cmol). Due to the association with hyperhomocysteinaemia, folate and B_{12} levels should be monitored every six months in CKD stages 4/5 and 'nutritionally at risk' patients should be recommended to take nutritional supplements. As well as BMI, the National Renal Data Set requires that waist and hip circumference should be measured. An excess of body fat, particularly round the waist, is linked with metabolic disturbances including raised inflammatory cytokines and insulin resistance. In patients with CKD a raised waist: hip ratio has been associated with increased myocardial infarction and fatal coronary artery disease (Elsayed *et al.* 2008). Significant correlations have been shown between the presence of inflammation (measured by CRP, TNFa and fibrinogen) and carotid plaques in patients preparing for dialysis, who have simultaneously demonstrated signs of muscle/protein wasting (low serum creatinine, LBM and urea nitrogen appearance); the so-called malnutrition-inflammation-atherosclerosis (MIA) syndrome. It is unclear whether CRP is raised in response to endothelial cell damage or whether CRP and other acute phase reactants such as IL-6 are actually involved in the initiation and progression of atherosclerosis (Stenvinkel *et al.* 1999, Stenvinkel 2003).

More studies are still needed to elucidate the role of diet, exercise, and weight reduction in reducing the risk of CVD and MIA in patients with CKD.

Interventions in Patients with Diabetes

The results of the Diabetes Control and Complications Trial (DCCT) (type 1 diabetes) and the UK Prospective Diabetes Study (UKPDS) (1998) (type 2 diabetes) showed that the careful control of blood glucose and hypertension significantly decreases the renal complications of diabetes which often begin with the appearance of microalbuminuria (UK Prospective Diabetes Study 1998; Yale 2005). Observational studies indicate improved cardiovascular risk with good glycaemic control. The Renal Association guidelines recommend a target HbA1c of 6.5% to 7.5% (48–58 mmol/mol) stating the benefits mentioned above. Medication to control hyperglycaemia will need to be adjusted regularly as requirements diminish and renal function declines.

A Cochrane systematic review by Robertson, Waugh and Robertson (2007) concluded that reducing protein intake does seem to slow progression of diabetic nephropathy although in a nonsignificant way; that is, increasing time to dialysis by only two months. They noted that compliance with such a protein reduced diet was difficult to achieve and also added that factors worth considering included changing the type of protein: vegetable versus animal, fish/white meat versus red meat. This may be a more practical and achievable approach than restricting the amount of protein, however the trials evaluating the effectiveness only involved small numbers of patients. There was insufficient evidence to support the use of lower protein intakes to slow down progression of nephropathy in type 2 diabetes (CARI guidelines 2006). The Diabetes UK guidelines base their recommendations regarding protein reduction on the systematic review by Robertson *et al.* (2007) and suggest that a 6- month trial of reduced protein may be initiated and continued if there is a response.

With the rising levels of diabetes in the population there needs to be a concerted effort in primary care to maximise blood glucose and blood pressure control, in order to prevent nephrology services from being overwhelmed with patients who have diabetes.

Calcium, Phosphate and Vitamin D Metabolism

The first signs of impaired calcium (Ca) and phosphate (P) homeostasis arise early in renal impairment (CKD 2) as parathyroid hormone (PTH) levels start to rise. This is due to phosphate retention and impaired hydroxylation (activation) of vitamin D, which results in reduced absorption of Ca from food in the small intestine. The ensuing hypocalcaemia stimulates an increased release of parathyroid hormone, which, in an attempt to normalise plasma calcium levels, releases calcium and phosphate from the bone (eventually causing weakened bones). As renal disease progresses the release of calcium and phosphate from the bone and reduced excretion of phosphate in the urine leads to hyperphosphataemia.

Monitoring of calcium, phosphorus, PTH, calcidiol (25OH vitamin D) and alkaline phosphatase (ALP) is recommended from CKD stage 3b (progressive). Treatment can include the use of: calcium supplements, vitamin D (including activated forms, alfacalcidol and calcitriol), calcimimetics, dietary phosphate restriction and phosphate binders or transport blockers (Sexton and Vincent 2004).

Calcium supplements

The recommended daily Ca intake for predialysis patients is 1000 – 1500 mg. If this is not being reached (particularly if protein intake is low), calcium supplements may be needed but should be taken in between meals, preferably at bedtime to maximise Ca absorption.

'Active' vitamin D

Vitamin D is a fat-soluble vitamin and is obtained from a small number of foods but mostly from exposure to sunlight (this may be reduced in the elderly and certain ethnic groups). It needs to be converted to an active form by hydroxylation in the liver and kidney. The use of active forms of vitamin D, alfacalcidol and calcitriol, can be troublesome. On the one hand, they reduce PTH levels (which will reduce the negative effects on bone) but, simultaneously, calcium and phosphate absorption from the gut increases, which can lead to hypercalcaemia and hyperphosphataemia if not monitored closely. The precipitation of this excess calcium and phosphate in the soft tissues (blood vessels, coronary arteries and aortic valves), is considered to be one of the major causes of morbidity and mortality in adults, particularly young adults, with renal failure (Block *et al*. 1998; Goodman *et al*. 2000).

Steddon and Sharples (2010) recommend measuring calcidiol levels from stage 3b and supplementing if levels show insufficiency (< 75 mmol/l). As vitamin D has many metabolic roles, there is a strong rationale for ensuring adequate levels of this hormone, not simply to normalise bone metabolism (Cherniack *et al.* 2008; Armas and Heaney 2011).

Dietary phosphate reduction

The Renal Association has advised that 'patients need dietary advice to reduce dietary phosphate.' Although the optimal time to start a reduction in phosphate intake/commence phosphate binders has not been established, the K/DOQI guidelines recommend that:

> Dietary phosphorus should be restricted to 800 to 1,000 mg/day (adjusted for dietary protein needs) when the serum phosphorus levels are elevated (1.49 mmol/l (>4.6 mg/dL)) at Stages 3 and 4 of CKD, and >1.78 mmol/l (5.5 mg/dL) in those with kidney failure (Stage 5).

UK guidelines suggest maintaining serum phosphate between 0.9 to 1.5 mmol/l and calcium should be within the normal reference range in Stages 3b to 5 CKD.

Calcium and phosphate are obtained from most foods with high protein content. Examples are milk and its products: cheese and yogurt. Phosphorus also appears in high-fibre cereal products and fish with edible bones, offal, pulses and nuts. Absorption from the gastrointestinal tract varies between 30–80%, and phosphorus from vegetable sources is less bioavailable.

Appendix 13.4 shows high-phosphorus foods, not all of which have alternatives with comparable nutrient content and therefore total elimination from the diet is not feasible. Hyperphosphataemia is difficult to control by dietary manipulation alone and needs to be combined with phosphate binders. A moderate protein reduction will also tend to reduce phosphate intake which is one of the arguments in favour of a protein reduction in the predialysis population. However, the impact on other nutrients must always be considered. For example wholemeal products contain more phosphorus as well as more fibre, yet fibre also improves bowel habits and the general well-being of patients. Serum phosphate levels may rise (by 0.25 mmol/l) with a high-fibre diet (Pender 1989); however, the benefits of a high fibre intake outweigh the risk of hyperphosphataemia and if necessary, phosphate binding agents can be increased.

Phosphate binders

Phosphate binding occurs in the stomach and small intestine and reduces the absorption of phosphate into the body. If calcium and aluminium salts are used as oral binders, these initially dissolve in the acid environment of the stomach and then form an insoluble precipitate with phosphate. This product is eliminated via the gastrointestinal route (not the kidneys). However a high gastric pH (i.e. less acidic), found generally in the elderly and particularly in people taking H_2-receptor antagonists such as ranitidine, can reduce the effectiveness of the binders and hyperphosphataemia can result (Tan *et al.* 1996).

Phosphate binders should be taken with food, particularly main meals and snacks containing phosphate, and with milk-based nutritional supplements. Ideally, the dose of the binder should be altered to reflect the phosphate content in a particular meal.

Both the calcium and aluminium in the binder are absorbed to some extent and this has given rise to worries about aluminium toxicity and calcium overload. More recently developed phosphate binders such as sevelamer hydrochloride (Renagel) and lanthanum carbonate do not contain calcium or aluminium and sevelamer has an added benefit in that it also binds cholesterol. The vitamin niacin is also being used to block phosphate absorption as well as increase HDL cholesterol. Calcimimetic agents are recommended for use in patients with hyperparathyroidism and control of calcium and phosphate in Stage 5 CKD (Steddon and Sharples 2010).

The timing and dose of the binders is crucial for good phosphate control and support from the MDT can help improve compliance and biochemistry results (Evans and Gardiner 2008).

Hyperkalaemia

Plasma potassium levels are tightly controlled in the body and, in order to maintain normal levels, 90% of potassium is usually excreted by the kidney with the remainder excreted via the gastrointestinal route. Progressive renal failure is often complicated by hyperkalaemia, (plasma potassium > 5.5 mmol/l) and may occur when renal function has declined to a GFR of 5 ml/min despite normal urine output. Hyperkalaemia can also

occur at an earlier stage when patients receive ACE inhibitors or angiotensin II receptor binders (ARBs) for blood pressure control. This can be exacerbated if combined with a high intake of potassium rich foods and is potentially life threatening, particularly as it is not associated with physical warning signs and requires immediate treatment. Dietary and nondietary causes of hyperkalaemia should be investigated at the same time.

Examples of nondietary causes are:

- metabolic acidosis;
- increased catabolism (and conditions which cause cell destruction: rhabdomyolysis, gastrointestinal bleed);
- endocrine abnormalities;
- drugs such as potassium supplements (i.e. slow K), some laxatives, potassium sparing diuretics, ACE inhibitors, ARBs and nonsteroidal anti-inflammatory drugs;
- constipation (and drugs that exacerbate constipation, for example iron tablets).

Dietary management

Dietary sources of potassium are listed in Appendix 13.5. A dietary intake of no more than 60–70 mmol/d (1 mmol/kg IBW) is sufficient to prevent or treat hyperkalaemia in the presence of an adequate urine output or dialysis treatment. However, serum K levels, in patients who are not on dialysis and not passing much urine, taking a 50 mmol potassium diet, can rise by 1 mmol/d despite gastrointestinal adaptation to increase potassium excretion.

Most foods contain potassium, but vegetables and fruits are major sources: some varieties contain more than others. Staple foods such as potatoes, yam, sweet potatoes, green bananas and plantain are high in potassium, but should be included in a potassium-reduced diet. Potassium-containing salts such as dipotassium phosphate, are used as food additives but in small quantities. Of greater concern is the use of potassium chloride as a substitute for sodium chloride as part of the food manufacturers' attempt to reduce the sodium content of food.

Patients should receive dietary advice regarding the potassium content of specific foods, avoiding or at least limiting the quantities eaten of those that are high. Cooking techniques such as boiling (and throwing away the water) will remove some of the potassium in vegetables. On the other hand cooking methods which *retain* potassium include cooking in a pressure cooker or microwave, stir-frying, roasting and casseroling vegetables.

Potassium and high-fibre foods

Constipation is a common problem for patients on peritoneal dialysis (PD), older and sedentary patients. High-fibre cereal products are recommended to prevent constipation and can have a beneficial effect on hyperlipidaemia. Some high-fibre foods are high in potassium (Pagenkemper *et al*. 1994), although earlier studies have showed that the overall effect of a high fibre diet on serum potassium was not significant – increasing serum potassium levels by about 0.3 mmol/l (McKenzie and Henderson 1986).

Potassium exchange resins

Potassium binders such as calcium or sodium ion-exchange resin (i.e. calcium or sodium resonium) may be used to control hyperkalaemia. Calcium resonium is a gritty textured powder and is best taken with a sweet drink to mask its taste. Calcium ions (or sodium) are exchanged for potassium ions in the gut and the potassium is then eliminated. The long-term use of calcium resonium can lead to severe constipation (unless appropriate laxatives are prescribed) and is therefore not used for routine control of plasma potassium levels.

Anaemia

Anaemia due to renal impairment can be diagnosed when GFR < 60 ml/min i.e. CKD stage 3a, although it is more prevalent in stage 4 CKD (Mikhail *et al.* 2010). It can impact on general nutritional status by causing general lethargy, taste changes and a poor appetite, hence it is always worth checking the patient's haemoglobin and ferritin levels if they present with these symptoms. Anaemia is also involved in the pathogenesis of left ventricular hypertrophy (LVH) and therefore increases the risk of CVD. A serum ferritin of < 100 ng/ml or a transferrin saturation of < 20% indicates relative iron deficiency. It is important to ensure an adequate intake of iron, B_{12} and folate. Vitamins B_6 and C also have important roles in erythropoiesis. The consumption of foods which are high in iron, such as red meat, offal and pulses may be reduced in a renal diet, particularly if protein- or phosphate-restricted diets have been prescribed. A potassium lowering diet may result in decreased iron, folate and vitamin C intakes.

If oral iron (Fe) supplements are used, 200–300 mg Fe/day is required to restore iron status. These can cause side effects such as constipation and black stools. They can also interact with other medication such as the calcium-containing phosphate binders. In order to obtain a rapid improvement in iron status, intravenous preparations are more often used.

Malnutrition

Irrespective of whether a therapeutic diet is recommended to treat any of the other problems listed above, all patients at CKD stage 4–5 should receive a dietary assessment and be screened for malnutrition. This is because a spontaneous decrease in protein intake has been measured in patients with renal diseases as the disease progresses (Ikizler *et al.* 1995). A patient with poor nutritional status at the start of dialysis will have a poor outcome in terms of survival and therefore it is important to prevent malnutrition from occurring at the outset (Walters *et al.* 2002). Some expert nephrologists have recommended that if the patient's protein intake has fallen below 0.8 g/kg/day, dialysis should be initiated (Hakim and Lazarus 1995).

Regular dietary follow-up in clinic or by telephone should help to maintain optimal nutritional status by ensuring that a balanced diet is being achieved – i.e. one that contains adequate macronutrients (protein, fat, carbohydrate) and micronutrients (vitamins and minerals). If specific dietary reductions are advocated, it is important that the impact of these reductions on the intake of other nutrients, as well as the social effects, are fully evaluated. The diet should provide sufficient dietary freedom and enable the patient to lead a near-normal life. This means that dietary flexibility must be incorporated and appropriate carers, relatives or friends should be involved while educating the patient to promote maximum dietary adherence.

Nutritional assessment

A full nutritional assessment includes collection of information from these five main categories:

- anthropometry: *circumferences; MAC, MAMC, waist and hip. BIA, DEXA*;
- biochemistry: *Urea, creatinine, electrolytes, haemoglobin (Hb) and micronutrient screen*;
- clinical;
- dietary intake;
- exercise : *physical function: sit to stand, grip strength*.

Renal Association (RA) guidelines recommend that patient with a GFR <20 ml/min who are not on dialysis, should have a nutritional assessment every 2–3 months.

Body composition changes

The Dialysis Outcome Quality Initiative (K/DOQI) (2003) guidelines have indicated the need for more information regarding '*the appropriate parameters to be used for assessment of body composition*'. Nonetheless, simple 'bedside' measurements can indicate a decline in nutritional status as long as oedema and signs of fluid overload are identified. These include actual body weight (in comparison with ideal body weight), weight loss of 5% in 3 months, BMI < 20 kg m^{-2} (Wright and Jones 2010). These authors of the RA guideline 'Nutrition in CKD' also recommend use of the Subjective Global Assessment (SGA), where a grading of B/C on a three-point scale or a score of 1–5 on the 7-point scale indicate declining status.

Insufficient energy intake will lead to protein catabolism, which may present as muscle wasting. This can be detected using hand grip strength and other measures of physical function (sit to stand, shuttle test). Mid-arm muscle circumference (MAMC) can be estimated from measurements of mid-arm circumference (MAC) and triceps skinfold. Conditions that exacerbate protein/muscle loss include sarcopenia (muscle loss due to ageing), inflammation, acidosis and lack of activity/exercise. Blood biochemistry may indicate whether there is inflammation (raised CRP, low albumin, raised white cell count) or acidosis (low bicarbonate levels) and if present, appropriate treatment should commence. There is growing evidence that low vitamin D levels and raised PTH are determinants of sarcopenia (Visser *et al.* 2003) and Wright and Jones (2010) suggested that supplementation of ergocalciferol or cholecalciferol may be beneficial in undernourished CKD patients.

Where there is an energy deficit, fat stores will also be used to provide energy. This initially may not be a problem, particularly if the patient is obese and can therefore mobilise these excess stores. The advantages of not having excess body fat include a decreased risk of CVD, hypertension and diabetes. Formation of a fistula or insertion of a Tenckhoff catheter is also more difficult in patients who are overweight or obese. However, fat is used to insulate the body, to provide cushioning for bones, and to provide an energy source when food intake is poor. Recent evidence has shown that whereas being underweight increases mortality in patients on dialysis, being overweight may actually confer some advantage, at least in the first few years of dialysis (Friedman 2006). This is reflected in the K/DOQI guidelines (2003) that have stated that a BMI of up to 28 kg m^{-2} is acceptable. The UK Renal Association guidelines recommend that patients with a BMI >30 kg m^{-2} should receive advice to assist weight loss (MacGregor and Taal 2011).

Nutritional requirements

Protein

Protein is an important nutrient for the repair and maintenance of tissue and for growth.

Quantity The level of dietary protein intake should maintain nitrogen balance (in a well nourished adult) or be sufficient for growth (in children) and repair (in patients recovering from malnutrition or illness). For instance, if a patient consumes a high protein diet (> 1.2 g/kg IBW), a reduction to 1.0 g/kg IBW may initially be sufficient which can be reduced to 0.8 g/kg IBW if renal function deteriorates at a later stage. This is an acceptable protein allowance for long-term use and it meets the maintenance require-

ment of 0.66 g/kg advised by WHO/FAO (Millward and Jackson 2003). The Renal Association guideline Nutrition in CKD (Wright and Jones 2010) recommended that a protein intake of no less than 0.75 g/kg is realistic and required an energy intake of 35 kcal/kg/day to prevent malnutrition.

Quality The quality of protein is affected by its digestibility and amino-acid content. Meat, fish, eggs, milk and soy protein are usually referred to as containing high biological value (HBV) protein because of the levels of essential amino acids when compared with a reference protein. Proteins from plant sources (cereals, vegetables, pulses and nuts) may be limited in lysine, threonine, methionine and cysteine and have poorer digestibility. Despite this, the amino acid content of a UK vegetarian diet is comparable with UK omnivores. Rice-based vegetarian diets have poorer amino acid content (compared with wheat-based diets) as well as lower digestibility. In order to ensure that a reduced-protein diet contains adequate levels of all the amino acids, it is particularly important for vegetarians to have proteins from a variety of sources including cereals, pulses and legumes (Millward and Jackson 2003).

Energy

Protein, fat, carbohydrate and alcohol all contribute to a person's energy intake.

Quantity Example: to calculate energy requirements for a 70 kg person (IBW):

$$70 \times 30\text{–}35 \text{ kcal } (126\text{–}150 \text{ kJ}) = 2100\text{–}2450 \text{ kcal } (8.8\text{–}10.3 \text{ MJ})$$

The range of energy requirements, 30–35 kcal/kg, is similar to the result obtained using the Schofield equations for basal metabolic rate and assumes a physical activity level of 1.3–1.4, which is low (Todorovic and Micklewright 2007). Patients with increased metabolism due to infection, injury or increased activity levels should have their requirements calculated using equations such as Schofield or Oxford with appropriate factors added for metabolic stress and activity levels.

Quality The quality of foods providing energy is as important as the quantity. Cardiovascular disease and some cancers are associated with a high proportion of saturated fat in the diet. Hypertriglyceridaemia (common in patients with renal disease) is associated with high intakes of rapidly absorbable carbohydrates and alcohol. If a protein reduction has been advised, there has to be an increase in calories to make up the deficit. This could take the form of mono-unsaturated fat (olive oil) and carbohydrates with a medium to low glycaemic index (pasta, basmati rice, new boiled potatoes, some fruits).

Micronutrients: vitamins and minerals

Vitamins and minerals regulate metabolic pathways and some of the most observable clinical features of uraemia (anaemia and renal bone disease) are caused, or at least exacerbated, by vitamin and mineral deficiencies. Metabolism of protein, carbohydrate and fat will be affected by deficiencies of vitamins and minerals. These can arise because uraemia alters their serum levels and body stores and also interferes with their function. Drug interactions can affect the absorption and utilisation of minerals (such as calcium, iron, zinc and magnesium) and vitamins (such as B_6, folate and B_{12}). Requirements for these three vitamins may be higher in renal disease in order to treat hyperhomocysteinaemia, which is a risk factor for CVD (Hong *et al.* 1998). Dietary reductions that limit protein, phosphate and potassium intake will inevitably limit the intake of various micronutrients. A low-protein diet can contain low levels of B vitamins (B_1, B_2, B_6, B_{12}), iron, calcium and zinc (Hadfield 1992). A low-potassium diet will limit intake of folic

acid, vitamins C and E, as well as phytochemicals such as fructo-oligosaccharides, phytosterols and polyphenols. A review by Steiber and Kopple (2011) found that vitamin deficiencies (particularly B_1 and B_6) in CKD stages 3–5 were common, with intake of other B vitamins decreasing with lower protein intake as described above.

However, there may be reduced renal losses of some nutrients. Vitamin supplements containing the fat-soluble vitamins A, D, and E are contraindicated in patients with renal disease. Vitamin A metabolites are less well excreted and accumulate over time; toxicity has been reported in patients receiving total parenteral nutrition containing a high dose of vitamin A (Muth 1991). High-dose vitamin E supplementation may potentially disrupt the clotting mechanisms. Rocco and Makoff (1997) stated that vitamin K supplementation is also contraindicated unless a patient is on chronic antibiotic treatment. However a more recent literature review cited articles that found evidence of deficiency in 60–97% of patients with CKD 3–5 and recommended ensuring that people at least meet the recommended nutrient intake which, in the United Kingdom, is 1μg/kg/day (Steiber and Kopple 2011). It is recommended that vitamin and mineral status should be included in the nutritional assessment.

Prevention and treatment of malnutrition should be started during the predialysis phase. Many renal departments hold multidisciplinary education sessions for patients to provide information on treatment options, diet and support from social services. Ideally a specialist renal nurse, dietitian, social worker and consultant should be involved in the sessions, with access to a counsellor if available. All patients should also receive individual dietary advice, and frequent monitoring is essential to accommodate any changes in renal function.

Nephrotic Syndrome

Nephrotic syndrome (NS) is characterised by proteinuria $>$ 3 g/day, which results in hypoalbuminaemia and generalised oedema. Hyperlipidaemia, clotting problems and hypertension are also present. Loss of immunoglobulins and proteins that bind iron, copper, zinc and vitamins A and D can result in an increased risk of infections and general malnutrition. The syndrome can arise in diseases that primarily cause glomerular damage such as focal segmental glomerulosclerosis (FSGS), membranous nephropathy (MN), minimal change nephropathy (MCN) or secondary to other diseases including diabetic nephropathy and auto-immune disease such as systemic lupus erythematosus (SLE). Treatment aims to control oedema, reduce proteinuria, and treat complications which arise including infections, hyperlipidaemia and clotting problems (Hull and Goldsmith 2008, de Seigneux and Martin 2009). Diet therapy has a role to play in several of these areas (Table 13.2).

Protein reduction

Historically, in nephrotic syndrome, a high-protein diet was advised with the aim of replacing protein losses. This is now thought to cause further damage to the glomerular basement membrane and exacerbate the proteinuria. An intake of 0.8–1 g protein/kg IBW/day is now recommended. This can result in reduced proteinuria, and improvements in other biochemical parameters such as, phosphate, lipid, renin and fibrinogen levels (thrombo-embolism is increased in NS: 10–30% of adult patients with NS may develop clotting problems). Not all studies have showed a corresponding increase in plasma albumin levels.

Table 13.2 Management of nephrotic syndrome.

Symptom	Dietary management
Hypertension and oedema	Dietary sodium reduction: 80–100 mmol/day. Fluid reductions may also be necessary, depending on the response to medication. Target weight loss 0.5–1 kg/day ACE inhibitors commonly used (monitor potassium levels)
Proteinuria/ hypoalbuminaemia	Moderate protein reduction: 0.8–1 g/kg IBW/day Good control of blood glucose in diabetes Medication can include steroids to treat the primary disease. ACE inhibitors also help to reduce proteinuria (monitor potassium levels)
Hyperlipidaemia	Standard lipid lowering advice; 30% calories from fat. Statins and bile acid sequestrants
Lower immunity	A balanced, nutritious diet will help prevent protein-energy malnutrition (PEM) and maintain micronutrient levels: monitor for signs of vitamin D deficiency and anaemia

Hyperlipidaemia

The incidence of myocardial infarction has been reported as 5–6 times greater in NS compared with normal. Increased liver synthesis of lipoproteins and impaired metabolism of triglycerides results in raised triglycerides and cholesterol. Standard lipid lowering advice can be given as well as the use of lipid lowering agents such as 5-hydroxy-methyl-glutaryl-coenzme A (HMG-CoA) reductase inhibitors (statins) and bile acid sequesters.

Dietary Management: Dialysis Treatments

Historical review

Since the early 1990s, considerable progress has been made regarding modes and quality of treatment. Regular haemodialysis (HD) became available from the mid-1960s onwards when patients were initially selected for treatment, so were usually young and free from concomitant disease. Dietary management was aimed at controlling the patient's fluid balance and biochemistry. During these early days of dialysis a strict diet (by present standards) was followed by many patients, which consisted of a daily intake of: 50 g protein, 50 mmol sodium, 50 mmol potassium, 3500 kcal and 300 ml fluid.

As the quality of dialysis treatment improved during the 1970s and 1980s, dietary reductions were relaxed to a daily intake of 60 g protein, 60 mmol sodium, 60 mmol potassium, 2500–3000 kcal and 300–500 ml fluid. Even this slightly more generous HD diet was nutritionally incomplete without the use of high-energy, low-electrolyte supplements and several books were published during the following years to promote dietary education (Vennegoor 1992).

During the early 1980s CAPD became established as a new chronic dialysis technique, although it had been used since the 1960s for patients who were haemodynamically too unstable for HD. By the mid-1980s, the diet for both HD and PD was similar to that prescribed today: 1–1.2 g protein/kg IBW/day for HD and 1.2–1.5 g protein/kg IBW/day for PD (Vennegoor 1992).

Current concepts of dialysis dietary management

Specific dietary requirements will need adjusting when the mode of therapy (HD, PD or transplantation) commences or changes. Current recommendations for dietary requirements are shown in Table 13.3.

Protein

During haemodialysis approximately 6–12 g of amino acids are lost per session. For peritoneal dialysis, 8–12 g protein, in addition to 3 g amino acids, are lost per day. On the basis of these figures alone the additional dietary protein required to replace these losses can be calculated as 0.1g/kg/day for patients on haemodialysis and 0.2g/kg/day for patients on PD. Some authors have argued that, as the minimum safe protein intake for healthy individuals (and in the predialysis phase) is approximately 0.75 g/kg/day as discussed above, the recommended minimum intake on dialysis should be as follows: 0.9 g/kg/day for HD and 1 g/kg/day for PD (Lim and Flanigan 2001). These are slightly lower levels than that recorded in Table 13.2 and, for *some* patients who are metabolically stable (i.e. not catabolic) nitrogen balance studies have shown that intakes at this level can be sufficient. As with any patient, in order to ensure that they are not becoming malnourished, it is important to measure nutritional status using a number of different methods such as those used in subjective global assessment (SGA) (McCann 1996). See Appendix 13.2.

Energy requirements

An intake of 35 kcal/kg IBW is recommended to maintain nitrogen (protein) balance in patients on HD and PD. For sedentary and older patients, 30–35 kcal/kg IBW is sufficient. Underweight patients may need additional calories (and supporting micronutrients) to encourage weight gain, while overweight patients may need a calorie adjustment to encourage weight loss if appropriate (Todorovic and Micklewright 2007; Wright and Jones 2010).

Table 13.3 Dietary recommendations for patients on renal replacement therapy.

	HD	PD	TXP
Protein (g/kg IBW)	1.0–1.2(1.1-1.4)[a]	1.0-1.2	EAR
Energy (kcal/kg IBW	30–35	30–35	EAR
Na (mmol/day)[b]	80–100	80–100	80–110
K (mmol/kg IBW)	1.0	1.0-1.3	Free
P (mmol/day)[c]	31–45(26–32)	31–45 (26–32)	Free
Vitamins	Yes	Yes	Not required
Phosphate binders	Yes	Yes	Not required

Notes: HD, haemodialysis; PD, peritoneal dialysis; TXP, transplantation; IBW, ideal body weight; EAR, estimated average recommendations (national agreement). [a]Protein and *energy* intake for HD and PD based on *Renal Association guidelines* (Wright and Jones 2010) *and* BDA-RNG *(2011)* guidelines. [b]80–110 mmol equals 1800–2500 mg sodium; [c] adjusting for protein requirement ie 0.32–0.6 mmol phosphate/g protein.

Source: Sodium, potassium and phosphorus intake for HD and PD based on EDTNA/ERCA and EBPG nutritional guidelines.

Dextrose (glucose) is used as an osmotic agent in peritoneal dialysis for the removal of fluid. Up to 70% of this glucose is absorbed through the peritoneum and this can exacerbate hyperglycaemia, hyperlipidaemia and obesity. The amount of glucose absorbed increases as the osmotic strength of the dialysate increases. When calculating energy requirements for patients on PD, the glucose (and hence calories) absorbed from the dialysate needs to be included in the calculation. Glucose absorption may provide approximately 70 kcal for a 2 L 1.36% exchange, 130 kcal for a 2 L 2.5% exchange and 200 kcal for a 2 L 3.86% exchange. Daily intake from this source could be between 100–300 g glucose (400–1200 kcal), depending on the strength and size of the exchanges used. Recent PD guidelines discourage the use of the higher glucose solutions and suggest the use of glucose polymers or amino acid containing solutions (Woodrow and Davies 2010). Icodextrin is a PD solution which contains glucose polymers with a larger molecular weight than glucose and is an effective osmotic agent. The calorie uptake is only half that of a comparable 3.86% exchange while achieving the same level of ultrafiltration. Some improvements in glycaemic control have been measured in patients who have diabetes, using one icodextrin exchange per day. See Chapter 9.

Sodium and fluid

Once a patient becomes oliguric and eventually anuric, the intake of salt and fluid will need to be reduced to control interdialytic weight gain (IDWG) with HD and fluid balance with PD. Excessive IDWG in patients on HD contributes to hypertension prior to HD treatments, necessitating antihypertensive medication (Ifudu *et al*. 1997). Long-standing fluid overload also results in left-ventricular cardiac hypertrophy (Konings *et al*. 2002).

A reduced fluid allowance is probably the most difficult part of the dialysis diet to cope with. Up to 86% of patients may exceed an IDWG guideline of 1.5 kg per day and there appears to be no difference between those who have diabetes and those who do not (Halverson *et al*. 1993). Some groups of patients with different ethnic backgrounds appear to have additional problems with IDWG. Indo–Asian patients in particular may often be unable to adhere to their fluid allowances and this is attributed to a higher fluid and salt content of traditional foods and meals (de Brito Ashurst *et al*. 2011).

Most renal centres in the United Kingdom regard an IDWG ranging from 1.5 to 2.0 kg as acceptable. Considering the differences in size of patients, it may be more appropriate to base IDWG on dry weight using 4–4.5% as an acceptable IDWG (EBPG 2007). However, an upper limit is recommended for patients with BMI $> 25\,\text{kg m}^{-2}$.

Sodium intake: the mechanism of thirst

It is important to remember what causes thirst. The sodium level in the body is finely tuned in healthy individuals as well as those with kidney disease. Too much dietary salt will cause the plasma sodium level to rise (transiently) and the thirst mechanism in the brain to act. It is then necessary to drink sufficient fluid to normalise the sodium level.

A sodium intake of 80–110 mmol/day can help control thirst. This can be achieved by following the advice listed in the earlier section on hypertension.

Excessive IDWG may not always be due to poor understanding of dietary advice. Even 'solid' food contains some fluid and patients with a good appetite will have higher IDWG; this can be established with a detailed dietary assessment, indicating a high protein and energy intake (Sherman *et al*. 1995).

Fluid includes anything liquid at room temperature (apart from vegetable oils) and includes jelly, ice-cream, ice cubes, gravy, soups, sauces and custard. A daily fluid allowance of 500–750 ml in addition to the average daily urine output is usually sufficient to prevent excess IDWG in patients on HD. Patients on PD can usually increase their intake to at least 750 ml plus average daily urine output. This amount may be modified depending on the level of ultrafiltration which is achieved with the lower strength exchanges of PD fluid. The following additional tips can help the patient keep to their fluid allowance:

- Measure the daily fluid allowance in a water jug: take out the equivalent amount after having a drink or if food with a significant amount of fluid is eaten.
- Divide the fluid allowance throughout the day.
- Use a small cup or glass instead of a mug or large glass.
- Drink only half a cup each time if possible.
- Ice cubes may be more thirst quenching, but each cube contains 30 ml fluid (2 tablespoons): lemon juice or other flavourings can be added.
- Rinse the mouth with water; gargle but do not swallow.
- Stimulate saliva production by sucking a piece of lemon or grapefruit, sherbets or chewing gum.
- Try artificial saliva sprays.
- Take medicines with meals unless contraindicated.
- When going out, save the allowance of fluid to allow for an extra drink when socialising.
- A daily weight check in the morning before breakfast will reveal the rate of fluid accumulation in between HD treatments and the fluid status on PD.

Potassium

Some patients starting dialysis continue to produce fairly good quantities of urine. This helps to some extent with the excretion of sodium, potassium and, of course, fluid. However the urine is often described as 'poor quality' in that the level of these solutes are lower than usual and plasma potassium levels should be monitored closely. The risk of hyperkalaemia is greater in patients who do not pass urine. The dietary intake of potassium should be reduced to 1 mmol/kg/IBW/day for patients on HD. Hyperkalaemia can be a frequent problem, especially on HD, and dietary indiscretion is sometimes partly to blame, although the amount of potassium removed during dialysis can vary by as much as 70%. Patients on PD, may have a more relaxed dietary potassium reduction, as potassium is constantly removed with PD and hypokalaemia has even been observed.

A detailed diet history should be taken for all patients so that the main sources of potassium in the patient's diet are known and the level of reduction and dietary advice given is based on a risk assessment of their usual dietary intake, urine output and plasma potassium levels. Other reasons for hyperkalaemia should be investigated simultaneously as previously described. Some patients on haemodialysis consume foods with high potassium content during the first couple of hours on dialysis. However the transit of food and fluid through the gastrointestinal tract may be slower while the patient is dialysing and so it is advisable to put a limit on this consumption as the potassium may not be completely removed.

Phosphorus

The recommended intake varies from 1000 to 1400 mg (31–45 mmol/day), or approximately 0.5 to 0.6 mmol phosphorus per gram of protein up to 45 mmol/day. However,

the more recent guidelines (EBPG 2007) are stricter than the previous nutritional guidelines as they suggest a maximum of 0.4 mmol phosphorus per gram of protein/day. It is recognised that with higher protein recommendations the phosphorus intake also increases and there has to be a balance between reductions which prevent hyperphosphataemia and preserving an adequate and acceptable diet for the patient to follow. Close collaboration of the multidisciplinary team is required to prevent hyperphosphataemia. A combination of adequate dialysis prescription and attainment, binders which are acceptable to the patient and taken at the right dose at the right time and clear dietary messages have been shown to improve phosphate biochemistry (Yokum *et al*. 2008, Gonzalez-Parra *et al*. 2012).

Vitamins and minerals

During dialysis the small molecules, such as water-soluble vitamins are removed; losses are even higher with high flux HD. The fat-soluble vitamin A is a larger molecule and vitamin A metabolites are therefore more difficult to remove and could lead to toxicity. However, with a functioning kidney there are also vitamin losses and so the question is whether dialysis removes greater amounts of vitamins than would normally occur. Evidence of vitamins at risk includes thiamin (B_1) in PD patients, pyridoxine (B_6) and ascorbic acid (vitamin C) in PD and HD, and folate in HD. To reduce cardiovascular risk the Renal Association guidelines recommend monitoring folate and B_{12} every 3 months if patients remain anaemic. Ascorbic acid is easily dialysed in both HD and PD. In an early study some patients, not receiving nutritional supplements, had vitamin levels fall below the normal range (Henderson 1984; Ramirez *et al*. 1986). A high-dose vitamin C supplement should be avoided to prevent hyperoxalosis: 60 mg may be sufficient with a normal dietary vitamin C intake, while a supplement of 500 mg vitamin C may increase serum oxalate levels. Oxalate deposits as crystals in soft tissues such as muscle tissue and vital organs, and may increase the risk of myocardial infarction, muscle weakness and bone disease.

The results of the Dialysis Outcomes and Practice Patterns Study (DOPPS) showed that water-soluble vitamin supplementation is associated with a 15% decrease in mortality (Fissell *et al*. 2004). At the time of the study only 3.4% of patients from the UK renal units were receiving water-soluble vitamins compared with 72% in the US. This has had an impact on the UK guidelines, which now recommend water-soluble vitamins for those undergoing haemodialysis (Wright and Jones 2010) and there seems to be a greater awareness and use of water-soluble vitamins on UK renal units (Hunt 2011). Table 13.4 lists the suggested daily recommendations in the United States (Makoff 1999) and Europe (EBPG 2007). The European guidelines are more conservative apart from the recommendations for vitamin C and vitamin E.

Early reviews identified that deficiencies of iron, zinc, copper, manganese and chromium are most likely to occur as a result of dietary restrictions, drug nutrient interactions and protein losses (Wolk 1993; Rocco and Makoff 1997). Iron may need to be supplemented to maintain ferritin levels above 100ng/ml. The EBPG guidelines (EBPG 2007) do not recommend routine zinc or selenium supplements but note that if symptoms of these deficiencies are detected (including thyroid dysfunction due to low selenium) then a 3-6 month trial is warranted. A more recent review of trace element deficiency in patients on HD identified 128 studies and concluded that levels of zinc, selenium and manganese were lower than control groups. They highlighted an association between zinc deficiency and increased risk of infection which requires further investigation in the renal population (Tonelli *et al*. 2009).

Table 13.4 Suggested daily dosage of vitamins for patients with ERF (EBPG and (US) guidelines).

Vitamins	EBPG	RNI (UK)
Vitamin A	0	600–700 µg
Vitamin E	400–800 (0) iu	no DRV given
Vitamin B_1	1.1–1.2 (1.5) mg	0.8–1 mg
Vitamin B_2	1.1–1.3 (1.7) mg	1.1–1.3 mg
Vitamin B_6	10 (10) mg	1.2–1.4 mg
Vitamin B_{12}	2.4 (6) µg	1.5 µg
Folic acid	1000 (800–1000) µg	200 µg
Pantothenic acid	5 (10) mg	no DRV given
Niacin	14–16 (20) mg	13–17 mg
Biotin	30 (300) µg	> 10 µg
Vitamin C	75–90 (60) mg	40 mg

Notes: RNI, recommended daily intake. Dietary reference values (DRV) for food energy and nutrients for the United Kingdom.

Malnutrition

Malnutrition is a complication of HD and PD and its consequences have been well documented since these techniques became available. Effects of malnutrition are:

- failure to thrive;
- increased morbidity:
  - delayed wound healing;
  - decreased resistance to infection;
  - electrolyte imbalance;
  - prolonged hospitalisation;
  - muscle wasting (skeletal muscle as well as heart/lung etc.);
  - loss of protective subcutaneous fat;
  - lethargy/apathy;
- increased mortality.

Causes of malnutrition

There are several overarching reasons for malnutrition in patients on dialysis and these are multifactorial in origin:

- Reduced dietary intake:
  - reduced appetite (see below);
  - existing malnutrition at the start of dialysis due to uraemia or unsupervised predialysis dietary restriction;
  - conflicting dietary recommendations – e.g. increasing protein whilst decreasing the intake of phosphorus;
  - dietary recommendations which decrease palatability of food: decreased salt intake, decreased fat or sugar intake;
  - co-existing gastro-intestinal disease (i.e. gastroparesis) or other co-morbidities such as cardiac failure, cancer, stroke;

  - multipharmacy prescriptions;
  - inadequate provision of nutrients in food provided by hospitals or nursing homes;
  - financial constraints;
  - decreased physical ability (shopping, cooking);
- reduced appetite;
  - raised cytokines; TNFα;
  - inadequate dialysis leading to uraemia;
  - suppression of appetite due to peritoneal dialysis; this may be due to glucose absorption, abdominal pressure from the dialysate fluid, constipation;
  - anaemia or other micronutrient deficiencies; zinc, B vitamins;
  - old age; taste, sight changes;
  - depression;
- Increased nutritional losses;
  - losses during dialysis: vitamins, minerals, proteins and amino acids;
  - persistent proteinuria;
  - protein loss during peritonitis;
- altered metabolism;
  - inflammatory response as a result of the dialysis process; the presence of inflammatory cytokines results in appetite loss, muscle breakdown and low albumin;
  - untreated acidosis: muscle and bone metabolism is impaired;
  - inadequate dialysis: buildup of waste products and cytokines;
  - low physical activity: low anabolic stimulation of muscle and bone;
  - intercurrent illness/infections: causing raised requirements, increased cytokines;
  - hyperparathyroidism: muscle and bone metabolism is impaired;
  - resistance to insulin, growth hormone and insulin like growth factor;
  - low 'active' vitamin D: muscle and bone metabolism is impaired.

Co-morbidities and drug nutrient interactions also have an impact on all of these four main points.

Detection of malnutrition

As discussed earlier, the detection of malnutrition should involve monitoring a number of components; anthropometry, biochemistry, clinical, diet and exercise/activity. Many screening tools only include two of these components. For example the Malnutrition Universal Screening Tool (MUST) incorporates anthropometry (weight, weight change) and diet. Subjective Global Assessment includes anthropometry, clinical, diet and exercise/activity although adapted versions have also included measurement of biochemistry (Kalantar-Zadeh *et al*. 2001). The Canada-USA (CANUSA) Peritoneal Dialysis Study Group showed the relative risk of death on PD increased with age, insulin independent diabetes mellitus, cardiovascular disease, low serum albumin and worsening nutritional status. Malnutrition (identified by SGA) correlated strongly with an increase in number of days hospitalised (Canada-USA Peritoneal Dialysis Study Group 1996).

Albumin has often been used as a marker for poor nutritional intake, and although it is certainly correlated with poor outcome (increase morbidity and mortality) it is probably the case that the conditions which cause a low albumin have an impact on nutrition as well as albumin – i.e. they co-correlate.

The use of different methods to determine the extent of malnutrition has led to some differences in the stated prevalence. BAPEN (a charitable association that raises awareness of malnutrition and works to advance the nutritional care of patients) has been coordinating the use of MUST in UK hospitals. The annual audit has indicated that the

prevalence of malnutrition in renal in-patients is 30%. However, using other scoring systems the prevalence has been much higher at 64–90%. The issue lies with the sensitivity and specificity of MUST. When MUST was compared with SGA in 64 patients on HD, the sensitivity was 31% and the specificity was 95%; that is, it had poor ability to detect 'true cases' of malnutrition (Fisher *et al*. 2010). In addition, MUST is a poor detector of malnutrition in liver disease which is similar to kidney disease in that it can be a long term condition which features many metabolic changes (Arora *et al*. 2012).

Protein Energy Wasting (PEW)

An expert working party convened by the International Society of Nutrition and Metabolism in Renal Disease (ISNMRD) has attempted to simplify the nomenclature used to describe malnutrition in renal disease (Fouque *et al*. 2008). The term they feel encompasses the changes indicating decreased nutritional status is 'protein energy wasting'. They define this as a 'state of decreased body stores of protein and energy fuels' which is 'often associated with diminished functional capacity'. It includes syndromes such as MIA but they emphasise that PEW, as can be seen from the list above, is not just due to an inflammatory component (although it is estimated that up to 50% of patients with renal disease show evidence of an ongoing inflammatory response).

Management of malnutrition

Assessing nutritional status

Whichever methods of assessment are used to assess nutritional status, they should be done regularly and systematically for all patients as physical deterioration can occur rapidly and is difficult to reverse. It is important to identify malnutrition, so early rehabilitation and improved clinical outcomes are possible. The National Institute for Health and Clinical Excellence (NICE) guidelines (National Institute for Health and Clinical Excellence 2006), recommended that 'All hospital in-patients on admission and out-patients at first appointment should be screened for presence or risk of malnutrition.' Screening should take place weekly for inpatients, and within 1 month of starting dialysis for outpatients (Wright and Jones 2010).

The European Society for Clinical Nutrition and Metabolism (ESPEN) guidelines (ESPEN 2002) have described the prerequisites of a useful assessment tool. This tool should have the following features:

- good predictive validity – the individual identified 'at risk' will benefit from intervention;
- good content validity – includes 'all' relevant components of the problem it is meant to solve;
- high reliability – small inter-observer variation;
- practical;
- linked to 'specific protocols for action';
- rapid and simple, so that it can be performed by admitting staff or community healthcare teams.

The authors of the K/DOQI guidelines recommended that further work needed to be carried in order to '*identify and validate*' the optimal panel of measures for screening and assessment of nutritional status in patients with renal diseases (K/DOQI 2000). In the meantime nutritional assessment should incorporate a number of complimentary measures that at least include dietary assessment and body composition measures

(Engel *et al*. 1995, EBPG 2007). The MUST tool (Stratton *et al*. 2003) and Subjective Global Assessment contain both these elements although the shortcomings with MUST have already been discussed. So far only SGA has been validated for use with patients with renal diseases and is recommended by the Renal Association guidelines (Wright and Jones 2010).

Methods of dietary assessment

Methods of dietary assessment include:

- Twenty-four hour recall: this is quick and assesses recent intake.
- Three-day food diary: can include a weekend day and one HD day and gives a better illustration of the variety of foods eaten. It may also reveal the disruption to meal times caused by a dialysis day – for HD patients significant decreases in all nutrients can occur three days out of seven.
- Urea content of 24-hour urine samples in predialysis patients and urine plus dialysate collection in patients on PD can be used to calculate urea nitrogen appearance. This is equivalent to dietary protein intake in nutritionally stable patients (PD dialysate collection can also be used to estimate protein losses).
- In patients on HD, changes in plasma urea measurements (collected for dialysis adequacy tests) can be used to calculate the protein catabolic rate (PCR). This is only equivalent to protein intake in patients who are nutritionally stable. Urinary urea also needs to be included in the calculation.

Techniques to Assess Body Composition

The best known techniques are:

- Height and weight (BMI), percentage weight loss over time. The minimum data set and diagnostic criteria for malnutrition recommended by the RA include: BMI $<$ 20 kg m^{-2}, actual body weight $<$ 85% ideal weight, unintentional oedema free weight loss of 5% in 3 months or 10% in 6 months.[2]
- Mid-upper arm anthropometry: mid-arm circumference (MAC), tricep skinfold, mid-arm muscle circumference. MAC is easy to perform, noninvasive and training can reduce observer error repeatable to an acceptable degree. Skinfolds are more prone to observer error; a measure of muscle function may be a better way of assessing muscle mass (e.g. grip strength, sit-to-stand test or walking test). MAMC can be calculated from a measurement of MAC and the triceps skinfold.
- Bioelectrical impedance: quick and noninvasive, but it is an indirect measure and it is influenced by hydration and electrode placement (Lindley *et al*. 2005). BIA measurement of phase angle may be helpful in determining hydration state. Renal Association guidelines recommend that BIA and handgrip strength may be useful in those diagnosed at risk of or with malnutrition.
- Dual-energy X-ray absorptiometry (DEXA): measures bone mineral content and density. It relies on assumptions about hydration status which may not be valid in patients with renal diseases, particularly for the measurement of lean body mass. However DEXA is expensive.

[2]SGA is included in the minimum data set for all patients with CKD stage 4–5.

Hypoalbuminaemia

It had always been assumed that serum albumin was a reliable marker of nutritional status, however this relationship has been questioned as other causes of low albumin are also common in renal disease including fluid overload and inflammation (Frieidman and Fadam 2010). As stated above, a low albumin is certainly predictive of a poorer outcome and an important predictor of morbidity and mortality. Lowrie and Lew (1990) showed that the relative risk of death increases as the serum albumin of the HD patient falls. These authors also concluded that longer treatment time and better nutritional status improve the clinical outcome of HD treatment. Later studies revealed that albumin was also a marker for morbidity and mortality in PD. Plasma albumin was lower in nonsurvivors after thirty months on PD (Davies *et al*. 1998) and as albumin decreased by 10 g/l there was an increased risk of morbidity (hospitalisation) which was five times greater in nondiabetic patients on PD and ten times greater in people on PD who had diabetes (Spiegel *et al*. 1993).

The correct diagnosis is crucial for appropriate medical management as there are several potential causes of hypoalbuminaemia:

- Decreased synthesis due to poor nutritional intake – albumin has a half-life of 2–3 weeks, therefore complete starvation can take at least this length of time to make an impact on plasma levels. In 'partial' starvation, where patients are not quite meeting their requirements and are slowly losing weight, albumin levels can be maintained for months even when substantial amounts of weight are lost, due to adaptive mechanisms.
- Decreased synthesis due to the acute phase response – this is part of the body's immune response to cell damage which can arise through trauma, infection or cancer. The cytokine IL6 is thought to be the mediator which instructs the liver to reduce production of certain proteins (albumin, transferrin) and increase production of others (CRP, ferritin). This interrelation between CRP and albumin may explain why a low albumin has been associated in so many studies with increased morbidity and mortality.
- The presence of inflammation can also cause the endothelium to become 'leaky', with the redistribution of albumin pools, for example from vascular spaces to the intervascular space, which may have an impact on the efficacy of dialysis.
- Albumin losses due to proteinuria, dialysis losses or peritonitis.
- Dilution – if the patient is fluid overloaded, for example before a HD session, or if dry weight needs to be adjusted. For example, 3 L overload can dilute plasma albumin from 42 g/l to 37 g/l.
- Albumin assay methods vary – it is important to use the same method of measurement each time or if comparing patients based at different renal units.

Subjective global assessment

Subjective global assessment (SGA) is an assessment of nutritional status and was first performed on surgical patients (Detsky *et al*. 1987). It is based on patient history and physical examination. A simple questionnaire is usually completed by a trained nurse or dietitian.

History

The history includes weight changes, dietary intake, gastrointestinal symptoms and functional status and can include comorbid disease

Physical examination

Physical examination takes into account loss of subcutaneous fat, muscle wasting, oedema, ascites. Each section is rated on a three- or seven-point scale by the interviewer.

An overall score is then assigned depending on the severity of symptoms. For the 3 point scoring system subjects are given a score of A, B, or C: A for well nourished, B for mild- moderate malnutrition and C for severe malnutrition. The seven-point score subdivides these categories into: A, A–, B+, B, B–, C+, C or sometimes a numerical score is used: SGA scores of 6–7 (well nourished), 3–5 (mild-moderate under nutrition) and 1–2 (severe under nutrition) (Appendix 13.2).

The seven-point SGA was developed for the CANUSA study (Churchill *et al*. 1996) and was found to positively correlate with BMI, percentage body fat and MAMC (Visser *et al*. 1999). A 1 unit lower SGA score was associated with a 25% increase in the relative risk of death and a 1 unit increase in score was associated with reduction in days hospitalised. Reproducibility was good: 81–91% when two observers were compared. A prospective longitudinal study of 1600 patients concluded that SGA could distinguish different degrees of PEW and confirmed that a greater degree of PEW was associated with increased mortality (de Mutsert *et al*. 2009).

K/DOQI Guidelines (K/DOQI 2000) stated that 'SGA is a valid and clinically useful measure of protein- energy nutrition status in maintenance dialysis patients'. The UK Renal Association also supports the use of the three- or seven-point SGA.

Protein energy wasting

The panel of measures which the ISNMRD panel recommend to diagnose PEW include:

- Serum chemistry: albumin, prealbumin, cholesterol.
- Body mass: unintentional weight loss, total body fat percentage.
- Muscle mass: muscle wasting, MAMC, creatinine appearance.
- Dietary intake: protein intake, energy intake.

They acknowledged that, whilst nutritional scoring systems such as SGA will to some extent identify PEW, they will not provide a definitive diagnosis (Fouque *et al*. 2008).

Treatment of malnutrition

A thorough assessment should identify the nutritional state of the patient and any modifiable causes of deterioration. This is the diagnosis stage in the Nutrition Care Process outlined by the American Dietetic Association and illustrated with respect to patients with renal disease (Memmer 2013). Although there are usually several possible causes and potential treatments a protocol should be in place so that an initial intervention can be started immediately (a good example of this in patients who do not have renal disease is illustrated by the MUST tool, which describes the actions to be taken for each level of malnutrition). This may require nursing staff to start monitoring the patient using food charts or to start appropriate supplements (suitable for patients with renal disease) in the first instance and alert the renal dietitian. The dietitian will carry out a full nutritional assessment, however, identifying and targeting the multiple barriers to achieving good nutritional status requires a team approach and the correct interventions and care plan can result in improvements in several nutritional parameters (Leon *et al*. 2006).

The primary aim of nutrition support is for patients to meet their nutritional requirements (macro and micronutrients) in the least invasive, most effective way. Protein and energy requirements are calculated using the formula previously shown. The patient's protein and energy intake can be calculated from food intake charts or a 24-hour recall.

requirements – current intake = nutrient deficit

This deficit has to be met using the following methods of nutrition support:

- Oral – for patients who are able to eat and drink normally: fortified foods or foods with a high nutrient content or sip feeds; support and encouragement with eating if necessary.
- Nasogastric or gastrostomy feeding for patients who are unable or unwilling to eat or drink normally. Oral and tube feeding can be combined (for example, tube feeding overnight, while the patient sleeps and encouraging normal eating/drinking during the day).
- Intraperitoneal amino acids (IPAA) with PD.
- Intradialytic parenteral nutrition (IDPN) during HD.
- Total parenteral nutrition (TPN) for patients whose gastrointestinal tract is not functioning sufficiently.

Nutrition support is ineffective without close team work and each member of staff agreeing to carry out specific roles. All healthcare workers directly involved in in-patient care should receive training in the following (National Institute for Health and Clinical Excellence 2006):

- the importance of nutrition;
- indications for nutrition support and delivery;
- when and where to seek advice on nutrition support.

Oral nutritional support (ONS)

The key stages in providing ONS are:

- identifying any barriers preventing the patients from meeting their requirements and referral to other specialists, if necessary;
- involving the patient in deciding which type of supplementation is appropriate.

Barriers to meeting requirements

Gastro-intestinal problems should be identified by a nutrition screening tool. If chewing and/or swallowing are a problem, the consistency of food may need to be modified. The catering department will have to be notified and it may be appropriate to refer to the speech-and-language therapist. People who lose weight rapidly often find that their dentures no longer fit properly; unfortunately this problem cannot usually be remedied during the patient's stay. Thrush infections are common in undernourished patients or patients who are prescribed immunosuppressants. This can cause a sore mouth, taste changes and swallowing problems and can be relatively easily treated with antifungal agents. Constipation and diarrhoea are equally deleterious to the patient's appetite, and need to be identified and treated.

Motivating and encouraging the patient at meal times is often necessary and needs to be supervised by a member of the nursing team. Actively involving older people in their nutritional care and allocating a nurse to oversee their nutritional needs can improve intake by 30% (Pederson 2005). If active depression is an underlying cause, it may be useful to involve the help of a counsellor.

Prior to admission, the patient may have had a long period of deterioration due to the lack of ability or facilities to cook and shop. These problems may be resolved by a social worker and involvement of other family members or friends. If physical weakness is a problem, a physiotherapist or occupational therapist can suggest exercises to strengthen the patient or tools to assist the patient.

In hospital, physical weakness may prevent the patient cutting up their food or removing packaging. Poor vision may also be a problem. Assistance must be provided when these problems are identified. Loss of muscle mass is one of the main consequences of malnutrition and, in elderly people in particular, this leads to decreased capacity for the activities of daily living, loss of independence and decline in mental status.

Physical activity and physiotherapy can improve muscle mass and should be part of nutrition support in the elderly patient (Suetta *et al.* 2004). Studies in patients on dialysis have shown improvements in muscle fibre and general muscle structure as well as exercise capacity, after a training programme has been initiated (Kopple *et al.* 2005). However, other authors have found a disappointing response to resistance exercise training (Ikizler 2011) and it may be that acidosis, which is prevalent in patients with kidney disease, actually worsens during exercise, thus preventing a more positive outcome (Clapp and Bevington 2011). Nonetheless, both UK and European guidelines promote physical activity in patients undergoing dialysis and recommend that patients should be given the opportunity to participate in regular exercise programmes (Wright and Jones 2010).

Food supplementation

This may involve providing fortified foods, snacks or drinks with high nutritional content. Some of these can be given between meals so that the patient can eat little and often. Examples of these foods include sweet biscuits, cakes, cheese and biscuits, yogurt and mousses.

Supplement drinks, mousses and soups are available as well as protein and energy powders and liquids, although the latter are more likely to be added during food preparation. In order to metabolise protein and energy supplements efficiently, the full range of micronutrients are required and an appropriate multivitamin and mineral supplement may be also given. The supplement drinks and desserts should be prescribed as a medicine and their listing on the drug chart may help improve distribution and monitoring of intake. The drinks may be milk shakes, juice drinks, yogurt drinks. The flavours can include various fruits, vanilla, chocolate, neutral and savoury. Mousses and bars are available and may be useful for patients with reduced fluid allowances.

The renal dietitian will be aware of the nutritional content of any supplements as well as potassium and phosphate content. The ratio of protein to energy may vary, which may suit the needs of different patients. A malnourished patient's potassium and phosphate intakes are usually poor and they may even have low plasma levels, however it is always necessary to be aware of the potassium content; powdered drinks which require the addition of milk may be unsuitably high in potassium. The patient will usually need to continue phosphate binders unless they are extremely malnourished.

Nursing and/or catering staff need to ensure that the supplements/fortified foods are given to the patient at the right time, at the correct temperature and that they are actually consumed by the patient.

Nasogastric and gastrostomy feeding

The insertion of a gastrostomy feeding tube enables long-term tube feeding to be carried out without the discomfort of a nasogastic (NG) feeding tube. NICE guidelines recommend gastrostomy placement if NG tube feeding is not appropriate or if feeding is likely to be required for more than four weeks. Renal formulae are available with reduced electrolyte content but high nutrient density to reduce the fluid intake. Surveys have shown that the majority of (nonrenal) patients (83%) accepted the gastrostomy

feeding well.[3] In comparison with NG feeding there were fewer complications, greater comfort, better quality of life and better nutritional efficacy (Loser *et al*. 2005). In adult patients on HD, there have been fewer reports of gastrostomy use. However, one study of eight patients (Sayce *et al*. 2000) showed improved dry weight, MAMC and albumin after three months of feeding. A PD case study also showed improved weight and albumin over six months (Patel and Raftery 1997). A review of ten patients on PD in one centre in the United States found that peritonitis was a frequent complication (Fein *et al*. 2001) although gastrostomy feeding in children seems more successful and perhaps some lessons need to be learnt from the techniques used in paediatrics (von Schnakenburg *et al*. 2006).

Renal-specific formulae

Low-electrolyte, low-fluid supplements and feeds, and multivitamin supplements have been developed for patients who have kidney disease. Even these adapted nutrition support regimens may not result in the best possible outcomes because they do not supply enough of the relevant nutrients, and they may even add to the burden of nutrients which cannot be efficiently utilised at the time. The metabolic changes in renal disease have already been mentioned and these include the inflammatory response, which may involve rapid turnover of immune cells, increased antibody production and production of acute phase proteins (such as CRP and fibrinogen). This creates an increased demand for certain nutrients such as branch chain amino acids, omega-3 fatty acids and glutamine. Future research will continue to investigate targeted nutrition, which aims to supply essential nutrients such as glutamine, arginine and DNA precursors, or attempts to attenuate the inflammatory response using omega-3 essential fatty acids in order to reduce catabolism in patients with kidney disease.

A meta-analysis of the effects of oral supplements and enteral tube feeding in dialysis patients concluded that albumin levels and overall dietary intake improved. More research was required to investigate other clinical end points (anthropometry, quality of life, physical function) and also to determine whether renal specific formulae had any advantage over standard feeds (Stratton *et al*. 2005).

Nutritional peritoneal dialysis

Dialysate containing 1.1% amino acid solution will provide a net gain of 18 g amino acids from one 2 L exchange. It is important to ensure that energy requirements are being met otherwise the aim of achieving a positive nitrogen balance will not be met. Studies have indicated an improvement in nitrogen balance with increases in albumin, the dialysate seems to be well tolerated (Taylor *et al*. 2002; Tjiong *et al*. 2005). Use of amino acid containing dialysate will also reduce the overall amount of glucose absorbed during dialysis (Woodrow and Davies 2010).

Intradialytic parenteral nutrition

Parenteral formulas containing 50–70 g amino acids and 1000 kcal from fat and carbohydrate, can be safely delivered via the venous return during the HD treatment. Glucose monitoring during treatment is essential to prevent hyperglycaemia and fluid balance can be adjusted accordingly. An oral multivitamin and mineral supplement may be required to ensure efficient use of the protein and calories. The cost of IDPN is ten times that of oral

[3]Gastrostomy tubes may be placed via a percutaneous endoscopic method (PEG) or radiological method (RIG).

supplementation, therefore the latter method should be encouraged first. Case reports have shown the good safety profile of this technique (Dukkipati *et al*. 2010), although patients must be monitored for refeeding syndrome, hyperglycaemia and hypertriglyceridaemia. However a systematic review only identified three randomised controlled trials comparing IDPN with alternative means of nutrition support and stated that there was insufficient evidence to demonstrate net benefit or harm (Sigrist *et al*. 2010). In the United Kingdom, IDPN is often used after alternative feeding methods have been tried (and failed) or discounted, because of the burden it would place on the patient and their carer.

Monitoring nutritional support

This may require daily recording of food intake charts and weighing the patient regularly. Food records are best completed as the meal is being finished in order to observe the patient and note any problems, as well as record the amount and type of food eaten. Patients can often forget what they have eaten within a couple of hours. Monitoring of biochemistry and fluid balance is also crucial for patients with renal disease (very low as well as high levels of potassium and phosphate are possible) and most renal units have computer systems that can identify values outside of the normal range and create an alert for action to be taken. Repeat assessments of nutritional status should occur 6–8 weeks after starting dialysis (the first measurement taken within one week of starting treatment), and then repeated every 4–6 months for stable dialysis patients. Those identified as malnourished will be assessed much more frequently e.g. dietary intake and oedema free weight may be assessed weekly but other body composition measures may take longer to change; arm anthropometry such as MAC can be repeated monthly.

Transplantation

Renal transplantation is thought to offer the patient with established renal failure the best chance of rehabilitation and a good quality of life.

Postoperative transplant care

Appetite may initially be poor postoperatively and steroids can increase protein catabolism; therefore, both kidney and gastrointestinal function should be monitored. The rate at which biochemistry and urine output return to normal can vary (sometimes within a couple of days after surgery, or it can take several weeks) and needs to be monitored closely. There may be an 'oliguric stage' where fluid and electrolyte reductions are still required. This can progress to a polyuric stage, where intravenous support may be necessary to prevent fluid and electrolyte levels dropping below normal; dehydration at this stage can damage the new kidney. Nutritional requirements and the need for nutrition support can be assessed as previously described. Uncomplicated surgery increases metabolic rate by 5 to 20% and this should be included in the protein and energy requirements.

Long-term post-transplant care

The advice given to patients should include healthy eating (with some advice on food hygiene), exercise, and avoidance of smoking, excess alcohol intake and exposure to too much sun. One the positive aspects of transplantation is that the dietary restrictions are relaxed; however it is necessary to reinforce advice on healthy eating to help reduce the risk of obesity, cardiovascular disease, diabetes and also cancer.

Nutrient requirements are based on recommendations for the general population. The 'Eat Well Plate' is an appropriate model on which to base nutritional advice and meal suggestions.

Cardiovascular disease

Cardiovascular disease is the cause of 60% of deaths in transplanted patients and the incidence of CVD is five times greater than expected for age and gender. The main risk factors are obesity, hypertension, hyperlipidaemia, diabetes, sedentary lifestyle and smoking. The European Best Practice Guidelines (EBPG 2002) for renal transplantation also list hyperhomocysteinaemia as a risk factor.

Obesity is common with a successful transplant and is multifactorial:

- The patient's appetite increases due to increased feeling of wellbeing and release from dietary constraints. Relaxation of restrictions after transplant can lead to a more liberal intake of high calorie foods such as dairy products, fried potato products and chocolate.
- Steroids stimulate the patient's appetite.
- Activity and exercise levels may be low. Patients are often reluctant to exercise for fear of damaging the new kidney, and also because of lack of confidence and low exercise tolerance owing to previous inactivity.

The combination of an increased calorie intake and low activity levels leads to a rapid gain in body fat. Obesity contributes to hypertension, hyperlipidaemia and insulin resistance and these in turn contribute to CVD. Transplant medication is also partly responsible for raising lipid levels. Graft survival is also lower in the obese and the patient should be made aware of the risk of obesity at an early stage, pretransplant if appropriate. Target lipid levels are the same as the general population (National Institute for Health and Clinical Excellence 2006b; Baker *et al.* 2011)

Other CVD risk factors are:

- elevated levels of serum triglyceride and cholesterol are found in 36% and 63% of transplant patients respectively;
- arterial hypertension is present in 60–85% of patients;
- post-transplant diabetes affects 4–18% of patients;
- homocysteine is elevated, although not to the same level as on dialysis.

Control of calorie intake and increasing energy expenditure through activity and exercise are usually necessary. Additionally, poor eating habits may have formed whilst adhering to the dietary allowances on dialysis: intake of fruit and vegetables and other 'cardio-protective' foods, such as oily fish are often low (very few patients have the recommended five portions of fruit and vegetable per day, or fish twice a week). Regular reinforcement of healthy eating advice can help reduce weight gain, improve lipid levels and also help control hypertension.

Bone disease

An improved lean body mass (muscle) and bone strength may also result from diet and exercise advice. Patients with or at high risk of developing osteoporosis may need to avoid steroids; DEXA scanning can be used to monitor the condition. The Royal College of Physicians guidelines for steroid induced osteoporosis are recommended (Royal College of Physicians 2002). These guidelines discuss the importance of vitamin D and

calcium intake, and weight bearing exercise to improve bone health. They also discourage smoking, excess weight and excess alcohol intake.

Diabetes

The development of new-onset diabetes after transplantation (NODAT) is exacerbated by immunosuppressive agents: steroids, tacrolimus and ciclosporin. Elderly, African-Caribbean and Hispanic patients are most at risk. Graft loss is four times greater for patients who have diabetes. Fasting blood glucose should be checked every three months in all nondiabetic transplanted patients. Diet and exercise interventions help reduce the risk of metabolic syndrome and developing diabetes (Engel 2003; Diabetes UK 2011).

Summary of dietary advice for renal transplant recipients

- Monitor biochemistry and blood pressure control. In particular lipid levels (cholesterol and triglycerides), blood glucose, potassium, bone minerals, PTH and haemoglobin.
- Aim for acceptable body mass index: the 'Eat Well Plate' is an appropriate food model to use.
- Emphasise eating a variety of fruit and vegetables: aim for at least five portions per day.
- Encourage high-fibre foods (soluble and insoluble).
- Encourage fish, particularly oily fish, lean meats and pulses.
- Foods high in sugar, saturated fat and salt should be used sparingly.
- Dairy products should be low fat – with attention to meeting calcium requirements.
- Alcohol consumption should be within usual recommendations.
- Be aware of good food hygiene practices.
- Encourage physical activity and regular exercise.
- Avoid smoking and too much sun exposure.

Ideally a team of specialists should be available to help with the rehabilitation of transplanted patients, including the dietitian, nurse, physiotherapist, social worker and counsellor.

Dietary Management in Paediatrics (also refer to Chapter 12)

Chronic kidney disease may present after birth or later in life and can proceed to established renal failure during childhood. Growth and neurodevelopment depend strongly on nutrition during early childhood and can be profoundly affected by chronic renal failure (Fischbach *et al.* 2011). This is especially the case during infancy and in very young children where spontaneous nutritional intake is poor. Early nutritional intervention is essential and must be maintained on a long-term basis. Fluctuating clinical and biochemical disturbances that come with changes in treatment necessitate the constant review and readjustment of the nutritional prescription by an experienced dietitian (Coleman 2008). Infants may present with particular problems such as anorexia and vomiting, and an understanding of the psychosocial effects often proves to be as important as the dietary advice (Norman *et al.* 1995). However growth and final height in infants with severe chronic kidney disease has been found to be influenced by comorbidity. Intensive feeding and early transplantation has been shown to result in a mean adult height within the normal range in patients without comorbidities (Mekahli *et al.* 2010).

Nutritional assessment should include the regular monitoring of growth (weight, height and head circumference) and dietary analysis by means of food diaries or dietary recall. Biochemical assessment with frequent review of fluid balance and prescribed medication such as phosphate binders and antireflux agents is recommended. The maintenance of normal serum calcium and phosphate levels is crucial to optimal bone development, and nutritional measures have a significant part to play, particularly in controlling phosphate levels. The KDOQI guidelines recommend starting to monitor bone biochemistry at CKD Stage 2. In children with a normal serum phosphate, with serum PTH concentrations exceeding the target range, a moderate dietary phosphate restriction has been shown to be beneficial with respect to the prevention and treatment of hyperparathyroidism, and safe with respect to growth, nutrition and bone mineralisation. Ongoing assessment for linear growth is encouraged (K/DOQI 2008).

The dietary aims in managing children with chronic kidney disease are dependent upon age, stage of CKD (K/DOQI 2008) and nutritional assessment, with particular attention paid to growth parameters. Oral nutritional supplements have an important role, and are frequently used. However, experience has shown that attempting to achieve adequate nutrition in this way can be stressful for families due to issues relating to vomiting, palatability and compliance.

A proactive approach to maintaining good nutrition and growth without the use of growth hormone has resulted in a programme of early instigation of dialysis in combination with nutritional support (Coleman *et al*. 1998; Lederman *et al*. 2002). Although nasogastric tubes are used successfully, supplementary feeding using a gastrostomy button device may be more suitable in the long term (Rees and Shaw 2007). The gastrostomy button also provides a convenient route for the administration of medication and fluids, which has undoubted benefits for the child and family.

Dialysis is seen only as a holding measure before transplantation. Most children do very well and resume normal eating and drinking post-transplant (Coleman and Watson 1998). However, even if the transplant is successful, with normal renal function attained, concerns remain that there may be a prolonged transition to exclusive oral nutrition in infants and children who commenced nutritional support via an enteral route early in life. Support should be provided to encourage oral stimulation from the time of commencement of tube feeding (Pugh and Watson 2006). Such children may continue to require a period of nutritional support post-transplant. Conversely, the lifting of dietary restrictions and initiation of steroid treatment in other children may require energy intake to be reduced to prevent rapid weight gain. A healthy, no-added-salt diet and exercise should be encouraged with ongoing dietetic advice.

Maintaining good nutrition in this group of children requires the collaborative efforts of a multidisciplinary team (Foster *et al*. 2012). An agreed philosophy of nutritional care and dietetic time to attend ward rounds regularly, outpatient clinics and psychosocial meetings are essential. Home and school visits with frequent telephone contact are also invaluable support measures.

Summary

This chapter has provided the opportunity for the reader to improve current theoretical and practical knowledge of renal nutrition. However dietary advice is constantly changing as a result of new research findings and evidence based guidelines. It is important that a positive effort is made to continuously review practice and to always involve patients in the decision making process.

Acknowledgements

With grateful thanks to Marianne Vennegoor, who was the original author of this chapter, and to Pearl Pugh who updated the section on paediatric nutrition.

References

Armas, L.A.G. and Heaney, R.P. (2011) Vitamin D: the iceberg nutrient. *Journal of Renal Nutrition* **21,** 134–139.

Arora, S., Mattina, C., McAnenny, C. *et al.* (2012) Assessment of Nutritional Status in Patients with Cirrhosis: MUST is Not a Must. MSc thesis, University of Surrey.

Baker, R., Jardine, A. and Andrews, P. (2011) *Renal Association Guidelines: Post-Operative Care of the Kidney Transplant Recipient,* www.renal.org/clinical/guidelinessection/Post-operative-Care-Kidney-Transplant-Recipient.aspx (accessed 13 June 2013).

BDA-RNG (2011) *Evidence Based Dietetic Guidelines: Protein Requirements of Adults on Haemodialysis and Peritoneal Dialysis,* www.bda.uk.com/publications/statements/RNG_ProteinRequirementsAdultsHaemodialysisPeritonealDialysis.pdf (accessed 20 May 2013).

Block, G.A., Hulbert-Shearon, T.E., Levin, N.W. *et al.* (1998) Association of serum phosphorus and calcium phosphate product with mortality risk in chronic hemodialysis patients: a national study. *American Journal of Kidney Disease* **31,** 607–617.

Brenner, B. (1983) Hemodynamically mediated glomerular injury and the progressive nature of kidney disease. *Kidney International* **23,** 647–655.

Canada–USA Peritoneal Dialysis Study Group (1996) Adequacy of dialysis and nutrition in continuous peritoneal dialysis: association with clinical outcomes. *Journal of the American Society of Nephrology* **7,** 198–207.

Cherniack, E.P., Levis, S. and Troen, B.R. (2008) Hypovitaminosis D: a stealthy epidemic that requires treatment. *Geriatrics* **63** (4), 24–30.

Churchill, D.N., Taylor, D.W. and Kesehaviah, P.R. (1996) Adequacy of dialysis and nutrition in continuous peritoneal dialysis: association with clinical outcomes. *Journal of the American Society of Nephrology* **7,** 198–207.

Clapp, E.L. and Bevington, A. (2011) Exercise induced biochemical modifications in muscle in chronic kidney disease: occult acidosis as a potential factor limiting the anabolic effect of exercise. *Journal of Renal Nutrition* **21** (1), 57–60.

Coleman, J.E. (2008) The kidney, in *Clinical Paediatric Dietetics,* 2nd edn (eds V. Shaw and M. Lawson), Blackwell Scientific Publication, Oxford, pp. 158–182.

Coleman, J.E. and Watson, A.R.(1998) Growth post-transplantation in children previously treated with chronic dialysis and gastrostomy feeding, in *Advances in Peritoneal Dialysis* (ed. R. Khanna), University of Toronto Press, Toronto, pp. 271–273.

Collier, J. and Watson, A.R. (1994) Renal failure in children: specific consideration in management, in *Quality of Life Following Renal Failure* (eds H, McGee and C. Bradley), Harwood Academic Publishers, Chur, pp. 225–245.

Davies, S.J., Phillips, L., Griffiths, A.M. *et al.* (1998) What really happens to people on long-term peritoneal dialysis? *Kidney International* **54,** 2207–2217

de Brito-Ashurst, I., Perry, L., Sanders, T.A. *et al.* (2011) Barriers and facilitators of dietary sodium restriction amongst Bangladeshi chronic kidney disease patients. *Journal of Human Nutrition Dietetics* **24** (1), 86–95.

de Mutsert, R., Grootendurst, D.C., Boeschoten, E.W. *et al.* (2009) SGA of nutritional status is strongly associated with mortality in chronic dialysis patients. *American Journal of Clinical Nutrition* **89,** 787–793

De Seigneux, S. and Martin, P.-Y. (2009) Management of patients with nephrotic syndrome. *Swiss Medical Weekly* **139** (28–30), 416–422.

Detsky, A.S., McLaughlin, J.R., Baker, J.P. *et al.* (1987) What is subjective global assessment of nutritional status? *Journal of Parenteral and Enteral Nutrition* **11,** 8–13.

Diabetes UK (2011) *Evidence-Based Nutrition Guidelines for the Prevention and Management of Diabetes,* www.diabetes.org.uk/nutrition-guidelines (accessed 13 June 2013).

Dukkipati, R., Kalantar-Zadeh, K. and Kopple, J.D. (2010) Is there a role for intradialytic parenteral nutrition? A review of the evidence. *American Journal of Kidney Disease* **55** (2), 352–364.

EBPG (2002) European best practice guidelines for renal transplantation. *Nephrology Dialysis Transplantation* **17** (suppl.) 4, 50–55.

EBPG (2007) EBPG guideline on nutrition. Nephrology Dialysis Transplantation 22 (suppl. 2), ii45–ii87

Elsayed, E.F., Tighiouart, H., Weiner, D.E. *et al.* (2008) Waist to hip ratio and body mass index as risk factors for cardiovascular events in CKD. *American Journal of Kidney Disease* **52,** A45–A46.

Engel, B. (2003) Nutritional management of diabetic renal transplant recipients, in *Nutritional Management of Diabetes Mellitus* (eds G. Frost, A. Dornhorst and R. Moses), John Wiley & Sons, Inc., New York.

Engel, B., Kon, S.P. and Raftery, M.J. (1995) Identification of malnutrition in haemodialysis patients. *Journal of Renal Nutrition* **5** (2), 62–66.

ESPEN (2002) ESPEN guidelines for nutrition screening. *Clinical Nutrition* **22** (4), 415–421.
Evans, A. and Gardiner, C. (2008) Dietetic management of hyperphosphataemia. *Complete Nutrition* **8,** 40–42.
Fein, P.A., Madane, S.J., Jorden, A. *et al.* (2001) Outcome of percutaneous endoscopic gastrostomy feeding in patients on peritoneal dialysis. *Advances in Peritoneal Dialysis* **17,** 148–152.
Fischbach, M., Fothergill, H., Seuge, L. and Zaloszyc, A. (2011) Dialysis strategies to improve growth in children with chronic kidney disease. *Journal of Renal Nutrition* **21** (1), 43–46.
Fisher, K., Paxton, R., Jackson, H. and Engel, B. (2010) Comparison of screening tools in patients undergoing haemodialysis. Paper presented at the BDA Research Conference, London, 2010.
Fissell, R.B., Bragg-Gresham, J.L., Gillespie, B.W. *et al.* (2004) International variation in vitamin prescription and association with mortality in the Dialysis Outcomes and Practice Patterns Study (DOPPS). *American Journal of Kidney Disease* **44** (2), 293–299.
Foster, B.J., McCauley, L. and Mak, R.H. (2012) Nutrition in infants and very young children with chronic kidney disease. *Pediatric Nephrology* **27,** 1427–1439.
Fouque, D., Kalantah-Zadeh, K., Kopple, J. *et al.* (2008) A proposed nomenclature and diagnostic criteria for protein energy wasting in acute and chronic kidney disease. *Kidney International* **73,** 391–398.
Fouque, D., Laville, M. and Boissel, J.P. (2006) Low protein diets for chronic kidney disease in non diabetic adults. *Cochrane Database of Systematic Reviews* **3**.
Fouque, D., Wang, P. and Laville, M. *et al.* (2000) Low protein diets delay end-stage renal disease in non-diabetic adults with chronic renal failure. *Nephrology Dialysis Transplantation* **15,** 1986–1992.
Friedman, A.N. (2006) Adiposity in dialysis: good or bad? *Seminars in Dialysis* **19** (2), 136–140.
Friedman, A.N. and Fadem, S.Z. (2010) Reassessment of albumin as a nutritional marker in kidney disease. *Journal of the American Society of Nephrology* **21**(2), 223–230.
Ginn, H., Rigalleau, V. and Aparicio, M. (1999) Which diet for diabetic patients with chronic renal failure? *Nephrology Dialysis Transplantation* **14,** 2577–2579.
Goodman, W.G., Goldin, J., Kulzon, B.D. *et al.* (2000) Coronary artery calcification in young adults with end-stage renal disease who are undergoing dialysis. *New England Journal of Medicine* **342,** 1478–1482.
Gonzalez-Parra, E., Gracia-Iguacel, C., Egido, J. and Ortiz, A. (2012) Phosphorus and nutrition in kidney disease. *International Journal of Nephrology* DOI: 10.1155/2012/597605.
Hadfield, C. (1992) The nutritional adequacy of a low protein diet. *Journal of Renal Nutrition* **2** (3), (suppl. 1), 37–41.
Hakim, R.M. and Lazarus, J.M. (1995) Initiation of dialysis. *Journal of the American Society of Nephrology* **6,** 1319–1328.
Halverson, N.A., Wilkens, K.G., Worthington-Roberts, B. (1993) Interdialytic fluid gains in diabetic patients receiving hemodialysis treatment. *Journal of Renal Nutrition* **3,** 23–29.
Henderson, I.S., Leung, A.C., Shenkin, A. (1984) Vitamin status in CAPD. *Peritoneal Dialysis Bulletin* **4,** 143–145.
Holt, S. and Goldsmith, D. (2010) *Cardiovascular Disease in CKD,* www.renal.org/Clinical/GuidelinesSection/CardiovascularDiseaseInCKD.aspx (accessed 20 May 2013).
Hong, S.Y., Yang, D.H. and Chang, S.K. (1998) Plasma homocysteine, vitamin B_6, vitamin B_{12} and folic acid in end-stage renal disease during low-dose supplementation with folic acid. *American Journal of Nephrology* **18,** 367–372.
Hull, R.P. and Goldsmith, D.J.A. (2008) Nephrotic syndrome in adults. *British Medical Journal* **336,** 1185–1189.
Hunt, L. (2011) Provision of water-soluble vitamin supplementation for haemodialysis patients. *Journal of Human Nutrition and Dietetics* **24** (3), 289–290.
Ifudu, O., Dawood, M., Homel, P. *et al.* (1997) Excess interdialytic weight gain provokes antihypertensive drug therapy in patients on maintenance hemodialysis. *Dialysis Transplant* **26,** 541–559.
Ikizler, T.A. (2011) Exercise as an anabolic intervention in patients with end stage renal disease. *Journal of Renal Nutrition* **21** (1), 52–56.
Ikizler, T.A., Greene, J.H., Wingard, R.L. *et al.* (1995) Spontaneous dietary protein intake during progression of chronic renal failure. *Journal of the American Society of Nephrology* **6,** 1386–1391.
Ikizler, T.A. and Hakim, R.M. (1996) Nutrition in end-stage renal disease. *Kidney International* **50,** 343–357.
Joint British Societies (2005) JBS2 Joint British Societies Guidelines on prevention of cardiovascular disease in clinical practice. *Heart* **1** (suppl. V), v1–v52.
Johnson, D.W. (2006) Dietary protein restriction as a treatment for slowing chronic kidney disease progression: the case against. *Nephrology* **11**, 58–62.
Jones, C.H., Wells, L., Stoves, J. *et al.* (2002) Can a reduction in extracellular fluid volume result in increased serum albumin in peritoneal dialysis patients*? American Journal of Kidney Diseases* **39,** 872–875.
Kalantar-Zadeh, K., Kopple, J.D., Block, G. and Humphreys, M.H. (2001) A malnutrition-inflammation score is correlated with morbidity and mortality in maintenance hemodialysis patients. *American Journal of Kidney Disorders* **38** (6), 1251–1263.
Kari, J.A., Gonzalez, C., Ledermann, S.E. and Rees, L. (2000) Outcome and growth of infants with severe chronic renal failure. *Kidney International* **57,** 1681–1687.

K/DOQI (2000) Clinical practice guidelines for nutrition in chronic renal failure. National Kidney Foundation. *American Journal of Kidney Diseases* 35 (suppl. 2), S1–140.

K/DOQI (2003) National Kidney Foundation. K/DOQI Clinical Practice Guidelines for Managing Dyslipidemias in Chronic Kidney Disease. *American Journal of Kidney Diseases* **41** (suppl. 3), S1–S92, www.kidney.org/professionals/kdoqi/guidelines_lipids/index.htm (accessed 20 May 2013).

K/DOQI (2008) Clinical Practice Guidelines for Nutrition in Children with CKD: 2008 update. Executive summary. *American Journal of Kidney Diseases* **53,** S11–S104.

Klahr, S., Levey, A.S., Beck, G.J. *et al.* (1994) The effects of dietary protein restriction and blood-pressure control on the progression of chronic renal disease. *New England Journal of Medicine* **330,** 878–884.

Konings, C.J., Kooman, J.P. and Schonck, M. (2002) Fluid status, blood pressure, and cardiovascular abnormalities in patients on peritoneal dialysis. *Peritoneal Dialysis International* **22,** 477–487.

Kopple, J.D., Storer, T. and Casburi, R. (2005) Impaired exercise capacity and exercise training in maintenance haemodialysis patients. *Journal of Renal Nutrition* **15** (1), 44–48.

Kopple, J.D., Wolfson, M., Chertow, G.M. *et al.* (2000) Clinical practice guidelines for nutrition in chronic renal failure. *American Journal of Kidney Diseases* **35,** S17–S140.

Ledermann, S.E., Lewias, S., Moloney, J. *et al.* (2002) Gastrostomy feeding in infants and children on peritoneal dialysis. *Pediatric Nephrology* **17,** 246–250.

Leon, J.B., Albert, J.M., Gilchrist, G. *et al.* (2006) Improving albumin levels among haemodialysis patients: a community-based randomized controlled trial. *American Journal of Kidney Diseases* **48** (1), 28–36.

Lim, V.S. and Flanigan, M.J. (2001) Protein intake in patients with renal failure: comments on the current NFK-DOQI guidelines for nutrition in chronic renal failure. *Seminars in Dialysis* **14** (3), 150–152.

Lindley, E., Devine, Y., Hall, L. *et al.* (2005) A ward based procedure for assessment of fluid status in peritoneal dialysis patients using bioimpedance spectroscopy. *Peritoneal Dialysis International* **25** (suppl. 3), S46–S48.

Loser, C., Aschl, G., Hebuterne, X., *et al.* (2005) ESPEN guidelines on enteral nutrition – percutaneous endoscopic gastrostomy (PEG). *Clinical Nutrition* **24,** 848–861.

Lowrie, E.G. and Lew, N.L. (1990) Death risk in hemodialysis patients: the predictive value of commonly measured variables and an evaluation of death rate differences between dialysis facilities. *American Journal of Kidney Diseases* **15,** 458–482.

MacGregor, M.S. and Taal, M.W. (2011) *Detection, Monitoring and Care of Patients with CKD,* www.renal.org/Clinical/GuidelinesSection/Detection-Monitoring-and-Care-of-Patients-with-CKD.aspx (accessed 20 May 2013).

Makoff, R. (1999) Vitamin replacement therapy in renal failure patients. *Mineral Electrolyte Metabolism* **25,** 349–351.

Mandayam, S. and Mitch, W.E. (2006) Dietary protein restriction benefits patients with chronic kidney disease. *Nephrology* **11,** 53–57.

McCann, L. (1996) Subjective global assessment as it pertains to the nutritional status of dialysis patients. *Dialysis Transplant* **25,**190–202, 225.

McIntyre, C., Harper, I., Macdougall, I.C. *et al.* (1997) Serum C-reactive protein as a marker of infection and inflammation in regular dialysis patients. *Clinical Nephrology* **48,** 371–374.

McKenzie, S.I. and Henderson, I.S. (1986) The effect of increased dietary fibre intake on regular haemodialysis patients, in *Aspects of Renal Care* (eds E. Stevens and P. Monkhouse), Baillière Tindall, London, pp. 172–178.

Mekahli, D., Shaw, V., Ledermann, S.E. and Rees, L. (2010) Long-term outcome of infants with severe chronic kidney disease. *Clinical Journal of the American Society of Nephrology* **5** (1), 10–17.

Memmer, D. (2013) Implementation and practical application of the nutrition care process in the dialysis unit. *Journal of Renal Nutrition* **23** (1), 65–73.

Mikhail, A., Shrivastava, R. and Richardson, D. (2010) Renal Association Guidelines: Anaemia in CKD, www.renal.org/Clinical/GuidelinesSection/AnaemiaInCKD.aspx (accessed 20 May 2013).

Millward, D.J. and Jackson, A.A. (2003) Protein/energy ratios of current diets in developed and developing countries compared with a safe protein/energy ratio: implications for recommended protein and amino acid intakes. *Public Health Nutrition* **7** (3), 387–405.

Muth, I. (1991) Implications of hypervitaminosis A in chronic renal failure. *Journal of Renal Nutrition* **1,** 2–8.

National Institute for Health and Clinical Excellence (2006a) Nutritional Support in Adults – Oral Supplements, Enteral Tube Feeding and Parenteral Nutrition, NICE, London.

National Institute for Health and Clinical Excellence (2006b) *CG43; 2006 Obesity: NICE Guideline,* www.nice.org.uk/guidance/CG43/NICEGuidance (accessed 20 May 2013).

National Institute for Health and Clinical Excellence (2008) *CG73 2008 CKD: Early Identification and Management of Chronic Kidney Disease in Adults in Primary and Secondary Care,* www.nice.org.uk/CG73 (accessed 20 May 2013).

National Institutes of Health (1993) *Morbidity and Mortality of Dialysis. NIH Consensus Statement,* National Library of Medicine, Office of Medical Applications of Research, National Institutes of Health, Bethesda, MD, pp. 1–33.

Norman, L.J., Coleman, J.E. and Watson, A.R. (1995) Nutritional management in a child on chronic peritoneal dialysis; a team approach. *Journal of Human Nutrition* **8,** 209–213.

Pagenkemper, J.J., Burke, K.I., Roderick, S.L. *et al.* (1994) Potassium availability in selected bran products: implications for the renal patient. *Journal of Renal Nutrition* **4,** 27–31.
Patel, M.G. (1998) The effect of dietary intervention on weight gains after renal transplantation. *Journal of Renal Nutrition* **8** (3), 137–141.
Patel, M.G. and Raftery, M.J. (1997) Successful percutaneous endoscopic gastrostomy feeding in CAPD. *Journal of Renal Nutrition* **7** (4), 208–211.
Pederson, P.U. (2005) Nutritional care: the effectiveness of actively involving older patients. *Journal of Clinical Nursing* **14,** 247–255.
Pedrini, M.T., Levey, A.S., Lau, J. *et al.* (1996) The effect of protein restriction on the progression of diabetic and nondiabetic renal disease: a meta-analysis. *Annals of Internal Medicine* **124,** 629–632.
Pender, F.T. (1989) The effect of increasing the dietary fibre content of diets of patients with chronic renal failure treated by haemodialysis at home. *Journal of Human Nutrition and Dietetics* **2,** 423–427.
Pugh, P., Watson, A.R. (2006) Transition from gastrostomy to oral feeding following renal transplantation. *Advances in Peritoneal Dialysis* **22,** 153–157.
Ramirez, G., Chen, M., Boyce, W. *et al.* (1986) Longitudinal follow up of chronic haemodialysis patients without vitamin supplementation. *Kidney International* **30,** 99–106.
Rees, L. and Shaw, V. (2007) Nutrition in children with CRF on dialysis. *Pediatric Nephrology* **22,** 1689–1702.
Robertson, L.M., Waugh, N. and Robertson, A. (2007) Protein restriction for diabetic renal disease. *Cochrane Database of Systematic Reviews* **4**: CD002181.
Rocco, M.V. and Makoff, R. (1997) Appropriate vitamin therapy for dialysis patients. *Seminars in Dialysis* **10,** 272–277.
Roubenoff, R., Heymsfield, S.B., Kehayias, J.J. *et al.* (1997) Standardization of nomenclature of body composition in weight loss. *American Journal of Clinical Nutrition* **66,** 192–196.
Royal College of Physicians (2002) *Glucocorticoid Induced Osteoporosis; A Concise Guide to Prevention and Treatment,* http://bookshop.rcplondon.ac.uk/contents/pub89-64206b70-b147-4976-9ee1-bf4948458468.pdf (accessed 20 May 2013).
Sayce, H.A., Rowe, P.A. and McGonigle, R.J.S. (2000) PEG feeding in HD out-patients. *Journal of Human Nutrition and Dietetics* **13,** 333–341.
Sexton, J. and Vincent, M. (2004) Remedying calcium and phosphate problems in chronic kidney disease. *The Pharmaceutical Journal* **274,** 561–564.
Sherman, R.A., Cody, R.P., Rogers, M.E. *et al.* (1995) Interdialytic weight gain and nutritional parameters in chronic dialysis patients. *American Journal of Kidney Diseases* **25,** 579–583.
Sigrist, M.K., Levin, A. and Tejan, A.M. (2010) Systematic review of evidence for the use of intradialytic parenteral nutrition in malnourished haemodialysis patients. *Journal of Renal Nutrition* **20** (1), 1–17.
Spiegel, D.M., Anderson, M., Campbell, U. *et al.* (1993) Serum albumin: a marker for morbidity in peritoneal dialysis patients. *American Journal of Kidney Diseases* **21,** 26–30.
Steddon, S. and Sharples, E. (2010) *Renal Association Guidelines CKD Mineral and Bone Disorders,* www.renal.org/Clinical/GuidelinesSection/CKD-MBD.aspx (accessed 20 May 2013).
Steiber, A.L. and Kopple, J.D. (2011) Vitamin status and needs for people with stages 3–5 chronic kidney disease. *Journal of Renal Nutrition* **21** (5), 355–368.
Stenvinkel, P. (2003) Interactions between inflammation, oxidative stress, and endothelial dysfunction in end-stage renal disease. *Journal of Renal Nutrition* **13,** 144–148.
Stenvinkel, P., Heimburger, O., Paultre, F. *et al.* (1999) Strong association between malnutrition, inflammation, and atherosclerosis in chronic renal failure. *Kidney International* **55,** 1899–1911.
Stratton, R.J., Bircher, G., Fouque, D. *et al.* (2005) Multinutrient oral supplements and tube feeding in maintenance dialysis: a systematic review and meta-analysis. *American Journal of Kidney Diseases* **46** (3), 387–405.
Stratton, R.J., Green, C.J. and Elia, M. (2003) *Disease Related Malnutrition: An Evidence Based Approach*, CABI International, Wallingford.
Suetta, C., Magnusson, S.P., Rosted, A. *et al.* (2004) Resistance training in the early postoperative phase reduces hospitalization and leads to muscle hypertrophy in elderly hip surgery patients – a controlled, randomized study. *Journal of the American Geriatrics Society* **52,** 2016–2022.
Tan, C.C., Harden, P.N., Rodger, R.S.C. *et al.* (1996) Ranatidine reduces phosphate binding in dialysis patients receiving calcium carbonate. *Nephrology, Dialysis, Transplantation* **11,** 851–853.
Taylor, G.S., Patel, V., Spencer, S. *et al.* (2002) Long-term use of 1.1% amino acid dialysis solution in hypoalbuminemic continuous ambulatory peritoneal dialysis patients. *Clinical Nephrology* **58,** 445–450.
Tjiong, H.L., van den Berg, J.W., Wattimena, J.L. *et al.* (2005) Dialysate as food: combined amino acid and glucose dialysate improves protein anabolism in renal failure patients on automated peritoneal dialysis. *Journal of the American Society of Nephrology* **16,** 1486–1493.
Todorovic, V.E. and Micklewright, A. (2007) *A Pocket Guide to Clinical Nutrition,* British Dietetic Association, Nottingham.

Tonelli, M., Webbe, N., Hemmelgarn, B. *et al.* (2009) *Trace Elements in Haemodialysis Patients: A Systematic Review and Meta-Analysis,* http://biomedcentral.com/1741-7015/7/25 (accessed 20 May 2013).

UK Prospective Diabetes Study (UKPDS) (1998) Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). *Lancet* **352,** 837–853.

Vennegoor, M. (ed.) (1992) *Enjoying Food on a Renal Diet,* King Edward's Fund for London, London.

Visser, M., Deeg, D.J. and Lips, P. (2003) Low vitamin D and high parathyroid hormone levels as determinants of loss of muscle strength and muscle mass (sarcopenia): the Longitudinal Aging Study, Amsterdam. *Journal of Clinical Endocrinology and Metabolism* **88** (12), 5766–5772.

Visser, R., Dekker, F.W., Boeschoten, E.W. *et al.* (1999) Reliability of the 7-point subjective global assessment scale in assessing nutritional status of dialysis patients. *Advances in Peritoneal Dialysis* **15,** 222–225.

Von Schnakenburg, C., Feneburg, R., Plank, C. *et al.* (2006) Percutaneous endosopic gastrostomy in children on PD. *Peritoneal Dialysis International* **26** (1), 69–77.

Walters, B.A., Hays, R.D., Spritzer, K.L. *et al.* (2002) Health related quality of life, depressive symptoms and malnutrition at start of hemodialysis initiation. *American Journal of Kidney Diseases* **40** (6), 1185–1194.

Watson, A.R. (1995) Strategies to support families of children with end-stage renal failure. *Paediatric Nephrology* **9,** 628–631.

Wolk, R. (1993) Micronutrition in dialysis. *Nutrition in Clinical Practice* **8,** 267–276.

Woodrow, G. and Davies, S. (2010) *Renal Association Guidelines: Peritoneal Dialysis,* www.renal.org/Clinical/GuidelinesSection/PeritonealDialysis.aspx (accessed 20 May 2013).

Wright, M. and Jones, C. (2010) *Renal Association Guidelines: Nutrition in CKD,* www.renal.org/Clinical/GuidelinesSection/Guidelines.aspx (accessed 20 May 2013).

Yale, J.F. (2005) Oral antihyperglycaemic agents and renal disease: new agents new concepts. *Journal of the American Society of Nephrology* **16** (suppl. 1), S7–10.

Yokum, D., Glass, G., Cheung, C.F. *et al.* (2008) Evaluation of a phosphate management protocol to achieve optimum serum phosphate levels in hemodialysis patients. *Journal of Renal Nutrition* **18** (6), 521–529.

Useful web sites

Cochrane Renal Group: www.cochrane-renal.org (accessed 20 May 2013).

EDTNA-ERCA: www.edtnaerca.org (accessed 20 May 2013).

KDIGO 2012 Clinical Practice Guideline for the evaluation and management of chronic kidney disease www.kdigo.org/clinical_practice_guidelines/index.php (accessed 20 May 2013).

K/DOQI National Kidney Foundation: www.kidney.org (accessed 20 May 2013).

Renal Association Guidelines www.renal.org/clinical/guidelinessection/guidelines.aspx (accessed 20 May 2013).

Appendix 13.1: Calculation of Body Mass Index (BMI) and Ideal Body Weight (IBW)

Body mass index (BMI) can be calculated by dividing the weight in kg by the height in metres squared. If the patient has oedema the BMI will be overestimated and is not valid. In estimating oedema-free body weight (BW_{ef}), weight should be measured after HD or after drainage of dialysis fluid in PD.

Example

A person weighs 65 kg and is 1.70 m tall.

$$\text{BMI} = 65/(1.7 \times 1.7) = 22.5\,\text{kg m}^{-2}$$

Normal range: 18.5–24.9.

Underweight < 18.5.

Preobese (overweight): 25–29.9.

Obese class 1: 30–34.9.

Obese class II: 35–39.9 (obese).

Obese class III: > 40 (morbidly obese)

The K/DOQI guidelines recommend the use of adjusted oedema free body weight (aBW_{ef}) to calculate protein or energy requirements or to assess intake. The following method can be used. Standard body weight: a BMI between 18.5 and 24.9 kg m^{-2} and its corresponding weight in kilograms, is considered within the normal range (WHO 1998). However, given the increased mortality of patients at the lower end of the 'normal' range, it may be prudent to calculate the standard weight for a BMI of 23 kg m^{-2} and this can be used in the equation below. The following equation has been suggested:

$$\text{IBW} = \text{aBW}_{ef} = \text{BW}_{ef} + ((\text{standard body weight} - \text{BW}_{ef}) \times 0.25)$$

These figures should be used to calculate protein and energy requirements for individual patients.

The important point for audit purposes and comparison across renal units is to note clearly how you have calculated IBW. As there is no consensus regarding this issue a simpler method would be to use the weight corresponding to a BMI of 23 kg m^{-2}

Appendix 13.2: Seven-Point Subjective Global Assessment

Name ..... Hospital No. ..... D.o.B.....

Date					
Overall weight change over last 6 months					
❖ Gain **(7)**/<5% loss **(6)**					
❖ 5–10% sustained loss **(4–5)**					
❖ >10% sustained loss **(1)**					
❖ >10% loss but gaining (relative to dry weight) **(2–3)**					
❖ >5–10% loss but gaining **(4)**					
Weight change over past 2 weeks					
❖ No change/normal weight **(6–7)**					
❖ Increased/increasing (**rate 1 score above previous**) **(3–4–5)**					
❖ Stable but below normal (relative to dry weight) **(2–3)**					
❖ Decreased/decreasing **(1)**					
Change in dietary intake compared to normal					
❖ Good intake/no change/small change **(7)**					
❖ Borderline intake/decreasing **(3)**					
❖ Poor intake/no change **(2)**					
❖ Poor intake/increasing **(3–4–5)**					
❖ Poor intake/decreasing **(1)**					
Duration/type of change in diet					
❖ <2 weeks, normal diet **(7)**					
❖ >2 weeks, sub-optimal normal diet **(3)**					
❖ Full fluid diet/NG **(3–4–5)**					
❖ Hypocaloric liquids **(2)**					
❖ Starvation **(1)**					
GI symptoms					
Nausea Vomiting Diarrhoea Anorexia					
❖ None/few intermittent symptoms **(7)**					
❖ Some symptoms >2 weeks **(3–4–5)**					
❖ Most/all symptoms >2 weeks **(1)**					
Subcutaneous fat (triceps/chest)					
❖ Little or no depletion **(6–7)**					
❖ Moderate depletion some/all areas **(3–4–5)**					
❖ Severe depletion most/all areas **(1–2)**					
Muscle wasting (quads/deltoids)					
❖ Little or no depletion **(6–7)**					
❖ Moderate depletion some/all areas **(3–4–5)**					
❖ Severe depletion most/all areas **(1–2)**					
Total score:					

Appendix 13.3: Foods with a High and Low Sodium (Salt) Content

It may not be possible to eliminate all the listed foods or meals, unless a low-sodium alternative is available. A compromise may be reached by allowing some salty foods for sandwiches or main meals, but preparing the rest of the meals at home without salt. Adding herbs and spices during meal preparation or thereafter compensates for the loss of salt.

Foods with a high sodium content	Suitable alternative (always check with dietitian)
Dairy products	
Salted butter or margarine	Use unsalted or salt-reduced alternatives instead
Cheese, cheese spreads	
Meat and meat products	
Canned and cured meat products such as bacon, gammon, salt beef, corned beef, ham, tongue, all types of sausages, pâtés	Fresh-cooked meat Fresh-cooked poultry Fresh-cooked fish
Meat pies, quiches and sausage rolls	Home-cooked meals
Processed meals	
Fast food-type meals	
Vegetables	
Canned vegetables, sauerkraut, instant potato powder, salted potato crisps	Fresh or frozen vegetables
Nuts	
Roasted and salted nuts	
Miscellaneous	
Salt, sea salt, salt substitutes such asLo Salt, Solo, Selora	Herbs, spices
Mayonnaise, salad dressings	Home-made dressings, i.e. French dressing
Bottled sauces, pickles	Vinegar, lemon, lime juice
Canned or packet soups or ready-made soups	Home-made soup
Pasta sauce, curry paste, soya sauce	Home-made sauces
Meat or yeast extracts and bouillon cubes, packet gravy, gravy cubes or powders	Use herbs and spices for curries Use fresh ingredients for pasta dishes
Foods containing monosodium glutamate	
Salted savoury snacks	
Asian foods	
Poppadums, samosas, other savoury snacks, chutneys, pickles, chevra, chana	
Greek foods	
Taramasalata, canned vine leaves, houmus	Home-made houmus
Chinese foods	
Dried fish, salted fish	
Peking duck and similar products	

Appendix 13.4: Foods with High and Low Phosphorus Content

All foods with a high protein content also contain a fair amount of phosphorus. However, some of these foods are an essential part of the diet and cannot be eliminated.

Foods with a high phosphorus content	Suitable alternative (always check with dietitian)
Cereals	
Natural Bran, All-Bran, Bran Flakes, Bran Buds, cereals containing nuts	All other breakfast cereals Porridge
Rye bread	Wholemeal or white bread, croissant
Crispbread containing rye	Puri, pitta bread, chapatti, nan
Oatcakes, scones	Yorkshire pudding
Soya flour	Flour, barley, sago Semolina, tapioca, cornflour, custard powder Pasta, noodles, rice, wild rice
Dairy products	
Milk, yoghurt (see allowance allocated by renal dietitian)	Cream, crème fraîche
Evaporated and condensed milk	Fromage frais, quark
Milk powder, Horlicks	Cottage cheese and curd cheese
Most types of hard cheese, e.g. cheddar	Full-fat or reduced-fat cream cheese, such as Boursin, Philadelphia, roulé, marscapone, riccota
Stilton, cheese spread	
Eggs (no more than one daily); however, these quantities may need to be adapted for vegetarian diets	Egg white, meringue
Meat and meat products	
Liver, kidney, liver pâté and liver sausage, black pudding	Beef, veal, lamb, pork, chicken, turkey, sausages, meat pies (see meal plan suggested by the renal dietitian)
Fish and fish products	
Fish with edible bones, such as anchovies, herring, kippers, pilchards, salmon, sardines, sprats, whitebait, fish roe, fish paste	Fresh or smoked fish, such as cod, haddock, halibut, plaice, mackerel, tuna, fish fingers, fish cakes Canned fish, such as tuna, salmon with all bones removed Cockles, mussels, squid Occasionally use: crab, lobster, prawns, scampi, trout
Vegetables	
Pulses, such as dried peas, dried beans, lentils, baked beans, chick peas	All other vegetables
Savoury snacks	
All types of nuts such as peanuts, peanut butter	Popcorn, corn snacks
Bombay mix, chevra, chana, ganthia	
Poppadoms	
Sweets	
Chocolate, cocoa powder, Ovaltine, Mars bars, Snickers, Bounty, halva, burfi with nuts	Sweets, barley sugars, butterscotch, mint, fruit pastilles, starburst, sherbets, jelly babies, wine gums, marshmallows, Turkish delight, chewing gum, plain toffee and fudge, lollipops, ice lollies
Cakes and pastries	
Chocolate cake, Battenburg cake	All other types of cakes, biscuits, pastries
Any cakes and pastries containing chocolate or nuts	Doughnuts, cream cakes, gingerbread
Biscuits	
Chocolate biscuits, Jaffa cakes	Plain biscuits, such as Digestives
All biscuits containing nuts or chocolate	Cream crackers, Rich Tea, shortbread, sponge fingers, cream-filled biscuits

Puddings	
Milk pudding, custard, bread pudding, Christmas pudding, sponge	Pancakes, pastries, sweet or savoury, fruit jelly, sorbets
Chocolate mousse, chocolate ice cream, desserts containing nuts and chocolate	Plain ice cream, cheesecake
Beverages	
Milk and milk drinks, such as milk shakes, Build-up, Complan, Nutrament, drinking chocolate, cocoa, Bournevita, Ovaltine, Jamaican punch, some soft drinks contain added phosphate	Tea, coffee
	Soft drinks, fruit squash, lemon barley, blackcurrant drink, lime juice cordial, Crusha syrup, rosehip syrup
Condiments and miscellaneous	
Meat and yeast extracts, such as Marmite, Bovril, Vegemite	Sugar, jam, marmalade, honey, lemon curd, golden syrup
Marzipan, peanut butter	Gelatine, yeast, pickles, chutney, tomato ketchup, tomato purée, lemon juice, vinegar, mustard, mayonnaise, salad cream, salad dressing, tartare sauce, chilli sauce, soya sauce, herbs and spices, apple sauce, cranberry sauce, redcurrant jelly, horseradish, mint sauce, mint jelly
Seeds such as sesame, tahini	
Chocolate and nut spread	

Appendix 13.5; Foods with High, Medium and Lower Potassium Content

Potassium is found in many foods including milk which may be restricted, but also protein rich foods such as meat, fish and pulses. The tables below should only be used as a guide in combination with up-to-date food composition tables and manufacturers data.

Foods with a high potassium content	Foods with a lower potassium content
Savoury snacks	
• Bombay mix, curu snacks, all nuts including peanuts, all types of seeds, potato crisps, potato hoops, twiglets, vegetable samosas	• Pop corn, corn snacks such as tortilla chips, rice cakes and rice based snacks, wheat based snacks
Sweets and sweet snacks	
• Chocolate; plain, milk, white and all sweets containing chocolate	• Sugar, jam, marmalade, honey, lemon curd, golden syrup
• Liquorice allsorts, toffees, fudge and other sweets containing nuts, chocolate	• Boiled sweets, barley sugar, peppermint, Turkish delight, jelly babies, fruit pastilles, fruit gums, sherbets, marshmallows, lollipops, ice lollies, chewing gum
• Dried fruit; dried apples, dried apricots, dried banana chips, currants, dates, dried figs, prunes, raisins, sultanas, other dried fruit	• Crystallised, glace fruit
• Marzipan, treacle	
Beverages	
• Coffee in excess	• Tea (milk from allowance)
• Milk powder and drinks containing milk powder, such as Ovaltine, Horlicks, Complan, Build-up, drinking chocolate, milk shakes, Nutrament, cocoa powder.	• Soft drinks; with low real fruit juice content, tonic, soda water, ginger beer, lemonade, fizzy water, bitter lemon
• Milk shakes	• Fruit squash
• All fruit juices unless exchanged for fruit, cane sugar juice, vegetable juices; tomato juice, carrot juice	• Rice, Oat milk

(continued)

Foods with a high potassium content	Foods with a lower potassium content
Alcohol	
• Ale, barley wine, beer, cider, lager, red wine, white wine, sherry, port,	• Spirits
Cereals and cereal products	
• All bran, bran flakes, oatbran flakes, cereals with dried fruit, nuts or chocolate • Oat cakes, rye crispbread • All puddings, cakes, biscuits and cereal bars containing dried fruit, nuts or chocolate	• Corn flakes, rice crispies, • Rice, barley, sago, semolina, tapioca • Flour, noodles, pasta • Bread, croissant, chapati, pitta bread, puri, • Plain cake, biscuits, pastry (icing sugar, butter icing)
Condiments and flavourings	
• Tomato ketchup, tomato chutney, tomato puree, coconut • Meat and yeast extracts • Salt substitutes containing potassium chloride	• Spices; including, cinnamon, chilli powder, coriander, cumin, curry powder, ginger, mustard powder, nutmeg, pepper, turmeric • Herbs; (fresh or dried) basil, bayleaf, coriander, dill, mint, oregano, parsley, sage, tarragon, thyme • Garlic, lemon juice, Tabasco, vinegar • Piccalilli, horseradish, chutney and pickles
Dairy, fats and oils	
Yogurts, milk puddings, custard, evaporated and condensed milk	Cream; double, single, whipping Butter, lard, vegetable oils and margarines

Potassium portions

Potassium portions or exchanges can be used to encourage variety. Fruits and vegetables contain potassium in varying quantities. A patient may be advised to have (daily) one portion from the potato/tuber and pulse exchange list, two portions from the vegetable list, two portions from the fruit list. This however depends on biochemistry, body size, the diet as a whole and patients may be advised to avoid certain foods in the high potassium list.

Cooking methods such as boiling and throwing the water away will remove some potassium. Steaming, baking, stir-frying, pressure cookers and microwaving will not remove potassium.

Potatoes, tubers and pulses: Note: one portion contains approximately10 mmol potassium.

150 g boiled potatoes may be replaced by:
75 g baked potato in skin or 75 g new potatoes or 75 g roast potato or 75 g boiled green banana or plantain.
50 g chips (2 tablespoons) or 6 oven chips or 2 potato croquettes
150 g boiled parsnips
150 g ravioli or spaghetti in tomato sauce
150 g yam, sweet potato, dasheen, eddoes, coco yam, boiled bread fruit
150 g rice and peas (without coconut)
150 g soaked and boiled butter beans, haricot beans, black-eyed beans, baked beans in tomato sauce, dried peas, split peas, chick peas, lentils
100 g red kidney beans, boiled.

Vegetables: Each portion contains approximately 5 mmol (200 mg) potassium.
Quantities are based on fresh or boiled and drained vegetables unless indicated.

High; As a guide, one portion is 75 g (1-2 tablespoons):	Medium; As a guide, one portion is 100g (2–3 heaped tablespoons):	Low; As a guide, one portion is 150g (3–4 heaped tablespoons):
beetroot (boiled) brussel sprouts (6) fennel okra (6 pods) spinach mushrooms (boiled in water first) tomatoes (fresh, canned). fried onion vegetable juices Raw vegetables: a small portion of a mixture of salad: beetroot, red cabbage, carrots celery, chicory, coleslaw corn kernels, cucumber, lettuce mustard and cress, peppers (red, green, yellow or orange) radish, spring onions tomato (no more than half a tomato), watercress.	aubergine french beans broccoli celery courgettes curly kale leeks mangetout capsicum / peppers (red or green) sweetcorn kernels, on the cob or baby sweet-corn, fresh or canned turnip	asparagus (6 medium spears) runner beans beansprouts bamboo shoots cauliflower carrots globe artichoke red, white or Savoy cabbage marrow pumpkin peas (processed, canned, frozen, mushy peas) onions boiled, pickled or silverskin spring greens.
Fruit: Each portion contains approximately 5 mmol (200 mg) potassium. Quantities are based on fresh, stewed or canned fruit.		
High; As a guide, one portion is 50-75 g (1-2 tablespoons):	Medium; As a guide, one portion is 100 g or 3 tablespoons:	Low; As a guide, one unit of fruit is 150 g or 5 tablespoons:
1 fresh apricot ½ small banana blackcurrants 5 dates (fresh or dried) 1 figs (fresh) 4 greengages (fresh) gooseberries (fresh or stewed) grapes 1 kiwi fruit 6 prunes (dried or canned) redcurrants rhubarb (stewed or canned) Fruit juices	apricots (canned in syrup or juice) blackberries (fresh or stewed) 12 cherries 6–8 kumquats 1 lemon or lime loganberries (fresh) 6 lychees (fresh) 3 slices mango melon 1 nectarine paw paw (papaya) 1 medium peach (fresh or in natural juice) pineapple (1 medium thick slice) 2 pomegranates plums: 1 large or 2 small raspberries (fresh) (about 20) 1 sharon fruit 8 small strawberries.	1 apple 1 clementine ½ grapefruit a thin slice of watermelon 1 small orange 2 passion fruits 1 medium-sized pear 1 satsuma 1 tangerine.

CHAPTER 14

Quality Improvement in Renal Nursing

Nicola Thomas
London South Bank University, UK

Learning Outcomes

- To explain what is meant by quality improvement.
- To identify what is meant by patient safety.
- To understand the process of implementing and evaluating clinical practice guidelines.
- To plan and evaluate the components of a nursing audit of renal care.
- To be familiar with the basic techniques in quality improvement methodology.

Introduction

In 1998, the UK Secretary of State announced specific measures to ensure that 'all patients should receive a first class service' (Department of Health 1998). The document in which this announcement was made highlighted that there were unacceptable variations in performance and practice, and in clinical outcomes. In England, Lord Darzi's NHS Next Stage Review report put 'quality at the heart of everything we do' (Department of Health 2008, p. 47), whereas the more recent publication *Equity and Excellence: Liberating the NHS* commits to establishing improvement in quality and healthcare outcomes as the primary purpose of all NHS-funded care, placing patient safety 'at the heart of the NHS' (Department of Health 2011, p.21).

This chapter will explore the ways in which renal nurses can promote a high-quality service, through understanding of quality improvement methods, use and evaluation of best practice guidelines and insight into nursing audit. Nurses have a vital role to play in the promotion of quality care in the renal specialty and are in a key position to understand the needs of individual patients and their carers.

Quality Improvement

Quality improvement (QI) has been defined as 'the combined and unceasing efforts of everyone (healthcare professionals, patients and their families, researchers, payers, planners and educators) to make the changes that will lead to better patient outcomes (health), better system performance (care) and better professional development'

Renal Nursing, Fourth Edition. Edited by Nicola Thomas. Published 2014 by John Wiley & Sons, Ltd.

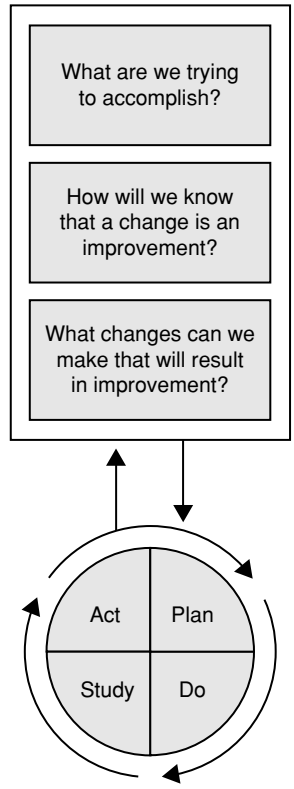


Figure 14.1 The Model for Improvement.

Source: Institute for Healthcare Improvement (2012). The 'model for improvement' in *How to Improve,* Massachusetts: Institute for Healthcare Improvement (available on www.ihi.org).

(Batalden and Davidoff 2007). The Royal College of Nursing (RCN) has recognised that new approaches to quality improvement processes and ways of measuring quality of care continue to be developed and implemented (Royal College of Nursing 2013).

First, nurses have to understand the quality improvement methods that guide improvement work. The Model for Improvement (Langley *et al.* 2009), is a simple, yet powerful tool for accelerating improvement. The Model for Improvement implements small tests of change using Plan-Do-Study-Act (PDSA) cycles. See Figure 14.1

The RCN has also identified three main topic areas within QI that help nurses improve the quality of care for patients: these are patient safety, clinical effectiveness and clinical audit.

Patient Safety

Patient safety refers to the concept that patients in healthcare settings are achieving intended outcomes. Ensuring patient safety involves the establishment of systems and processes that reduce the likelihood of errors and increase the likelihood of intercepting them before any harm occurs (Royal College of Nursing 2013).

There are two comprehensive resources available that can provide renal nurses with practical help in addressing patient safety issues. One is the Institute for Health

Improvement (USA) and the other the NHS Institute for Innovation and Improvement. The NHS Institute closed in March 2013 but publicly available content is still available on The National Archives website: http://webarchive.nationalarchives.gov.uk/*/http://institute.nhs.uk (accessed 23 May 2013). The IHI has a wide range of freely available resources and downloads (upon registration) to help nurses in every-day practice (http://www.ihi.org/, accessed 23 May 2013).

One example (Luther and Resar 2013) describes a methodology that helps frontline staff to 'see' patient safety problems in their systems and enables them to solve the problems and share that learning with others. The methodology is constructed around an informal unit visit and designed to be a 'conversation' about safety issues, versus an inspection or evaluation. This approach seeks to identify problems as they occur and solve them as soon as they are seen. A renal nursing manager could implement this type of 'conversation' with staff on a monthly basis. A detailed example is shown in Table 14.1

Table 14.1 The patient safety conversation.

The unit visit conversation		
Conversation Steps	**Specific Duties**	**Desired Outcomes**
1. Organise the visit to the unit beforehand	• Select a mix of Frontline staff (six to eight) • Select a small leadership team • Arrange for at least 60 minutes of conversation	• A cross section of staff working on the unit are included in the conversation • Schedule enough time for all staff to be able to discuss their work • The location selected for the conversation will minimise interruptions
2. Arrange for all participants to describe the jobs they do	• Establish a nonthreatening atmosphere • Limit this part of the conversation to the first 10 or 15 minutes • Focus this portion of the conversation on understanding the work and the work environment	• Front-line staff trust that this conversation is not about assessing their personal work performance • Staff are willing to talk about their work, how they do it, and how they add value to the patients and the organisation
3. Assess the work environment using "anchoring questions"	• Use questions like: "What causes a bad day for you?" "When was the last time a case was delayed?" "What makes some people with diabetes more difficult to manage?" • Use these questions to learn about both clinical and nonclinical situations • Steer discussion away from solutions	• A specific example of a defect around which to anchor subsequent questions to staff about frequency, type of patient involved, previous attempts to fix the defect or what might happen if it were resolved • A discussion that's completely nonthreatening and blame free, to allow for maximum sharing of information • 10–15 defects that can be easily surfaced during a 60-minute conversation and compiled on a written list
4. Debrief	• First, debrief the team asking the above-mentioned questions • Debrief the frontline team	• A list of defects that the front line has surfaced • Buy-in from the frontline staff for possible action • Buy-in from the questioning team as to the need for action

Source: 'The Unit Visit Conversation' in Tapping Front Line-Knowledge. Cambridge, Massachusetts: Institute for Healthcare Improvement; [Jan/Feb 2013]. (Available on www.IHI.org)

Kidney Care Atlas of Variation

As patient safety on a wider level refers to how far patients in health care settings are achieving intended outcomes, it is important to be knowledgeable about the 'benchmark' at which to aim. For many years the UK Renal Registry (www.renalreg.com, accessed 20 May 2013) has provided a source of comparative data for audit/benchmarking, planning, clinical governance and research. More recently the Renal Registry launched the world's first interactive maps showing details of achievement of quality measures in the care of patients in kidney units, called the Atlas of Variation. The NHS Atlas of Variation is intended to support local decision making to increase the value which a population receives from the resources spent on their healthcare. It supports the search for unexplained variations, the identification and attention to unwarranted variation, helping clinicians to understand what is going on in their area and where to focus attention to improve the care they provide. The first NHS Atlas of Variation was published in November 2010 and in 2012 an Atlas for Kidney Care was published (www.rightcare.nhs.uk/index.php/atlas/kidneycare, accessed 20 May 2013). It includes 18 maps of indicators relating to chronic kidney disease, renal replacement therapy, acute kidney injury and patient experience.

Key findings from the 2012 Atlas included:

- A 2.3-fold variation among primary care trusts in the ratio of reported to expected prevalence of chronic kidney disease.
- The proportion of patients receiving dialysis (haemodialysis and peritoneal dialysis) at home ranged from 0.0% to 30.4% across renal centres in England. In eight of the 52 centres, more than 25% of patients were on home dialysis; in seven centres, less than 10% of patients were on home dialysis.
- An 11-fold variation in pre-emptive transplantation in England.
- A 2.8-fold variation in the rate of admissions for acute kidney injury per all emergency admissions in England.

Nursing leaders can therefore use these maps to review their nursing service (number of people on home dialysis for example) by benchmarking against other units, prior to putting patient safety mechanisms into place.

Clinical effectiveness: implementing clinical practice guidelines

Over the past 20 years, the renal specialty has seen the emergence of a number of national and international standards for renal care. When the government's way of setting clear national standards was announced in 1998, the main strategy for this was through National Service Frameworks (NSF) and through a National Institute for Clinical Excellence (NICE). In early 2004 and early 2005 the National Service Frameworks for Renal Services were published. This was the first NSF to be published in two parts and although the original publications were disseminated almost one decade ago, their publication has had a tremendous impact on how renal services have developed.

National service frameworks

As outlined in the Department of Health (1997) paper, *The New NHS,* the government will work with the professions and representatives of users and carers to establish clearer, evidence-based NSFs for major care areas and disease groups. That way, patients will receive greater consistency in the availability and quality of services, right across the National Health Service (NHS). The government uses them as a way of being clearer with patients about what they can expect from the NHS.

In summary the NSFs have:

- set national standards and defined service models;
- put in place programmes to support implementation;
- established performance measures against which progress within an agreed timescale will be measured.

Part One of the NSF for Renal Services (Department of Health 2004) set five standards and identified 30 markers of good practice that will help the NHS and its partners manage demand, increase fairness of access and improve choice and quality in dialysis and kidney transplant services. Part Two of the NSF for Renal Services (Department of Health 2005) sets four quality requirements and identified 23 markers of good practice to help the NHS limit the development and progression of chronic kidney disease; minimise the impact of acute kidney injury, and extend palliative care to people dying with kidney failure. Each of these documents is discussed in further detail in relevant chapters of this book.

In September 2005 a summary of progress to date towards achieving the standards and early actions set out in the Renal NSF, together with a review of the modernisation programme supporting delivery of the NSF, was published by the Department of Health (2005). In 2007 a second progress report was published and in 2009 another report (Department of Health 2009) highlighted the successes from the previous five years.

In June 2006 the National Service Framework for Renal Services: Working for Children and Young People was published. This document related specifically to the care of children and young people, in greater detail. It also brought together the recommendations from the NSF for Children, Young People and Maternity Services, to make an accessible, user-friendly document for all those with an interest in services for children and young people with kidney disease.

Many related projects and documents have been published following publication of the NSF for Renal Services, and many of these documents, such as practical advice for patients, can be found on the publication pages of the Department of Health website www.dh.gov.uk/health/category/publications/ (accessed 20 May 2013). More recently, a variety of projects and documents have been produced by NHS Kidney Care, who work with healthcare professionals and commissioners to improve every aspect of kidney care for patients. These resources can be found at http://www.dakc.nhs.uk/# (accessed 23 May 2013).

In renal nursing practice we are fortunate to have a variety of clinical standards and guidelines to help us achieve clinically effective practice. In other words, many of the clinical guidelines that are available have been based on research evidence or expert opinion, so we do not have to examine all aspects of our care as it has already been done for us. There now follows a review of the most important clinical standards and guideline documents available for renal nurses.

National Institute for Health and Care Excellence (NICE)

The National Institute for Health and Care Excellence produces and disseminates clinical guidelines based on relevant evidence, associated clinical audit methods and information on good practice. The Institute identifies new and existing health interventions, collects evidence, considers the implications for clinical practice, disseminates the findings, implements at a local level and monitors the impact. The guidelines produced by NICE that are specifically relevant to renal practice are to be found in Table 14.2.

For further details, see the NICE website: http://www.nice.org.uk/guidance/index.jsp?action=byType&type=2&status=3 (accessed 23 May 2013).

Table 14.2 Renal-specific NICE guidance.

Date of publication	Topic
2002	Renal failure – home versus hospital haemodialysis
2008	Type 2 diabetes
2008	Chronic kidney disease update due 2014
2011	Diabetic foot problems (in-patients)
2011	Anaemia management in chronic kidney disease
2011	Peritoneal dialysis
2012	Preventing type 2 diabetes: risk identification and interventions for individuals at high risk
2013	Acute kidney injury
2014	Update on type 1 diabetes
2013	Hyperphosphataemia in chronic kidney disease

NICE quality standards are a concise set of statements designed to drive and measure priority quality improvements within a particular area of care. The standards are derived from the best available evidence and are developed independently by NICE, in collaboration with NHS and social care professionals, their partners and service users.

The NICE quality standards are central in supporting the government's vision for an NHS and Social Care system focused on delivering the best possible outcomes for people who use services, as detailed in the Health and Social Care Act 2012. A quality standard for Chronic Kidney Disease was published in 2011 and covers the identification, assessment and clinical management of CKD in adults. The NICE quality standards for CKD are shown in Box 14.1.

The quality measures accompanying the quality statements aim to improve the structure, process and outcomes of healthcare, although expected levels of achievement for quality measures are not specified.

BOX 14.1

NICE quality standards for CKD

1. People with risk factors for CKD are offered testing, and people with CKD are correctly identified.
2. People with CKD who may benefit from specialist care are referred for specialist assessment in accordance with NICE guidance.
3. People with CKD have a current agreed care plan appropriate to the stage and rate of progression of CKD.
4. People with CKD are assessed for cardiovascular risk.
5. People with higher levels of proteinuria, and people with diabetes and microalbuminuria, are enabled to safely maintain their systolic blood pressure within a target range 120–129 mmHg and their diastolic blood pressure below 80 mmHg.
6. People with CKD are assessed for disease progression.
7. People with CKD who become acutely unwell have their medication reviewed and receive an assessment of volume status and renal function.
8. People with anaemia of CKD have access to and receive anaemia treatment in accordance with NICE guidance.

(Continued)

BOX 14.1 *(Continued)*

9. People with progressive CKD whose eGFR is less than 20 ml/min/1.73 m^2, and/or who are likely to progress to established kidney failure within 12 months, receive unbiased personalised information on established kidney failure and renal replacement therapy options.
10. People with established renal failure have access to psychosocial support (which may include support with personal, family, financial, employment and/or social needs) appropriate to their circumstances.
11. People with CKD are supported to receive a pre-emptive kidney transplant before they need dialysis, if they are medically suitable.
12. People with CKD on dialysis are supported to receive a kidney transplant, if they are medically suitable.
13. People with established kidney failure start dialysis with a functioning arteriovenous fistula or peritoneal dialysis catheter ***in situ***.
14. People on long-term dialysis receive the best possible therapy, incorporating regular and frequent application of dialysis and ideally home-based or self-care dialysis.
15. People with CKD receiving haemodialysis or training for home therapies who are eligible for transport, have access to an effective and efficient transport service.

Source: National Institute for Health and Clinical Excellence (2011) 'Chronic Kidney Disease' Quality Standard, National Institute for Health and Clinical Excellence,http://publications.nice.org.uk/chronic-kidney-disease-quality-standard-qs5/list-of-statements Reproduced with permission.

Best Practice Guidelines from International and National Renal Associations

In 1990, the European Dialysis and Transplant Nurses' Association/European Renal Care Association (EDTNA/ERCA) commenced work on writing European clinical standards and in 1995 published European Standards for Nephrology Nursing Practice (Van Waeleghem and Edwards 1995). This document was published alongside the European core curriculum for a postbasic course in nephrology nursing (Kuentzle and Thomas 1995). These standards were one of the first publications that recommended specific guidelines for renal nursing practice. In recent years, renal nurses have had access to a variety of multi-professional best practice guidelines and a summary of these are outlined below.

KDOQI / KDIGO

KDOQI guidelines (Kidney Disease Outcome Quality Initiative, originally called DOQI or Dialysis Outcome Quality Initiative). KDOQI provided evidence-based clinical practice guidelines developed by volunteer physicians and health care providers for all stages of chronic kidney disease and related complications, from diagnosis to monitoring and management. KDOQI guidelines not only address dialysis but all stages of chronic kidney disease. The first set of guidelines developed by K/DOQI on the evaluation, classification and stratification of CKD was published in February 2002.

In 2004 there were further developments as it was recognised that there was a need for a more uniform and global approach to the process of developing clinical guidance. The name under which the initiative is now incorporated is 'Kidney Disease: Improving Global Outcomes' (KDIGO). Its mission statement is 'Improve the care and outcomes of kidney disease patients worldwide through promoting coordination, collaboration and integration of initiatives to develop and implement clinical practice guidelines.' KDIGO is led by an international Board comprised of approximately 50 members. The majority of the Board members are practicing nephrologists, but also included are patient representatives, plus delegates from other medical specialties and disciplines – nephrology nurses, dieticians and social workers.

Since the original development of the DOQI guidelines in haemodialysis and peritoneal dialysis, there have been developments in certain areas of care, such as anaemia management. A list of recently published KDIGO guidelines is shown in Box 14.2.

For further information, visit www.kdigo.org (accessed 20 May 2013).

Renal Association

Within the United Kingdom, the Renal Association published the third edition of *Treatment of Adult Patients with Renal Failure – Recommended Standards and Audit Measures* in 2002. From mid-2006 the Clinical Practice Guidelines of the UK Renal Association have been published in modular form. Table 14.3 shows the current and upcoming modules and expected review date.

BOX 14.2

Published KDIGO guidelines

- Care of the transplant recipient 2009
- Mineral and bone disorder 2009
- Hepatitis C in CKD 2008
- Acute Kidney Injury 2012
- Blood pressure in CKD 2012
- Anaemia 2012
- CKD Classification and management 2012

Table 14.3 Renal Association clinical practice guidelines.

Module	Date	Review due
Blood-borne viruses	**14/07/09**	**2012**
Haemodialysis	**01/12/09**	**2012**
Vascular access for haemodialysis	**05/01/11**	**2014**
Peritoneal dialysis	**30/07/10**	**2013**
Peritoneal access	**22/09/09**	**2012**
Planning, initiation and withdrawal of RRT	**17/09/09**	**2012**
Assessment of the potential kidney transplant recipient	**12/01/11**	**2014**
Acute kidney injury	**08/03/11**	**2014**
Nutrition in CKD	**25/06/10**	**2013**
Anaemia in CKD	**15/11/10**	**2013**
Cardiovascular disease in CKD	**06/08/10**	**2013**
CKD-mineral and bone disorders (CKD-MBD)	**06/12/10**	**2013**
Detection, monitoring and care of patients with CKD	**28/02/11**	**2014**
Postoperative care of the kidney transplant Recipient	**05/02/11**	**2014**
RA and ART guideline on water treatment Facilities, dialysis water and dialysis fluid Quality for haemodialysis and related therapies	**20/01/12**	**2015**
Treatment of acute hyperkalaemia in adults	**01/07/12**	

For further information on the Renal Association guidance, visit the website: www.renal.org/ (accessed 20 May 2013).

Other Guidelines

A variety of clinical practice guidelines are available including the European Best Practice Guidelines (EBPG). The EBPG are published on behalf of the European Renal Association/European Dialysis and Transplant Association and can be found at www.era-edta.org/page-8-38-0-38-erbpeuropeanrenalbestpractice.html (accessed 20 May 2013). The International Society of Peritoneal Dialysis guidelines can be found at www.ispd.org/lang-en/treatmentguidelines/guidelines (accessed 20 May 2013).

Evaluation of Guidelines

There are numerous local, national and international guidelines that renal nurses can access for achieving clinically effective practice, although Mead (2000) questions how useful these guidelines can actually be in promoting good practice. She summarises her debate with the following recommendations – guidelines are guides, not rules; practitioners must critically appraise the included evidence; national guidelines must be adapted to local circumstances; and it is vital to ensure judicious and selective guideline development.

It is helpful to have a checklist to evaluate how useful guidelines are to a local renal nursing team. The following questions could be used for evaluation:

- Are the guidelines based on evidence, expert opinion or both?
- What is the quality of the evidence? (Does it consist of well conducted clinical studies, reports, opinions and clinical experience of respected professionals?)
- Are the guidelines specific enough?
- Are the guidelines local, national or international?
- Have patients been involved in the development?
- Do the guidelines measure nursing?

The last point is difficult to evaluate as, of course, nurses do not work in isolation and therefore all members of the multiprofessional team contribute to patient outcome. But it is important that nurses recognise that it is nursing that they have to measure, and not necessarily the easier-to-measure variables such as blood pressure, potassium level, *Kt/V* and haemoglobin levels. What matters to patients is the depth of the communication, the skill of the teaching and the quality of their life, and although it is recognised that all of these are very difficult to measure, surely nurses must strive to evaluate these as part of the audit process.

Finally, it could be argued that the impact of clinical guidelines on the quality of patient care is difficult to measure. In 1998 there had been no rigorous reviews of their effectiveness carried out (Thomas *et al*. 1998) and, to date, it appears that no other systematic reviews have been undertaken.

Nursing Audit

The National Institute for Health and Care Excellence provides clinical audit tools for all clinical guidelines. The aim of the clinical audit is to make the process of developing clinical audit projects easier through the provision of ready-to-use criteria, including

exceptions, definitions and data source suggestions. One example is the suggestions for clinical audit that accompany clinical guideline 73 (chronic kidney disease) http://guidance.nice.org.uk/CG73/AuditSupport/doc/English (accessed 20 May 2013).

For renal nurses, it has been shown that, although there are many national and international guidelines available, one of the difficulties is how to select topics for audit that really matter to patient care. It is recognised that quality-of-life instruments may be one way of measuring more qualitative outcomes, but that in itself is challenging as 'there are no agreed methods of assessment upon which audit of this aspect of renal care can be based' (Renal Association 2007). Nurses are often taking the lead in auditing patient experience and some local audit teams and endeavouring to audit topics related to the NSF.

Quality and Service Improvement Methods

A full explanation of the range of QI methods available is beyond the scope of this book. However the NHS Institute for Innovation and Improvement does provide an online searchable library of proven quality and service improvement tools, theories and techniques that can be applied to a wide variety of situations (http://webarchive.nationalarchives.gov.uk/*/http://institute.nhs.uk, accessed 23 May 2013).

One popular QI method used in renal care is the application of a care bundle. Care bundles are groups (bundles) of high impact evidence-based healthcare interventions. Implementation of a care bundle can provide a structured way in which to improve the processes of care and patient outcomes. They are defined as a small, straightforward set of evidence-based practices (usually three to five) that, when performed collectively and reliably, have been proven to improve patient outcomes (Institute for Health Improvement 2011).

Success is defined as the application of *all elements* of the bundle at *every opportunity*. The idea of defining reliable practice in this 'all-or-nothing' approach is known as 'composite reliability'. A care bundle approach aims to achieve a 95% level of reliability. Thus they can be used as tools to improve efficiency and also effectiveness – a smarter way of working that could be applied to renal nursing practice (Thomas 2011).

Care bundles have been used with good effect to reduce the rate of infection in those with central venous catheters. A renal vascular access audit (NHS Information Centre 2011) showed that at first dialysis, 39% of patients had a tunnelled central line, and 20% had a nontunnelled central line. After adjusting for sample size, bloodstream infections were more common in patients with catheters compared with other types of vascular access: six episodes/100 patients for an arterio-venous fistula (AVF), 13 episodes/100 patients for a nontunnelled venous catheter and eight episodes/100 patients for tunnelled catheters.

Units could implement and evaluate the use of a care bundle by using one of the examples of a care bundle for central venous catheters that are widely available. An adapted version of an IHI bundle has been amended for use in the UK. Further details including the background to the bundle and audit measures can be found here http://hcai.dh.gov.uk/files/2011/03/2011-03-14-HII-Central-Venous-Catheter-Care-Bundle-FINAL.pdf (accessed 20 May 2013).

Summary

Increasingly, renal nurses are being asked to identify and implement ways to improve the quality of care they provide. There are now a wide variety of resources available to help them, including those from the Royal College of Nursing and the Institute for

Health Improvement. However it is important to remember that patients must be at the centre of any QI intervention and must also be included in the planning phase. Renal nurses are increasingly contributing to the culture of continuous quality improvement in patient care and have a very important role to play in the implementation of clinical governance initiatives.

References

Batalden, P.B. and Davidoff, F. (2007) What is quality improvement-and how can it transform healthcare? *Quality and Safety in Health Care* **16** (1), 2–3.

Department of Health (1997) *The New NHS: Modern, Dependable,* HMSO, London.

Department of Health (**1998**) *A First Class Service. Quality in the New NHS,* HMSO, London.

Department of Health (2004) *National Service Framework for Renal Services – Part 1 Dialysis and Transplantation,* HMSO, London.

Department of Health (2005) *National Service Framework for Renal Services – Part 2,* HMSO, London.

Department of Health (2008) *High Quality Care for All: NHS Next Stage Review Final Report,* Department of Health, London.

Department of Health (2009) *Renal National Service Framework Updated,* HMSO, London.

Department of Health (2011) Equity and excellence: Liberating the NHS. London: DH.

Institute for Healthcare Improvement (2012) *How to improve* www.ihi.org/knowledge/Pages/HowtoImprove/default.aspx (accessed 20 May 2013).

Kuentzle, W. and Thomas, N. (eds) (1995) *European Core Curriculum for a Post-Basic Course in Nephrology Nursing,* European Dialysis and Transplant Nurses Association/European Renal Care Association, Ghent, Belgium.

Langley, G.L., Nolan, K.M., Nolan, T.W. *et al.* (2009) *The Improvement Guide: A Practical Approach to Enhancing Organizational Performance,* 2nd edn, Jossey-Bass, San Francisco.

Luther, K. and Resar, R.K. (2013) Tapping front-line knowledge. *Healthcare Executive* 28 (1), 84–87, www.ihi.org/knowledge/Pages/Publications/TappingFrontlineKnowledge.aspx (accessed 20 May 2013).

Mead, P. (2000) Clinical guidelines: promoting clinical effectiveness or a professional minefield? *Journal of Advanced Nursing* **31** (1), 110–116.

NHS Information Centre (2011) *National Kidney Care Audit: Vascular Access Report 2011*,
http://data.gov.uk/dataset/national-kidney-care-audit-report/resource/f0a39e6f-0ae8-433d-9769-30b86fc5cf75 (accessed 23 May 2013).

Renal Association (2002) *Treatment of Adult Patients with Renal Failure. Recommended Standards and Audit Measures,* 2nd edn, Renal Association, Bristol.

Renal Association (**2007**) *Treatment of Adult Patients with Renal Failure. Recommended Standards and Audit Measures,* Royal College of Physicians, London.

Royal College of Nursing (2013) *Improving Quality of Care – RCN Guidance for Nurses on Clinical Governance,* http://www.rcn.org.uk/development/practice/clinical_governance (accessed 23 May 2013).

Thomas, L H., McColl, E., Cullum, N. ***et al.*** (1998). Effect of clinical guidelines in nursing, midwifery, and the therapies: a systematic review of evaluations. *Quality in HealthCare* **7** (4), 183–191.

Thomas, N. (2011) Care bundles: are they of use in renal care? *Journal of Renal Nursing* **3** (6), 215–217.

Van Waeleghem, J.P. and Edwards, P. (1995) *European Standards for Nephrology Nursing Practice,* European Dialysis and Transplant Nurses Association/European Renal Care Association, Ghent, Belgium.

Index

Renal Nursing, Fourth Edition. Edited by Nicola Thomas. © 2014 John Wiley & Sons, Ltd. Published 2014 by John Wiley & Sons, Ltd.