Clinical Skills in Hospitals Project

Respiratory 2

Module 6: Rapid sequence intubation

Module 7: Tracheostomy care and management

Module 8: Arterial Blood Gases (ABGs)

Module 9: Non-Invasive Ventilation (NIV)

Module 10: Introduction to mechanical ventilation

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For further information please contact the project manager Julian Van Dijk:

(03) 9288 2900
julian.vandijk@svhm.org.au

Preface

In 2007 the Department of Human Services commissioned St Vincent's Hospital Melbourne, to design and develop simulation-based training packages for clinical skills trainers in Victorian hospitals.

The project provides Victorian health professionals—specifically, hospital clinical educators—with a resource to deliver simulation-based clinical skills training.

The information in this manual complements current training programs and should be considered as a resource in the workplace, rather than the definitive resource on the topic.

Every effort has been made to provide the most current literature references. Authors have consulted other health professionals and current programs when possible in development to ensure that the modules produced in this package are consistent with current health practices.

Course delivery in condensed form

Sample Timetable for 1 day workshop

This is an example of how the modules in Respiratory Package 2 could be combined into a 1 day workshop. A sample timetable is provided for a course consisting of Modules 6, 7, 8, 9 and 10.

Course 1 (Modules 6, 7, 8, 9 and 10)

Timing	Activity	Objective
8.30 to 8.45	Introduction Faculty and Participants	
8.45 to 9.15	Facilitated Discussion	Module 1
9.15 to 9.30	Case Study 1	Module 1
9.30 to 9.45	Case Study 2	
9.45 to 10.00	Case Study 3	
10.00 to 10.10	Summation main points from Module 1	Module 1: all
10.10 to 10.25	Morning Tea	
10.20 to 10.50	Facilitated Discussion	Module 2: 1 and 2
10.50 to 11.05	Skill Station 1	Module 2: 3 and 4
11.05 to 11.20	Skill Station 2	Module 2: 3 and 4
11.20 to 11.35	Skill Station 3	Module 2: 3 and 4
11.35 to 11.50	Skill Station 4	Module 2: 3 and 4
11.50 to 12.00	Summation main points from Module 2	Module 2: all
12.00 to 12.40	Lunch	
12.40 to 1.05	Facilitated Discussion	Module 3: 1,2,3,8 & 9
1.05 to 1.20	Skill station 1	Module 3: 4, 5, 6, & 7
1.20 to 1.35	Skill Station 2	Module 3: 4, 5, 6, & 7
1.35 to 1.50	Skill Station 3	Module 3: 4, 5, 6, & 7
1.50 to 2.05	Skill Station 4	Module 3: 4, 5, 6, & 7
2.05 to 2.25	Summation main points from Module 3	Module 3: all
2.25 to 2.45	Afternoon Tea	
2.45 to 3.15	Introduction and Facilitated Discussion	Module 4: 1, 4, 5
3.15 to 3.45	Skills station	Module 4: 3
3.45 to 4.00	Summation main points from Module 4 Course evaluation	Module 4: all

Respiratory 2

Respiratory 2 was developed as a teaching and learning tool for Victorian clinical educators. The information contained in each module was developed using evidence-based resources and examples of best practice. Where expert opinion varies, a discussion section is included. However, it is not within the scope of *Respiratory 2* to address the full spectrum of local variations. Variations can occur in several areas, including practices relating to types of equipment used, infection control processes, practice guidelines and so on. Therefore, educators should, where appropriate, adapt content to reflect their local policies, procedures and protocols. This will ensure the relevancy of the package content to your learners.

The modules are designed to be discrete courses in their own right. They are timetabled so they can be completed in a 1–2 hour timeframe. This timeframe was chosen after we received feedback from clinical educators requesting shorter courses, because health professionals often have limited time to educate away from patients. However, the packages may also be combined into a one- or two-day course.

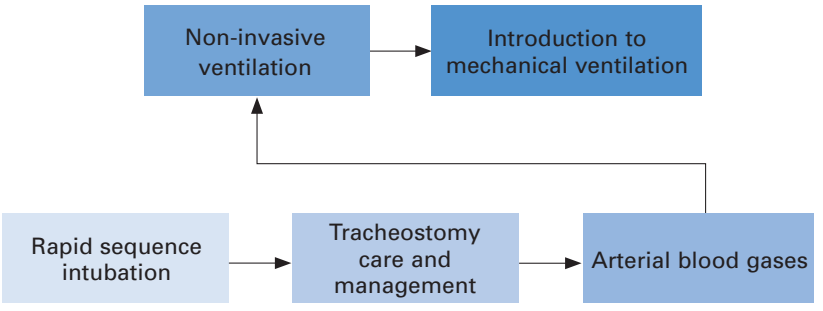
Respiratory 2 should be used as an educational tool to assist in the teaching of clinical skills. It is structured as a guide to assist clinical educators, and uses many concepts taught in the *Clinical Skills in Hospitals Project* (Train-the-Trainer courses). Educators are encouraged to build on this resource by adding their own scenarios which incorporate hospital/health service protocols, policies and other resources. Each module is designed as a lesson plan to incorporate the simulations into the teaching of clinical skills.

Aims

Respiratory 2 aims to make participants confident in their application of respiratory knowledge and skills on adults in different environments and settings.

Package structure

Respiratory 1 is the first of the two respiratory packages, and contains five modules that provide learning opportunities for health professionals at all levels of experience and from all health disciplines. Modules 1, 2 and 3 in *Respiratory 1* are regarded as fundamental, while Modules 4 and 5 are more difficult and are regarded as intermediate. *Respiratory 2* contains Modules 6–10, which are considered intermediate to complex. These modules focus on more complex respiratory management strategies that require participants to have completed *Respiratory 1*.

Level of complexity	Package structure
Complex For participants with more than 4 years experience or who have completed Modules 1–4	
Intermediate For participants in postgraduate years 3–4 or who have completed Modules 1 and 2	
Fundamental For participants in postgraduate years 1–2	

Respiratory 2 consists of: *Module 6: Rapid sequence intubation*, *Module 7: Tracheostomy care and management*, *Module 8: Arterial blood gases*, *Module 9: Non-invasive ventilation* and *Module 10: Introduction to mechanical ventilation*.

Respiratory 2 was designed to develop participants' knowledge, skills and behaviours in the use of respiratory skills and practices, as well as expose them to increasingly complex scenarios aimed at testing their ability to combine these individual skills, work as a team and problem solve in more difficult situations.

Educators delivering these modules should be aware of participants' level of experience and choose appropriate modules. Modules presume an increasing level of knowledge as they progress, ranging from a fundamental knowledge of anatomy and physiology for the fundamental modules, up to detailed knowledge of respiratory practices for the complex modules. Novice participants (such as first-year graduates) are expected to start with the fundamental modules, and only move onto intermediate and more complex modules as they demonstrate proficiency. More experienced participants may start at the intermediate level if the educator is satisfied that they have the prior knowledge and skills. Individual educators are responsible for assessing each participant's baseline knowledge and determining which modules they should complete. More specific descriptions of presumed knowledge are outlined in each module.

The design of these packages presumes that the clinical educators using them have knowledge and expertise in current best practice regarding the teaching of clinical skills and conducting facilitated discussions. Knowledge and expertise are presumed commensurate with the Department of Human Services' basic and advanced Train-the-Trainer programs. Clinical educators are encouraged to refer to the *Department of Human Services' Clinical Skills Facilitators Manual* for theory on:

1. Peyton's model for teaching clinical skills
2. leading small group discussions
3. giving feedback
4. crisis resource management skills.

Module 6: Rapid sequence intubation

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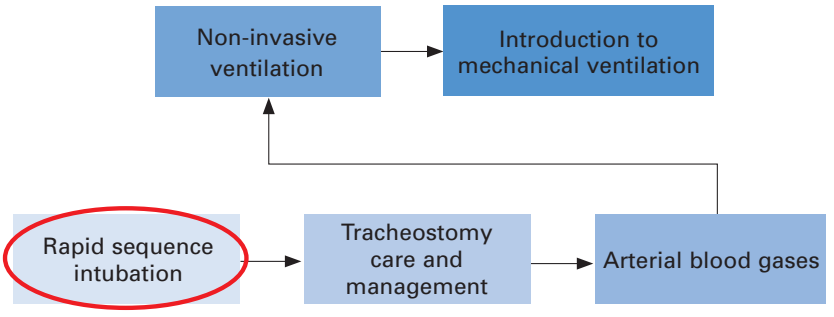
Complex For participants with more than 4 years experience or who have completed Modules 1–4	
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Module 6: Rapid sequence intubation

Author: Dr. Antony Tobin

Aims

This module teaches rapid sequence intubation skills relevant to both medical and nursing teams in the setting of a hospital clinical environment.

Rapid sequence intubation is a specialised skill, which requires appropriately qualified persons to run. While the skills stations for this module provide intubation opportunities for all participants, this does not give nursing staff increased scope of practice in the clinical setting.

Presumed knowledge

Participants attempting *Module 6: Rapid sequence intubation* should have completed an advanced life support program or, in the case of nursing staff assisting with this procedure, basic life support skills.

Because rapid sequence intubation (RSI) is a complex procedure, medical staff attempting this skill should seek clarification about their scope of practice in utilising these skills. This may also depend on a health service's policy.

Objectives

By the end of this module, participants should have:

1. identified the indication for RSI in the hospital clinical setting
2. discussed patient assessment, with particular attention to identifying the potentially difficult airway
3. identified and discussed relevant RSI pharmacology
4. identified and discussed the normal and failed attempt RSI algorithms
5. practised RSI algorithms using the three skills stations provided
6. participated as part of a team performing RSI, and debriefed, considering the aspect of team approach significant to this skill.

Background information for educators

RSI is the most common method used to establish a safe airway in emergency situations. It refers to pre-oxygenation of the patient followed by delivery of an induction agent and a muscle relaxant in association with cricoid pressure to reduce regurgitation. This produces a relaxed unconscious patient ideal for laryngoscopy and orotracheal intubation. RSI generally provides better conditions for intubation and is associated with fewer complications than intubation attempts with sedative drugs alone. RSI should only be performed by individuals who understand the technique, drugs and indications.

Indications

These include:

- hypoxia with a failed response to other interventions (SpO_2 < 90)
- hypercapnia with a failure to respond to other interventions, such as NIV and reversal of respiratory depressants
- altered mental state such that there is failure to protect the airway
- anticipation of threatened airway, for example, in the setting of thermal injury.

Anaesthesia is required for patient safety or to perform investigations. In cases of cardiac arrest, and often respiratory arrest, intubation can occur without drug administration, but the principles of airway manipulation are the same.

Assessment of the patient and situation

1. Is intubation needed/appropriate now?
2. Can it wait until more senior help arrives, or the patient is in a safer environment (ICU compared to general ward)?
3. Do I have appropriate equipment and assistance?
4. Do I have adequate skills/backup?

Airway assessment—anticipated ease of intubation

Although RSI is generally an urgent procedure, there is often time to assess the airway so that difficulty with intubation can be anticipated. This may either change your method of intubation (for example, change to awake fibre-optic) or delay your intubation until more senior assistance arrives. Absence of signs of a difficult airway does not mean that intubation will be easy.

Difficult airway

These characteristics may indicate a difficult airway:

- known history of difficult airway:
  - ask patient
  - check previous anaesthetic records in the medical history
- body habitus:
  - short neck, obesity, receding chin (all suggest laryngoscopy may be difficult)
  - presence of a beard (may make bag and mask difficult or hide anatomical variation)
- reduced neck mobility or severe kyphosis
- Mallampati class I–IV:

  - observation of the pharynx with the patient sitting, neck flexed, atlanto-axial extension (sniffing position) with tongue protruded
  - Class > 2 is associated with increased probability of difficult laryngoscopy (see Figure 1)
- thyromental distance:
  - distance between thyroid cartilage and chin—less than three finger widths is associated with increased difficulty
- mouth opening:
  - < 3 cm associated with increased difficulty
- teeth:
  - long incisor teeth (difficult)
  - edentulous (often easier).

In an anticipated difficult airway, call for assistance before intubation if possible, or choose an alternative method to orotracheal intubation using RSI.

The five Ps

Proper **P**reparation **P**revents **P**oor **P**erformance

Equipment

Ensure these items are at hand:

- monitoring:
  - SpO_2
  - blood pressure (preferably continuous)
  - ECG
  - Yankauer sucker
  - wall suction
- reliable oxygen supply
- bag and mask, preferably with PEEP valve available
- oropharyngeal airway
- good venous access (preferably 18G or larger) with IV crystalloid/colloid running
- assistance: at least one assistant plus another experienced individual if difficulty is anticipated
- laryngoscope with Macintosh size 3 and 4 blades
- endotracheal tube of appropriate size (75 for women, 80 for men)
- cuff—checked and lubricated

- introducing stylet and syringe
- end-tidal CO_2 indicator
- drugs:
  - induction
  - relaxant
  - vasopressor
- post-intubation drugs—drawn up and labelled with vasopressor kept separately
- stethoscope
- laryngeal mask (size 4) and bougie—although not standard for RSI, it is generally good practice to have them handy in case difficulties are encountered.

Drugs

Critically ill patients generally tolerate induction drugs poorly, so often require relatively small doses. Give the minimum dose required to induce hypnosis.

Pre-induction

Pre-induction is given to reduce anxiety and avoid the blood pressure rise and cardiovascular stress associated with intubation. This may be unnecessary in many emergent intubations.

Midazolam:

- sedative
- hypnotic often used as induction drug as relatively haemodynamically stable compared with propofol.

Fentanyl:

- sedative analgesic
- limits hypertensive response to intubation, but may induce hypotension and hypoventilation.

Induction drugs

Propofol:

- rapid-acting hypnotic with short half-life
- anticonvulsant and antiemetic
- at higher doses it produces apnoea and muscle relaxation
- its principal side-effect is hypotension, due to reduced systemic vascular resistance
- dose: 0.5–2 mg per kg body weight
- for unstable patients use a lower dose.

Thiopentone:

- rapid-acting hypnotic with a short duration of action
- associated with reduction in sympathetic activity and therefore hypotension
- hypotension may be profound in the hypovolaemic/septic patient
- the doses needed in critically ill patients are much smaller than traditional anaesthetic use (1–15 mg per kg body weight).

Relaxant drugs

Suxamethonium:

- depolarising muscle relaxant with rapid onset 30–60 seconds and short duration of approximately 5 minutes
- major complication is hyperkalaemia, which can induce cardiac arrhythmias
- contraindicated in history of malignant hyperthermia, uncontrolled hyperkalaemia, myopathy, chronic neuropathy/stroke, severe burns after 24 hours
- dose 15 mg per kg body weight
- do not under-dose, because insufficient dosage may impair ability to intubate the patient.

Rocuronium:

- alternative to suxamethonium when it is contraindicated
- non-depolarising muscle relaxant
- combined with propofol induction, it gives intubating conditions after 60 seconds equivalent to suxamethonium
- has prolonged action of 30 to 60 minutes
- dose 1 mg per kg body weight.

Vasopressors

Metaraminol:

- a potent sympathomimetic agent that increases blood pressure, principally by its vasoconstrictor action
- useful in the setting of intubation if induction agents cause hypotension unresponsive to volume
- give in aliquots of 0.5–1 mg every 1–2 minutes until response seen
- metaraminol comes as 10 mg in 1 mL
- it must be diluted for IV injection
- one mL of metaraminol (10 mg) diluted in 19 mL of diluent to make a 0.5 mg/mL solution is safest.

Sequence

Ensure all equipment is prepared and working.

Explain the procedure to the patient.

Ensure your assistant knows what is expected/what to do, for example, when and how to apply cricoid pressure.

Pre-oxygenate—this washes out nitrogen in the lungs, giving greater oxygen reserves for the intubation procedure:

- Pre-oxygenate the patient for 5 minutes using 100% rebreather mask or tight-fitting Hudson mask with 15 L per minute O_2.
- Alternatively, allow the patient to breath from the bag and mask with 15 L O_2 per minute.
- Ask alert patients to take eight deep breaths.
- Use of Continuous positive airway pressure (CPAP) / non-invasive ventilation (NIV) may enable 100% saturations in patients with severe lung disease.
- Do not provide PPV by bag and mask unless the patient is not breathing or saturations do not come up with 100% O_2.
- If PPV is required with bag and mask, provide cricoid pressure before intubation.

Ensure that the IV is running freely.

Consider pre-treatment drugs if the patient is fully conscious, or if there are concerns regarding hypertension, cardiovascular stress during intubation or raised ICP.

Give an induction drug, followed by a paralysis drug.

Apply cricoid pressure immediately induction drugs are given.

Position the patient's head on pillow and place head in the sniffing position (neck flexed and atlanto-occipital joint extended). This aligns the mouth, pharynx and larynx.

Insert the laryngoscope into the right side of the mouth, pushing the tongue to the left.

Visualise the epiglottis and advance the tip of the laryngoscope between the base of tongue and the epiglottis.

Lift the tongue and mandible forward at an angle of 45˚. Do not lever forwards.

Visualise the cords:

- Manipulate the larynx if necessary.
- BURP—backwards, upwards, rightwards pressure.

Visualise the endotracheal tube tip passing through the cords and pass to a depth of 1 cm past the cuff.

Inflate cuff and ventilate.

Check ETT position:

- end-tidal CO_2
- bilateral breath sounds
- the chest should rise and fall symmetrically
- ETT fogging and saturations should improve.

Release cricoid pressure after the ETT position has been confirmed.

Post-intubation management:

- Record ETT depth.
- Secure ETT.

Set and connect ventilator:

- Aim for 8 mL per kg body weight tidal volume.
- PEEP at minimum of 5 cm H_2O, but consider higher if difficult oxygenation.

Maintain sedation, analgesia and neuromuscular blockade.

Failed intubation algorithm

Occasionally, intubation is difficult or fails. In such circumstance you must have a plan for keeping the patient alive and for securing the airway.

Patients die from failure to oxygenate—not failure to ventilate or intubate. If saturations are satisfactory (SpO_2 > 88), and you cannot secure an orotracheal airway after 2–3 attempts, wait for assistance before making further attempts.

Plan

Call for assistance—another experienced clinician may be able to secure the airway or assist you in doing so.

Bag and mask ventilation:

- Consider two-person bagging (one to hold the mask with both hands and one to bag).
- Use a PEEP valve, especially in the presence of APO, and diffuse lung disease.
- Use an oropharyngeal airway.

If SpO_2 > 88, consider waiting for assistance—the emphasis should be on maintaining oxygenation, rather than securing airway.

If SpO_2 > 88, consider other methods/adjuncts for subsequent attempts:

- optimise head position
- BURP
- Macintosh No. 4 blade
- bougie
- size 7 ETT.

More than 2–3 attempts by the same operator using the same method will probably cause more harm (bleeding, oedema), and may be detrimental to attempts by others or other methods.

If SpO_2 < 88 with bag and mask try LMA or intubating LMA.

If unable to achieve SpO_2 > 88 by bag and mask or LMA, and you have failed attempts at intubation, consider:

- needle cricothyroidotomy and oxygenation by one of two methods (see www.resus.com.au/index.php?id=74)
- three-way tap with oxygen tubing connected for jet ventilation (1 second inspiration to 4 seconds expiration)
- 14G angiocath with bag connected via 3 mL syringe and size 7 ETT tip

or

- cricothryrotomy using Seldinger technique with proprietary tracheostomy tube/dilator over-wire kit (for example, Melker by Cook).

Learning activities

Suggested learning activities and timetables are outlined below.

Timing	Activity	Objective
30 minutes	Facilitated discussion	1, 2, 3, 4
20 minutes	Skills stations	5, 6
20 minutes	Skills stations	5, 6
20 minutes	Skills stations	5, 6
10 minutes	Summary of main points from	
5 minutes	Evaluation	

Total time = 1 hour 45 minutes

Facilitated discussion

The facilitator should lead a discussion amongst participants about the issues covered in the background information. The facilitator should not give a didactic lecture, but instead promote open discussion and knowledge sharing amongst participants. Participants should be encouraged to describe any real-life experiences they have encountered.

Key points to develop in the facilitated discussion:

- indication
- assessment, particularly in identifying the difficult airway patient
- procedural planning—team and equipment recourses required
- pharmacology options
- RSI algorithm
- failed RSI attempt algorithm.

Due to the potentially complex nature of this procedure, participants must leave this session with a clear understanding of the health service's policy and procedure regarding to RIS relevant to the clinical educators' workplace.

Skills stations

The two clinical skills stations provide opportunities to practise the core skill required in three clinical situations:

1. non-complicated RSI
2. difficult airway RSI
3. failed attempt RSI.

The skills stations require either full body manikins or airway trainers that can be intubated, and have the ability to change airway dynamics—that is, swelling of the tongue.

The skills stations can be set up in one room using tables or beds, depending on the resources available.

If only one airway manikin or full body manikin with the correct airway features is available, then run each skills station in sequence, allowing each participant to practise the skill. You may also reduce the group size from 12 to 6 to maximise individual participation.

Each RSI station should allow for the following to be demonstrated.

Skills station 1

1. Set up equipment and position the patient for RSI. Explain to patient and assistants what you will do and what they should do. Key learning points:
    a. Ensure all equipment is ready and working for RSI as described above, including selection of drugs. The scenario can be varied to include contraindications to suxamethonium.
    b. Explain the procedure to model and pre-oxygenate.
    c. Describe RSI to the assistants, including how to perform cricoid pressure—show the assistant where to put their fingers and state that the cricoid should not be removed until told.
2. The skills station should also consider the team approach to the situation, identifying roles and resources required to improve a team approach to RSI.

Skills station 2 (difficult airway)

The manikin for this station requires the ability to swell the tongue and obstruct the view of the vocal cords.

1. Set up equipment and position the patient for RSI. Explain to the patient and assistants what you will do and what they should do. Key learning points:
    a. Ensure all equipment is ready and working for RSI as described above, including selection of drugs. The scenario can be varied to include contraindications to suxamethonium.
    b. Explain the procedure to model and pre-oxygenate.
    c. Describe RSI to the assistants, including how to perform cricoid pressure—show the assistant where to put their fingers and state that the cricoid should not be removed until told.
2. Demonstrate how to use the laryngoscope and use the bougie for intubation.
3. The educator should also consider the team approach to the situation, identifying roles and resources required to improve a team approach to RSI.

Skills station 3: Failed airway

This station requires that there be a difficult airway present. It is handed over to the participants, who should employ the failed airway algorithm.

1. Set up equipment and position the patient for RSI. Explain to patient and assistants what you will do and what they should do. Key learning points:
    a. Ensure all equipment is ready and working for RSI as described above, including selection of drugs. The scenario can be varied to include contraindications to suxamethonium.
    b. Explain the procedure to model and pre-oxygenate.

   c. Describe RSI to the assistants, including how to perform cricoid pressure—show the assistant where to put their fingers and state that the cricoid should not be removed until told.

2. Demonstrate how to use the laryngoscope and use the bougie for intubation.
3. Display knowledge of an algorithm for dealing with failed intubation.
4. The educator should also consider the team approach to the situation, identifying roles and resources required to improve a team approach to RSI.

Summary

The summary session reinforces content covered in the learning activities, and is an opportunity for participants to reflect on what they have covered. No new material should be introduced.

Important points to include in the summary are:

- calls for assistance
- bag and mask techniques—two-hand, two-person, insertion of oropharyngeal airway, use of PEEP valve
- response to inability to maintain saturations and inability to intubate, for example, use of laryngeal mask, ability to perform needle cricothyrotomy, including setting up a system for oxygenation.

Resource list

The following resource list is based on two facilitators for 12 participants (1:6 ratio). As a minimum, the following resources are needed to conduct this module.

Resource	Quantity	Additional comments
Facilitators	Up to 2	Must be able to intubate and manipulate tongue swelling
Airway manikins	Up to 3	Must be able to intubate and manipulate tongue swelling
Laryngoscope	3	
Bag and mask sets	3	
ETT tubes sizes 6.5, 7 and 7.5	3 sets	
Bougie	3	
Catheter mounts	3	
O_2 tubing and wall or bottle outlets	3	
Simulated drugs for intubation	3 sets	
Tape for securing ETT in place	3	

Evaluation

A formal evaluation has been specifically developed for this module. It incorporates the objectives of the module and the perceptions of the participants about whether they have increased their understanding by working through the module. It is highly recommended that this formal evaluation be copied and completed by all participants at the completion of the module.

A range of informal evaluation tools may also be used in conjunction with this evaluation throughout the module, including those available in the Department of Human Services' *Clinical Skills Facilitators Manual* from the basic course conducted in 2007.

References

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3. Kabrhel C, Thomsen T, Setnik G and Walls R 2007 Orotracheal Intubation 356: e15 April 26 (available at content.nejm.org/cgi/video/356/17/e15/)
4. Intubation: www.youtube.com/watch?v=5ueZ9YO2sRM
5. Intubation during General Anaesthesia: www.youtube.com/watch?v=eRkleyIJi9U&feature=related
6. LMA (insertion of a laryngeal mask): www.youtube.com/watch?v=96e46PyARaU&NR=1
7. Needle Cricothyroidotomy by Resuscitation Education: www.resus.com.au/index.php?id=74
8. Hsiao J and Pacheco-Fowler NEJM 2008 Cricothyroidotomy Vol 358: e25 May 29: content.nejm.org/cgi/video/358/22/e25/

Resources

Facilitator feedback form

The following form should be used to assist you in giving feedback after each participant has practised their RSI skills at the skills station.

Feedback using the Pendleton model

Pendleton's model of feedback assists learners to maximize their potential at different stages of training, raise their awareness of strengths and areas for improvement, and identify actions to be taken to improve performance. Pendleton's rules are structured in such a way that the learner identifies the positives first, in order to create a safe environment. This is followed by the facilitator or group reinforcing these positives and discussing skills to achieve them. Different techniques are then suggested. The advantage of this method is that the learner's strengths are discussed first. Avoiding a discussion of weaknesses right at the beginning prevents defensiveness and allows reflective behaviour in the learner.

Below is a series of questions to assist you in this technique:

1. Ask the learner how they feel.
2. Ask the learner what went well and why (this can be combined with question 1 and 3).
3. Tell the learner what went well and why.
4. Ask the learner what could have been done better and why.
5. Tell the learner what could have been done better and why.
6. Summarise the learner's strengths and identify up to three things to concentrate on.

Note: This form does not need to be given to the participant — it is a guide for you, the group facilitator.

Module 6: Rapid sequence intubation—evaluation

Thank you for participating in this module. As part of our commitment to quality improvement the following questionnaire will be used to plan future implementation of this module. We appreciate your time completing this evaluation.

1. Overall

How would you rate this module?

☐ poor ☐ fair ☐ good ☐ very good ☐ outstanding

2. Learning objectives

Please consider whether this module was successful in meeting the following learning objectives:

Respiratory 2 Learning objectives of Module 6: Rapid sequence intubation	Strongly disagree	Disagree	Slightly agree	Agree	Strongly agree
Identified the indication for RSI in the hospital clinical setting	☐	☐	☐	☐	☐
Discussed patient assessment, particularly identification of the potentially difficult airway	☐	☐	☐	☐	☐
Identified and discussed relevant RSI pharmacology	☐	☐	☐	☐	☐
Identified and discussed the normal and failed attempt RSI algorithms	☐	☐	☐	☐	☐
Practised RSI algorithms using the three skills stations provided	☐	☐	☐	☐	☐
Participated as part of a team performing RSI, and debriefed, considering the aspect of team approach significant to this skill	☐	☐	☐	☐	☐

3. Important learning outcomes

What are the three most important things you have learned from this module?

4. Module implementation

Please indicate to what extent you agree or disagree with each of the following statements in relation to the implementation of the module.

	Strongly disagree	Disagree	Slightly agree	Agree	Strongly agree
The facilitator respected my experience	☐	☐	☐	☐	☐
The facilitator encouraged my participation	☐	☐	☐	☐	☐
I was able to ask the facilitator questions	☐	☐	☐	☐	☐
The facilitator was able to answer my questions	☐	☐	☐	☐	☐
The feedback I received was clear	☐	☐	☐	☐	☐
The feedback I received will assist me my future performance	☐	☐	☐	☐	☐
There was adequate time for the skills stations	☐	☐	☐	☐	☐
There was adequate time for the facilitated discussions	☐	☐	☐	☐	☐
There was adequate time for the simulations	☐	☐	☐	☐	☐
I have increased my confidence in performing or supporting an RSI procedure	☐	☐	☐	☐	☐
I have identified future learning needs in this topic area	☐	☐	☐	☐	☐

5. Future module implementation

Do you think the module should be altered in any way? ☐ yes ☐ no

If yes, what recommendations do you have?

Thank you

PowerPoint presentation

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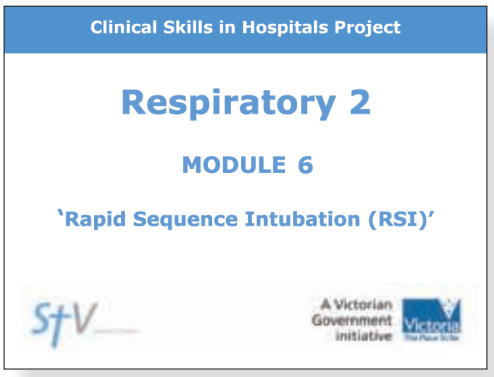

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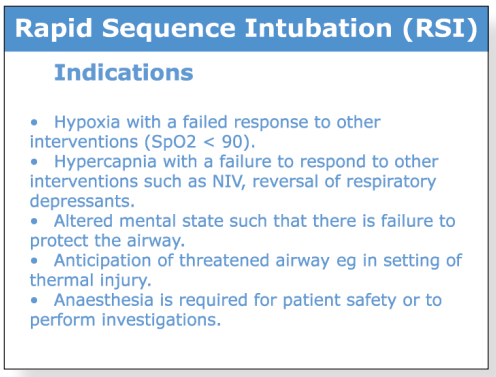

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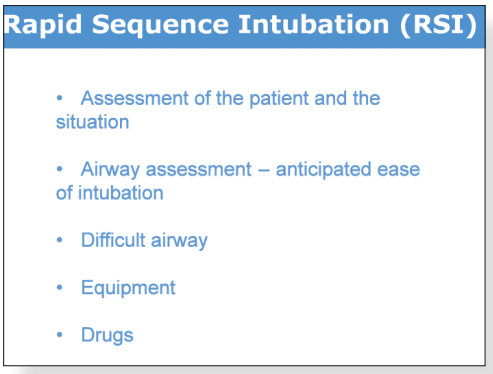

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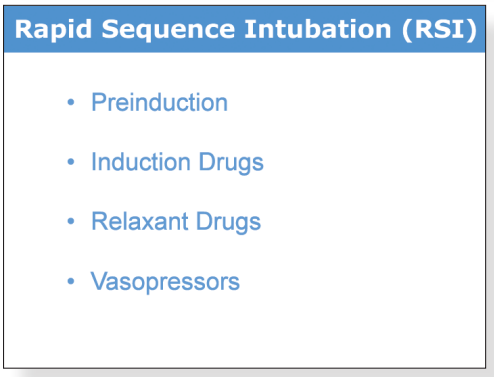

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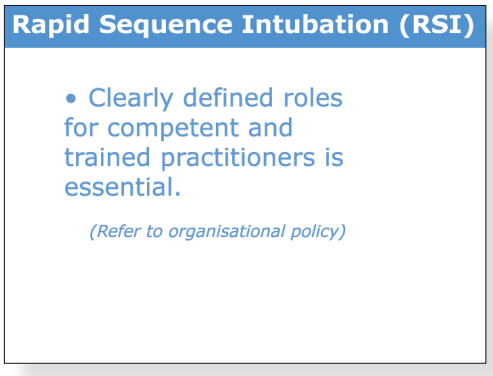


Module 7: Tracheostomy care and management

Introduction

Respiratory 2 was developed as a teaching and learning tool for Victorian clinical educators. The information contained in each module was developed using evidence-based resources and examples of best practice. Where expert opinion varies, a discussion section is included. However, it is not within the scope of *Respiratory 2* to address the full spectrum of local variations. Variations can occur in several areas, including practices relating to types of equipment used, infection control processes, practice guidelines and so on. Therefore, educators should, where appropriate, adapt content to reflect their local policies, procedures and protocols. This will ensure the relevancy of the package content to your learners.

The modules are designed to be discrete courses in their own right. They are timetabled so they can be completed in a 1–2 hour timeframe. This timeframe was chosen after we received feedback from clinical educators requesting shorter courses, because health professionals often have limited time to educate away from patients. However, the packages may also be combined into a one- or two-day course.

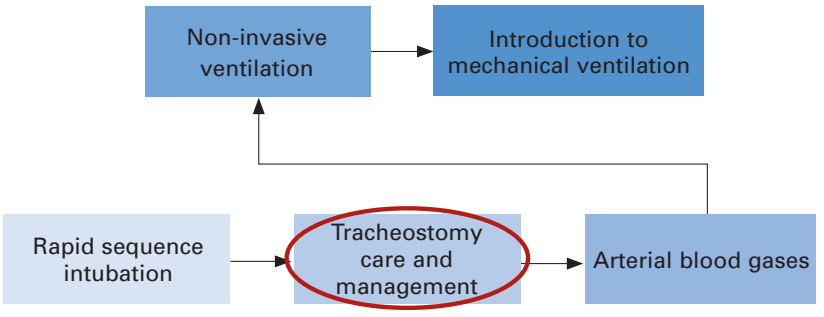
Respiratory 2 should be used as an educational tool to assist in the teaching of clinical skills. It is structured as a guide to assist clinical educators, and uses many concepts taught in the Clinical Skills in Hospitals Project (Train-the-Trainer courses). Educators are encouraged to build on this resource by adding their own scenarios which incorporate hospital/health service protocols, policies and other resources. Each module is designed as a lesson plan to incorporate the simulations into the teaching of clinical skills.

Aims

Respiratory 2 aims to make participants confident in their application of respiratory knowledge and skills on adults in different environments and settings.

Package structure

Respiratory 1 is the first of the two respiratory packages, and contains five modules that provide learning opportunities for health professionals at all levels of experience and from all health disciplines. Modules 1, 2 and 3 in *Respiratory 1* are regarded as fundamental, while Modules 4 and 5 are more difficult and are regarded as intermediate. *Respiratory 2* contains Modules 6–10, which are considered intermediate to complex. These modules focus on more complex respiratory management strategies that require participants to have completed *Respiratory 1*.

Level of complexity	Package structure
Complex For participants with more than 4 years experience or who have completed Modules 1–4	
Intermediate For participants in postgraduate years 3–4 or who have completed Modules 1 and 2	
Fundamental For participants in postgraduate years 1–2	

Respiratory 2 consists of: *Module 6: Rapid sequence intubation*, *Module 7: Tracheostomy care and management*, *Module 8: Arterial blood gases*, *Module 9: Non-invasive ventilation* and *Module 10: Introduction to mechanical ventilation*.

Respiratory 2 was designed to develop participants' knowledge, skills and behaviours in the use of respiratory skills and practices, as well as expose them to increasingly complex scenarios aimed at testing their ability to combine these individual skills, work as a team and problem solve in more difficult situations.

Educators delivering these modules should be aware of participants' level of experience and choose appropriate modules. Modules presume an increasing level of knowledge as they progress, ranging from a fundamental knowledge of anatomy and physiology for the fundamental modules, up to detailed knowledge of respiratory practices for the complex modules. Novice participants (such as first-year graduates) are expected to start with the fundamental modules, and only move onto intermediate and more complex modules as they demonstrate proficiency. More experienced participants may start at the intermediate level if the educator is satisfied that they have the prior knowledge and skills. Individual educators are responsible for assessing each participant's baseline knowledge and determining which modules they should complete. More specific descriptions of presumed knowledge are outlined in each module.

The design of these packages presumes that the clinical educators using them have knowledge and expertise in current best practice regarding the teaching of clinical skills and conducting facilitated discussions. Knowledge and expertise are presumed commensurate with the Department of Human Services' basic and advanced Train-the-Trainer programs. Clinical educators are encouraged to refer to the *Department of Human Services' Clinical Skills Facilitators Manual* for theory on:

1. Peyton's model for teaching clinical skills
2. leading small group discussions
3. giving feedback
4. crisis resource management skills.

Module 7: Tracheostomy care and management

Author: Alicia Martin

Aims

The purpose of this module is to teach and/or consolidate participants' knowledge of clinical skills necessary to safely and effectively manage patients with a tracheostomy.

Presumed knowledge

This module is targeted to health professionals with little or no experience in tracheostomy care. However, they are expected to have completed *Respiratory 1—Module 1: Pathophysiology, Module 2: Respiratory assessment and Module 5: Airway suctioning*. Other presumed prior knowledge includes:

- upper airway anatomy: mouth, tongue, pharynx, larynx, trachea and oesophagus
- cardiovascular anatomy and pathophysiology: blood pressure, circulation and oxygenation.

Objectives

By the end of this module, participants should have:

1. identified what a tracheostomy is and the indications for one
2. identified local/hospital policies and procedure
3. identified the differences between types of tracheostomies (for example, cuffed compared to uncuffed) and why they might be chosen
4. identified differences between tracheostomy sizes and why they might be chosen
5. practised the basic technique of setting up a humidifier
6. practised suctioning via a tracheostomy on a simulated manikin
7. practised removal/insertion of inner cannulae and cleaning of inner cannulae
8. practised tracheostomy cuff inflation and deflation
9. practised measuring cuff pressures and learned how to identify an air leak
10. practised how to identify blocked tracheostomies and gained familiarity with emergency procedures
11. developed an understanding of factors influencing tracheostomy weaning and removal
12. understood the roles of AH involved in tracheostomy weaning.

The purpose of this module is to teach participants how to care for patients with a tracheostomy. This module is not intended to cover airway insertions—this will be covered in *Respiratory 2—Module 10: Introduction to mechanical ventilation*.

Background information for educators

Tracheostomy

A tracheostomy is a surgical opening made in the trachea between the first and second, or second and third tracheal cartilages, through which a tracheostomy tube is inserted.

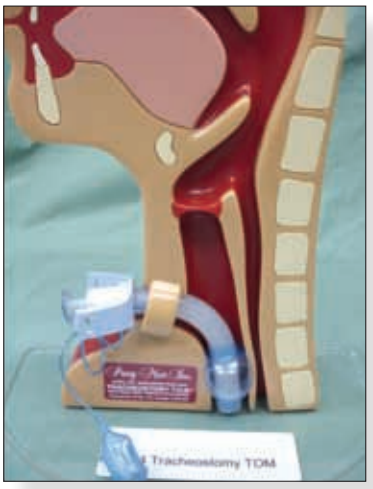


Figure 1: Tracheostomy

Temporary tracheostomy

A temporary tracheostomy is an elective procedure, with a view to removing it when indicated. This can be done either surgically or as a percutaneous procedure. Percutaneous tracheostomies are more commonly performed in the ICU by medical staff.

Surgical tracheotomies are conducted in theatre, usually by ENT or faciomaxillary doctors.

Permanent tracheostomy

A permanent tracheostomy may be inserted when required for permanent airway patency (for example, subglottic stenosis, bilateral vocal cord palsy).

Emergency tracheostomy

An emergency tracheostomy is performed in an emergency situation, when the airway is acutely obstructed and endotracheal intubation is not possible. A cricothyroidotomy may be performed in this situation. Alternatively, a tracheostomy may be performed, depending on a multitude of factors, including who the operator is, the patient's anatomy and the clinical scenario.

Indications for a tracheostomy

The most common reasons for a tracheostomy include:

- physical obstruction of the airway
- airway protection to prevent/minimise aspiration into the lungs
- sputum clearance for patients who cannot adequately clear their secretions
- to assist weaning from mechanical ventilation, especially where it is anticipated to be slow.

Equipment

Refer to local hospital policies and procedures. A supply of equipment in the same clinical area as the patient is generally recommended, to allow for daily management, as well as in the event of an emergency.

Recommended equipment:

- tracheal dilators
- two spare tracheostomy tubes—one should be the same size as is currently inserted and the other one size smaller
- manometer
- 10 mL syringe
- suction catheters (appropriate size)
- Yankauer sucker
- Guedel airway (appropriate size)
- gloves
- goggles
- infectious waste bag
- hospital-approved hand hygiene materials (for example, antiseptic hand rub)
- brush to clean inner cannula and spare inner cannula (if applicable)
- an appropriately sized anaesthetic face mask and endotracheal catheter mount (generally available on resuscitation trolley)
- a humidifier and suction canister/wall suction should also be in the bed area.

Types of tracheostomy

- cuff compared to uncuffed—pilot balloon

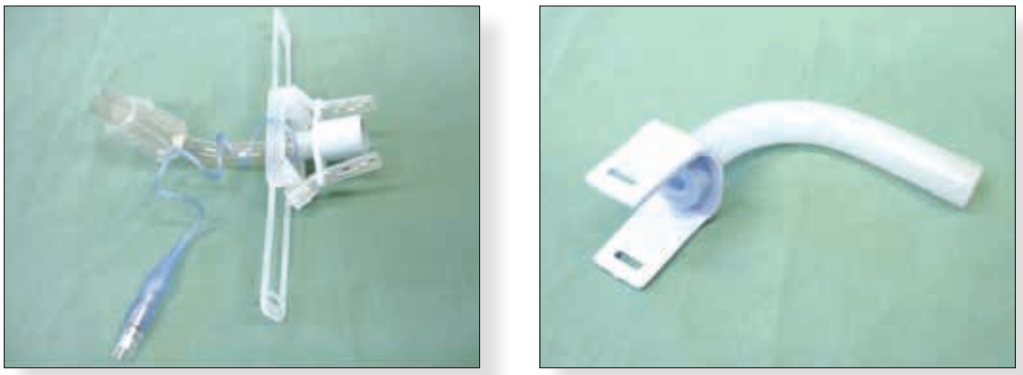


Figure 2: Cuffed compared to uncuffed tracheostomy

- double/single lumen (with or without inner cannula)

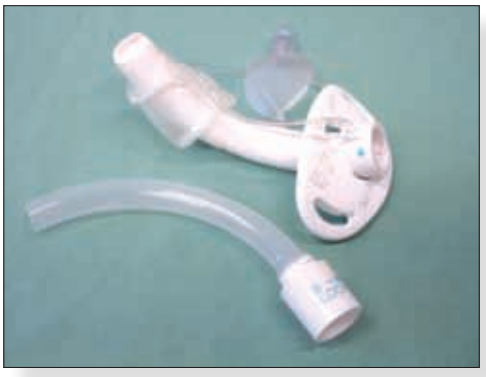


Figure 3: Double and single lumen tracheostomy

- talking foam compared to mini trache
- sizes of tracheostomy—according to patient size and neck size.

Figure 4: Passy-Muir values

Speaking valves

These include the Passy-Muir speaking valve. The speech pathologist usually advises when this is appropriate to commence. Speaking valves should only be placed when the cuff is deflated, and it is also recommended that they be placed only during daytime hours. Speaking valves allow the patient to speak. When the patient inhales, the speaking valve opens, allowing air to enter the tracheostomy tube and lungs. At the end of inspiration the valve closes, and remains closed during exhalation. During exhalation, the air is redirected around the tracheostomy tube and through the larynx and pharynx, thus allowing air to pass through the vocal cords, producing voice.

Oxygen

Oxygen should be delivered to the patient via a tracheostomy shield with a humidifier in situ. Refer to local hospital policies and procedures regarding humidifiers. Heated humidifiers are recommended, for example, Fisher & Paykel. Follow local procedures to set up the humidifier and for changing of humidifier systems (weekly is recommended).

Refer to local hospital policies and procedures regarding oxygen therapy. Ensure correct flow to deliver FiO_2 as required.

Suctioning

Limit suctioning to when clinically indicated. This is essential to avoid potential adverse side-effects associated with suctioning. The frequency of suctioning required should be documented.

See prerequisite suctioning module.

Secretions

When suctioning, take note of the secretions removed. Note and document:

- amount—small, moderate, large, copious
- consistency—thick, thin
- colour—clear, creamy, yellow, green.

Patients should also generally have their bedhead raised, to avoid aspiration of secretions. Early mobilisation is encouraged to assist with secretion removal.

Assessment of the patient with a tracheostomy

At the beginning of each shift check:

- patient assessment, including standard vital signs, cough, oxygen requirements, pain
- tracheostomy size
- patency of inner cannula (if applicable)

- stoma and clean once per shift
- tracheostomy tapes
- cuff pressure with manometer (if applicable)
- suction
- humidifier and oxygen therapy (including trache shield)
- secretions and need for suctioning
- equipment, including emergency equipment required
- medical file for:
  - tracheostomy weaning plan (if applicable)
  - documentation from medical and allied health staff involved
  - identification of issues arising from previous shift.

See further details below for detailed procedures.

Tracheostomy changes

Refer to local hospital policies and procedures.

Only experienced staff should change tracheotomies, with appropriate medical support available if required.

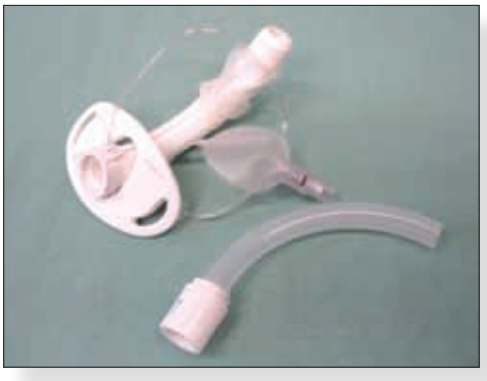


Figure 5: Checking the inner cannula

Checking the inner cannula (if appropriate)

- At minimum, remove once per shift, or more regularly if required (for example, if copious, thick secretions are present). Gently pull on plastic ring, and follow the anatomical lines of trachea to remove.
- Replace the removed cannula immediately with a spare inner cannula. If the outer tube is left for any length of time without an inner cannula, this may lead to crusting of secretions and potentially an obstructed tracheostomy.

- Follow anatomical lines of trachea to insert.
- Don goggles.
- Perform hand hygiene and don non-sterile gloves.
- Place the dirty inner cannula in a clean kidney dish and cover with sterile normal saline.
- Agitate secretions to remove. If necessary, use an approved bristle brush.
- Do not soak the inner cannula, because this may lead to colonisation of bacteria.
- Remove gloves and perform hand hygiene.

Assessing the stoma

Wound care is vital to avoid infection or ulceration of the stoma. This area is at risk due to constant moisture from heated humidified oxygen and/or secretions.

Assess:

- skin integrity—clean, dry, intact
- colour—watch for redness
- drainage—ensure dressing and tapes are clean and dry
- swelling and potential subcutaneous emphysema.

If sutures are present, check patency. Sutures are generally removed after approximately seven days.

Cleaning the stoma and changing tracheostomy tapes

These should be cleaned once per shift. Refer to local policy. However, the following equipment is generally required:

- dressing pack
- extra sterile gauze (if a large amount of exudate is present)
- sterile normal saline
- clean tracheostomy tapes
- goggles and non-sterile gloves
- infectious waste bag
- tracheostomy dressing (refer to local hospital policy)
- a second person to assist with tracheostomy tapes.

Procedure:

- Follow local hand hygiene and don gloves.
- Prepare dressing pack.
- One person must hold tracheostomy tube firmly in place while the other removes the tapes.
- Remove dressing.
- Clean around the tube, under the flanges and around the edge of the stoma, removing all residue.
- Replace dressing.
- Replace tapes. Tapes should be tied firmly, so that only two fingers can fit snugly under them. Watch for pressure areas caused if tapes are too tight.
- Dispose of waste.
- Remove gloves and follow local hand hygiene procedures.

Checking cuff pressures

If the patient has a cuffed tracheostomy, the pressures should be checked every 8 hours. Cuff pressures should be maintained at between 20–30 cm H_2O. Record the pressure at the end of expiration. The result should be documented on the observation chart.

Also check the cuff if there is an audible air leak, or if the tracheostomy tube has just been re-inflated or changed.

Too-low pressures may produce an air leak and potential aspiration. If the pressure is too low, add 1 mL of air into the balloon in increments until the correct pressure is obtained.

Too-high pressure may cause tracheal mucosal necrosis/ischaemia, or the cuff may burst, rendering it ineffective.

If, over time, the cm H_2O reduces (as measured by the manometer), then an air-leak is present.

If a persistent air leak is present:

1. Ensure no part of the tracheostomy tube beyond the flange is sitting outside the patient. Ensure tracheostomy tapes are secure and do not allow the tube to move. If the tube has moved, it will require repositioning. Refer to local policy. If the patient is also in respiratory distress, then call MET/code blue (as per hospital policy), because medical attention is required.

2. If air has been repeatedly inserted without a change in pressure, then the cuff may have perforated. This requires a tracheostomy change. Refer to local hospital policies and procedures regarding changing of tube.

Weaning a tracheostomy tube

Refer to local hospital policies and procedures. A multidisciplinary approach is recommended involving:

- medical staff
- nursing staff
- speech pathologist
- physiotherapist
- where appropriate, dietician and social worker.

Weaning can commence when the primary issue for the need for the tracheostomy has resolved. The patient must also be medically stable before commencing weaning.

Factors involved include:

- airway patency
- ability to protect own airway
- ability to produce an adequate cough (including expectorating of secretions either out of mouth or tube)
- decreasing suctioning and oxygen requirements
- stable ventilation, including work of breathing
- improved chest x-ray appearance
- improved other clinical signs, for example, white cell count, C reactive protein.

Weaning usually commences as a short, supervised trial, with duration extended as per multidisciplinary clinical assessment. Generally, aim for the patient to tolerate a full 24 hours of cuff deflation before decannulation.

The preference for initial cuff deflation is for the speech pathologist and physiotherapist to do it together; however, refer to local hospital policies and procedures.

As part of the weaning process, the speech pathologist may recommend the use of a speaking valve (see above). The patients cuff must be deflated before placing speaking valve. The speaking valve must be removed before re-inflating the cuff.

The patient is at risk of asphyxiation and death if the speaking valve is not removed before cuff re-inflation.

Occasionally, a tracheostomy may be downsized as part of the weaning process, or the patient may have a period with a mini-trache, if required. This is a multidisciplinary, individual case decision.

Deflating and inflating a cuff

Equipment required:

- suctioning equipment
- pressure manometer
- oxygen saturation monitor
- 10 mL syringe
- two-person technique.

Steps:

- Explain the process to the patient.
- Ensure the patient is positioned upright.
- Follow hand hygiene procedures and don non-sterile gloves.
- Ensure tracheostomy tapes are secure.
- Ask the patient to cough to clear the tracheostomy tube if they are able.
- Suction the oral cavity first, if required.
- The second person should connect a 10 mL syringe to the end of the pilot balloon.
- Use a new suction catheter to insert into the tracheostomy tube.
- Insert to the point just before patient coughs.
- Instruct the second person that you are ready.
- The second person should remove the air from cuff (deflation), while the first person simultaneously suctions. This allows capture of secretions sitting above the cuff.
- Take note of how many mL of air are removed.
- Remove the suction catheter.
- Remove gloves and follow hand hygiene procedures.
- Monitor the patient's respiratory condition, including work of breathing, oxygen saturation, respiratory rate and cough (generally by physiotherapist). Swallow, secretion management, bulbar function and voice should also be assessed (generally by the speech pathologist).
- Document how many mL of air are removed, as well as patient response.

- If the patient becomes distressed (for example, increased work of breathing, desaturation, increased respiratory rate, increased secretions, poor swallow) then re-inflate cuff.

To re-inflate cuff:

- Reinsert the volume of air previously removed from the cuff via a syringe attached to the pilot balloon.
- Recheck pressure with manometer.

Removal of a tracheostomy tube

This is usually a multidisciplinary decision. However, refer to local hospital policies and procedures. It will usually be performed by medical staff, or an appropriately experienced staff member with medical backup if required. This person must be qualified to reinsert the tracheostomy if required.

General prerequisites for decannulation:

- the patient has tolerated a 24-hour period of continuous cuff deflation
- gastric/enteric feeds have been turned off for approximately 4 hours
- no sedation has been given for approximately 12 hours
- no coagulopathy is present
- no upper airway obstruction is present
- adequate general muscle strength is evident
- the patient displays an adequate cough (and is able to remove secretions effectively)
- the patient can swallow adequately and management of oral secretions is satisfactory
- FiO_2 is less than 40%.

Equipment required for decannulation:

- oxygen (face mask or nasal prongs as appropriate)
- dressing (for example, Tegaderm, gauze and sleek)
- emergency equipment (including spare tracheostomy/dilators if it requires reinsertion).

Procedure:

- Explain the process to the patient.
- Position the patient (upright with neck in slight extension).
- Monitor oxygen saturation levels.

- Wear goggles.
- Follow hand hygiene procedures.
- Don non-sterile gloves.
- Ask the patient to cough first, or suction first to remove secretions.
- Ensure the cuff is fully deflated (check with a 10 mL syringe).
- Unfasten tracheostomy tapes (ensuring that the tracheostomy remains secure).
- Ask the patient to exhale while the tracheostomy is simultaneously removed (outward and downward fashion).
- Clean the stoma.
- Dress the stoma with occlusive dressing (refer to local hospital policy—recommend gauze, Tegaderm and sleek).
- Remove gloves.
- Follow hand hygiene procedures.
- Administer appropriate oxygen therapy.
- Show the patient how to support the stoma when coughing.
- Monitor the patient for any respiratory distress.
- Ensure the patient has a call bell.
- Leave emergency equipment at bedside for 24 hours.

If respiratory distress develops, call MET/code. Provide respiratory support via a resuscitation bag as needed.

Adverse events

Complications arising from tracheostomies can be potentially life threatening. Therefore, immediate action is required to ensure the patient has a patent airway, sufficient ventilation and to minimise long-term detrimental effects.

Common potential complications are:

- obstruction
- haemorrhage
- dislodged or removed tracheostomy.

Always refer to hospital policies and procedures regarding procedures during an adverse event. The following instructions are recommendations only, and may vary between hospitals.

Obstruction

Obstruction may occur due to:

- inadequate humidification causing sputum plugging and blockage of airways or inner cannula
- cuff rupture
- tracheal tear or flap occluding lumen
- tracheostomy dislodged into pre-tracheal space
- misplaced tracheostomy, for example, against the tracheal wall or endobronchial intubation
- patient occlusion via large neck (double chin) causing external occlusion.

Signs:

- sudden respiratory distress, including shortness of breath and change of respiratory rate
- decreased oxygen saturation
- stridor/wheeze
- physical distress, for example, agitation
- clammy skin/change in colour.

Action required:

- medical emergency team/code blue (as per local hospital policies and procedures)
- remove inner cannula (if one present) and check for blockage
- suction
- ensure cuff is deflated
- ventilate via resuscitation bag at 100% oxygen until resuscitation team arrives
- if unable to ventilate, then escalate MET to code blue.

Haemorrhage

If a patient is regularly suctioned, has a coagulopathy or is receiving anti-coagulation therapy, small flecks of bright or dark-stained blood may appear in the sputum. If so, then report to medical staff or tracheostomy multidisciplinary team.

'Frank bleeding' may occur due to stoma ulceration, tracheal wall erosion, vessel erosion between the trachea and skin, or due to bronchi trauma. In the event of frank bleeding, call MET/code blue (as per hospital policy).

Dislodgement of tracheostomy

Refer to hospital policy. The following courses of action are recommended:

If tube is **partially dislodged**:

- call MET emergency if the patient is stable
- if the patient is in respiratory distress, remove the tube (after deflating the cuff) and ventilate with resuscitation mask on 100% oxygen and call code blue.

If the tube is **completely removed**:

- call MET emergency if the patient is stable
- administer oxygen via face mask
- call code blue if the patient is unstable
- ventilate with resuscitation mask on 100% oxygen.

Documentation

Precise documentation is vital for management of patients with a tracheostomy, so that all staff are aware of the patients condition and any changes to care.

Documentation post insertion must always detail:

- the reason for insertion
- technique used
- any complications
- tracheostomy type and size
- who is medically responsible.

The multidisciplinary team should also document their assessments, including a clear weaning plan, if applicable.

Each nursing shift, documentation is required pertaining to the following:

- equipment safety check
- patient respiratory assessment, including strength of cough, RR, patient comfort
- frequency of suctioning required
- secretions (amount, colour and consistency)
- stoma assessment
- weaning plan, if applicable
- whether the cuff is inflated or deflated (if applicable), and amount of air in the cuff and pressure
- humidifier check
- FiO_2
- flow and saturation levels
- any complications.

Learning activities

Suggested learning activities and timetable are outlined below.

Timing	Activity	Objective
30 minutes	Facilitated discussion	1, 2, 3
15 minutes	Scenario 1	4, 5
15 minutes	Scenario 2	4, 5
15 minutes	Scenario 3	45
10 minutes	Summary	
5 minutes	Evaluation	

Total: 1 hour 40 minutes

Facilitated discussion

The facilitator should lead a discussion amongst participants about the issues covered in the background information. Go through the subheadings. The facilitator should not give a didactic lecture, but instead promote open discussion and knowledge sharing amongst participants. Participants should be encouraged to describe any real-life experiences they have encountered.

The facilitator may use the PowerPoint presentation to summarise this information. Suitable question time should be accommodated.

Skills stations

The skills stations allow participants to practise their skills in tracheostomy management on an appropriate model, and via common tracheostomies. During this practice session, participants should receive feedback in a structured format from peers and/or facilitators.

First run through a basic checklist to identify:

- tracheostomy type
- tracheostomy size
- cuff compared to uncuffed
- pilot balloon
- patient assessment (including observations, cough, RR)
- single or double lumen (if double lumen, then identify inner cannula)
- oxygen requirements and delivery method (ensure humidifier is switched on)
- identify what sized suction catheters are required and check suction.

Practise the following:

- removal, cleaning and insertion of inner cannula
- deflating and inflating cuff
- checking of cuff pressure
- checking of bedside equipment
- suctioning via a tracheostomy
- placing speaking valve on/off tracheostomy tube (ensuring cuff deflated before placing valve on and also ensuring valve removed before re-inflating).

This is followed by a series of specific scenarios.

The program and resources required assume one facilitator for every four participants, a ratio of 1:4. Each facilitator should have one manikin suitable for having artificial airways in situ and suitable to allow suctioning via these airways. A second airway manikin is desirable and allows those participants not directly instructed or observed to practise before or after their turn.

Feedback should just be given by the facilitator/peers at the completion of each scenario.

Scenario 1

A 46-year-old man has been admitted with brain haemorrhage. A tracheostomy has been inserted to assist with weaning from mechanical ventilation. He has now been weaned and has been transferred to your ward from the ICU.

Discuss what information you should acquire before going in to assess the patient.

- Where would you find this information?
- What size suction catheters do you need?

Discuss what equipment should be in the patient's room to ensure safe management.

On assessment, the patient is currently:

- size 8 Portex, cuffed with inner cannula
- slightly agitated
- febrile, HR 120 (SR), SpO_2 = 88% on FiO2 = 0.40 at 8 L per minute (desaturating), BP—140/65, RR 32
- ausc—coarse bibasal creps
- cough—weak ++, moist, non-productive
- suction—frequent suctioning, moderate amounts thick yellow sputum
- bibasal expansion—poor.

Do you think it is appropriate to start cuff deflation? Discuss reasons.

What should you do next?

- Check the inner cannula and clean if appropriate.
- Suction, then reassess patient, including RR and SpO_2, assess cuff pressures.
- Increase oxygen requirements if able.
- Check that the humidifier is on and check temperature.
- Call for a medical review or MET if the patient meets hospital criteria.

Two days later, the patient is:

- settled
- afebrile, HR 90 (SR), SpO_2 = 96% on FiO_2 = 0.4 at 8 L per minute, BP 127/67, RR 22
- ausc—bibasal crep's
- cough—mod, moist, expectorating small volumes thick yellow sputum
- suction—4 times per shift.

The speech pathologist and physiotherapist trialled cuff deflation for one hour yesterday. Check whether this was well tolerated. What are you looking for?

What is the plan for today?

- Trial two hours cuff deflation.
- Practise cuff deflation.
- On deflation, the patient starts coughing violently.

What do you do?

- The coughing has now persisted for 10 minutes and the patient is now desaturating with a RR of 38. What do you do?

Scenario 2

A 76-year-old man who underwent emergency tracheostomy due to stridor has an obstruction in the upper airway. It is likely cancer. He is cachectic and generally of slim build.

A size 7 Shiley tracheostomy is in situ. It has a double lumen and is cuffed.

Practise stoma assessment and cleaning. Change the tracheostomy tapes.

At the commencement of your shift, during your assessment you check the cuff pressure. It read zero. What do you do and what should you assess in order to make your decision?

After resolving the initial problem, you return two hours later to discover the tracheostomy is partially dislodged. What do you do?

Scenario 3
A 29-year-old woman with cerebral palsy had a mini-tracheostomy inserted to assist with secretion management. Her cough is now strong, and she can expectorate sputum from her mouth. She has had a 24-hour period without requiring suction, is currently medically stable, and is on 2 L oxygen via nasal prongs.

Is she ready for decannulation? What parameters are required?

Practise decannulation and applying dressing.

Resource list

Resource	Quantity	Additional comments
Facilitators		Allow 1:4 ratio
Suction (wall or portable)	1 unit	
Suction canisters		
Suction catheters		
Manikin with ability to insert tracheostomy	1	
Tracheostomy (Shiley, Portex, mini-trache)	1 set of each type	
Humidifier	1 set	Including heaters and sterile water
Trache shield	1	
Dressings—gauze, Tegaderm, sleek	5 packs	
Tracheostomy tapes	5 sets	
Spare inner cannula	As per trache kit	
Oxygen saturation monitor	1	
Dilators	1	
Goggles	Up to 8	
Gloves	3 boxes	
Lubricant	10 packets	
Evaluation forms	1 per participant	

Note: if running two skills stations, double the list quantities.

Summary

The summary session reinforces content covered in the learning activities, and is an opportunity for participants to reflect on what they have covered. No new material should be introduced.

Major points to revise in the summary include:

- indications for tracheostomy
- potential adverse effects of tracheostomy and actions required
- importance of individual patient assessment
- importance of regular monitoring
- importance of multidisciplinary team
- factors involved in decision making regarding weaning and decannulation.

Participants should be encouraged to review the references in their own time to reinforce the skills acquired in this module. They should be offered access to equipment and educators in the future to allow them to practise these skills if they need improve their skill level or confidence. Participants might also be encouraged to attend and observe a real patient being managed with a tracheostomy in order to put these skills into a clinical context. If possible, availability of an educator to observe the participants first interaction with a real tracheostomised patient is ideal.

Evaluation

A formal evaluation has been specifically developed for this module. It incorporates the objectives of the module and the perceptions of the participants about whether they have increased their understanding by working through the module. It is highly recommended that this formal evaluation be copied and completed by all participants at the completion of the module.

A range of informal evaluation tools may also be used in conjunction with this evaluation throughout the module, including those available in the Department of Human Services' *Clinical Skills Facilitators Manual* from the basic course conducted in 2007.

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17. Thompson L (2000): Suctioning Adults with an Artificial Airway—A systematic review. *The Joanna Briggs Institute* 9: 1–87

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Resources

Facilitator feedback form

The following form should be used to assist you in giving feedback after each participant has practised their Tracheostomy skills at the skills station.

Feedback using the Pendleton model

Pendleton's model of feedback assists learners to maximize their potential at different stages of training, raise their awareness of strengths and areas for improvement, and identify actions to be taken to improve performance. Pendleton's rules are structured in such a way that the learner identifies the positives first, in order to create a safe environment. This is followed by the facilitator or group reinforcing these positives and discussing skills to achieve them. Different techniques are then suggested. The advantage of this method is that the learner's strengths are discussed first. Avoiding a discussion of weaknesses right at the beginning prevents defensiveness and allows reflective behaviour in the learner.

Below is a series of questions to assist you in this technique:

1. Ask the learner how they feel.
2. Ask the learner what went well and why (this can be combined with question 1 and 3).
3. Tell the learner what went well and why.
4. Ask the learner what could have been done better and why.
5. Tell the learner what could have been done better and why.
6. Summarise the learner's strengths and identify up to three things to concentrate on.

Note: This form does not need to be given to the participant — it is a guide for you, the group facilitator.

Module 7: Tracheostomy care and management—evaluation

Thank you for participating in this module. As part of our commitment to quality improvement the following questionnaire will be used to plan future implementation of this module. We appreciate your time completing this evaluation.

1. Overall

How would you rate this module?

☐ poor ☐ fair ☐ good ☐ very good ☐ outstanding

2. Learning objectives

Please consider whether this module was successful in meeting the following learning objectives:

Respiratory 2 Learning objectives of Module 7: Tracheostomy care and management	Strongly disagree	Disagree	Slightly agree	Agree	Strongly agree
Identified what a tracheostomy is and the indications for one	☐	☐	☐	☐	☐
Identified local/hospital policies and procedures	☐	☐	☐	☐	☐
Identified the differences between types of tracheostomies (for example, cuffed compared to uncuffed) and why they might be chosen	☐	☐	☐	☐	☐
Identified differences between tracheostomy sizes and why they might be chosen	☐	☐	☐	☐	☐
Practised the basic technique of setting up a humidifier	☐	☐	☐	☐	☐
Practised suctioning via a tracheostomy on a manikin	☐	☐	☐	☐	☐
Practised removal/insertion of inner cannulae and cleaning of inner cannulae	☐	☐	☐	☐	☐
Practised tracheostomy cuff inflation and deflation					
Practised measuring cuff pressures and learned how to identify an air leak	☐	☐	☐	☐	☐
Practised how to identify a blocked tracheostomies and gained familiarity with emergency procedures	☐	☐	☐	☐	☐
Developed an understanding of factors influencing tracheostomy weaning and removal	☐	☐	☐	☐	☐
Understood the roles of AH involved in tracheostomy weaning	☐	☐	☐	☐	☐

3. Important learning outcomes

What are the three most important things you have learned from this module?

4. Module implementation

Please indicate to what extent you agree or disagree with each of the following statements in relation to the implementation of the module.

	Strongly disagree	Disagree	Slightly agree	Agree	Strongly agree
The facilitator respected my experience	☐	☐	☐	☐	☐
The facilitator encouraged my participation	☐	☐	☐	☐	☐
I was able to ask the facilitator questions	☐	☐	☐	☐	☐
The facilitator was able to answer my questions	☐	☐	☐	☐	☐
The feedback I received was clear	☐	☐	☐	☐	☐
The feedback I received will assist me my future performance	☐	☐	☐	☐	☐
There was adequate time for the skills stations	☐	☐	☐	☐	☐
There was adequate time for the facilitated discussions	☐	☐	☐	☐	☐
There was adequate time for the simulations	☐	☐	☐	☐	☐
I have increased my confidence in performing BLS	☐	☐	☐	☐	☐
I have identified future learning needs in this topic area	☐	☐	☐	☐	☐

5. Future module implementation

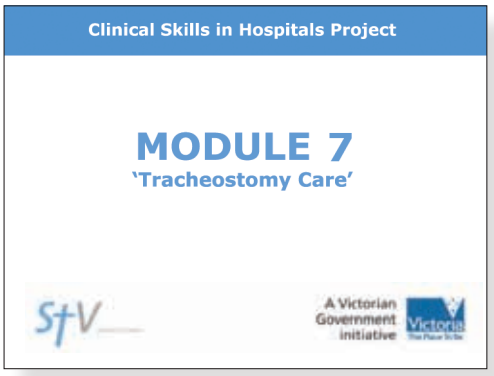
Do you think the module should be altered in any way? ☐ yes ☐ no

If yes, what recommendations do you have?

Thank you

PowerPoint presentation

1.



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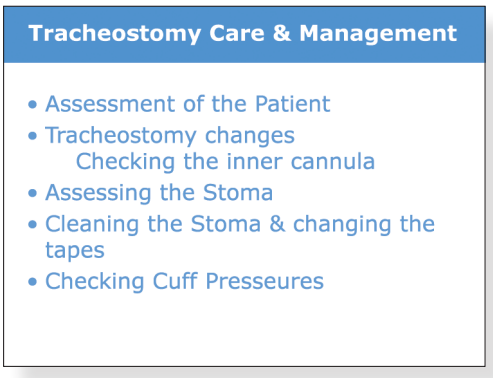

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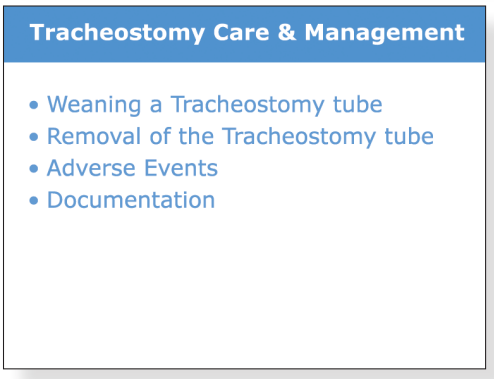

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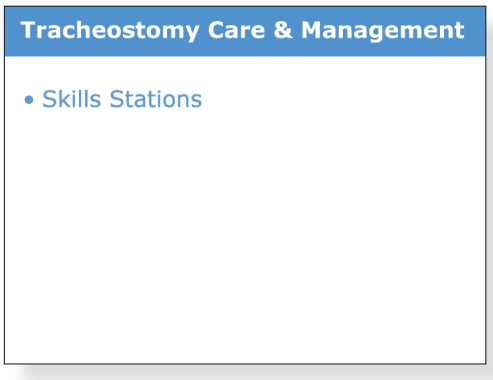


Module 8: Arterial Blood Gases (ABGs)

Introduction

Respiratory 2 was developed as a teaching and learning tool for Victorian clinical educators. The information contained in each module was developed using evidence-based resources and examples of best practice. Where expert opinion varies, a discussion section is included. However, it is not within the scope of *Respiratory 2* to address the full spectrum of local variations. Variations can occur in several areas, including practices relating to types of equipment used, infection control processes, practice guidelines and so on. Therefore, educators should, where appropriate, adapt content to reflect their local policies, procedures and protocols. This will ensure the relevancy of the package content to your learners.

The modules are designed to be discrete courses in their own right. They are timetabled so they can be completed in a 1–2 hour timeframe. This timeframe was chosen after we received feedback from clinical educators requesting shorter courses, because health professionals often have limited time to educate away from patients. However, the packages may also be combined into a one- or two-day course.

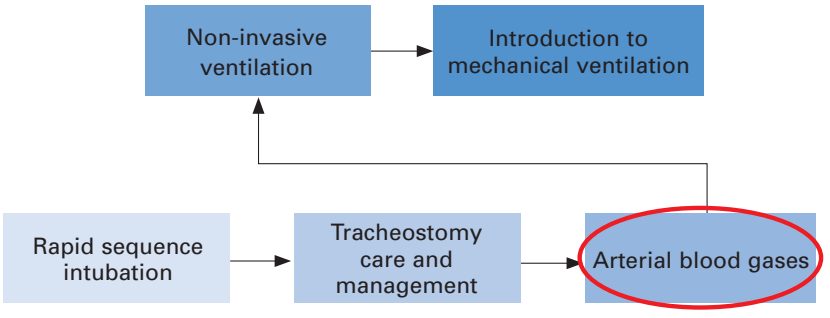
Respiratory 2 should be used as an educational tool to assist in the teaching of clinical skills. It is structured as a guide to assist clinical educators, and uses many concepts taught in the Clinical Skills in Hospitals Project (Train-the-Trainer courses). Educators are encouraged to build on this resource by adding their own scenarios which incorporate hospital/health service protocols, policies and other resources. Each module is designed as a lesson plan to incorporate the simulations into the teaching of clinical skills.

Aims

Respiratory 2 aims to make participants confident in their application of respiratory knowledge and skills on adults in different environments and settings.

Package structure

Respiratory 1 is the first of the two respiratory packages, and contains five modules that provide learning opportunities for health professionals at all levels of experience and from all health disciplines. Modules 1, 2 and 3 in *Respiratory 1* are regarded as fundamental, while Modules 4 and 5 are more difficult and are regarded as intermediate. *Respiratory 2* contains Modules 6–10, which are considered intermediate to complex. These modules focus on more complex respiratory management strategies that require participants to have completed *Respiratory 1*.

Level of complexity	Package structure
Complex For participants with more than 4 years experience or who have completed Modules 1–4	
Intermediate For participants in postgraduate years 3–4 or who have completed Modules 1 and 2	
Fundamental For participants in postgraduate years 1–2	

Respiratory 2 consists of: *Module 6: Rapid sequence intubation, Module 7: Tracheostomy care and management, Module 8: Arterial blood gases, Module 9: Non-invasive ventilation* and *Module 10: Introduction to mechanical ventilation*.

Respiratory 2 was designed to develop participants' knowledge, skills and behaviours in the use of respiratory skills and practices, as well as expose them to increasingly complex scenarios aimed at testing their ability to combine these individual skills, work as a team and problem solve in more difficult situations.

Educators delivering these modules should be aware of participants' level of experience and choose appropriate modules. Modules presume an increasing level of knowledge as they progress, ranging from a fundamental knowledge of anatomy and physiology for the fundamental modules, up to detailed knowledge of respiratory practices for the complex modules. Novice participants (such as first-year graduates) are expected to start with the fundamental modules, and only move onto intermediate and more complex modules as they demonstrate proficiency. More experienced participants may start at the intermediate level if the educator is satisfied that they have the prior knowledge and skills. Individual educators are responsible for assessing each participant's baseline knowledge and determining which modules they should complete. More specific descriptions of presumed knowledge are outlined in each module.

The design of these packages presumes that the clinical educators using them have knowledge and expertise in current best practice regarding the teaching of clinical skills and conducting facilitated discussions. Knowledge and expertise are presumed commensurate with the Department of Human Services' basic and advanced Train-the-Trainer programs. Clinical educators are encouraged to refer to the *Department of Human Services' Clinical Skills Facilitators Manual* for theory on:

1. Peyton's model for teaching clinical skills
2. leading small group discussions
3. giving feedback
4. crisis resource management skills.

Module 8: Arterial Blood Gases (ABGs)

Author: Dr. Antony Tobin

Aims

This module offers participants with arterial blood gases (ABGs) interpretation skills the opportunity to apply them in clinical practice.

Presumed knowledge

Participants are expected to have completed *Respiratory 1—Module 1: Pathophysiology* and *Module 2: Respiratory assessment*.

Objectives

By the end of this module, participants should have:

1. identified the normal physiological parameters for ABGs
2. identified how normal ABG vales are maintained
3. identified and discussed abnormal ABG values:
    a. respiratory acidosis
    b. respiratory alkalosis
    c. metabolic acidosis
    d. metabolic alkalosis
4. participated in four case studies and practised ABG analysis.

Background information for educators

Analysis of arterial blood gases is important for nursing and medical staff working in all areas of acute medicine. Blood gases are important in the diagnosis and management of respiratory problems, but are also relevant to cardiac, renal, gastroenterology and endocrine problems, as well as toxic ingestions. This module provides some basic tools for interpretation of blood gases. It focuses on respiratory and metabolic acidosis, because these acid–base disorders are of greatest clinical importance.

Testing for arterial blood gases includes several biochemical tests, including pH, oxygen and carbon dioxide partial pressures, bicarbonate levels and oxyhaemoglobin concentrations. Generally, sodium, potassium, chloride, haemoglobin and lactate are also given. These values provide an enormous amount of useful information to help guide diagnosis and management of your patient. Normal values are shown in Table 1.

Table 1: Normal values

	Normal range
pH	7.35–7.45
PaO_2	85–105 mmHg
$PaCO_2$	36–44 mmHg
HCO_3^-	22–26
SaO_2	95–100%
Base Excess	-2–2 mmol/L
Na^+	135–145
K^+	3.5–5.0
Cl^-	97–107
Lactate	0.5–2.0 mmol/L

The body's pH is kept in a relatively strict range of 7.35 to 7.45. A pH below 7.35 is termed an acidosis, and above 7.45 an alkalosis. Perturbations to pH either acidosis or alkalosis are classified as either respiratory or metabolic. Determining what sort of pH disturbance is present requires some understanding of how normal pH is maintained.

Maintenance of pH

The major regulator of pH in the body is the carbon dioxide/bicarbonate system, which is controlled by the respiratory and renal system.

Metabolism in the body's cells produces carbon dioxide (CO_2). About 10% of the CO_2 is dissolved in the plasma, but most of the CO_2 combines with water (H_2O) in red blood cells to form carbonic acid (H_2CO_2). Hydrogen ions combine with haemoglobin and bicarbonate moves into the plasma. In the lungs, oxygen combines with the haemoglobin, and hydrogen ions are displaced, which then combine with bicarbonate (HCO_3^-) to form CO_2 and H_2O. CO_2 then moves into the alveoli and is exhaled. Thus, the CO_2 in the blood reflects ventilation, and pH and HCO_3^- are related to CO_2 levels. As $PaCO_2$ rises, pH falls and HCO_3^- rises, and vice versa. Thus, the carbon dioxide level and its resultant affect on pH are determined by ventilation. Changes in ventilation, by increasing or decreasing $PaCO_2$ levels, can cause rapid changes in pH.

The kidneys excrete or retain bicarbonate to maintain pH. As pH falls, hydrogen is excreted into the renal tubules, where it is excreted with buffers, and sodium bicarbonate is retained. Thus, the kidneys' response to a rise in $PaCO_2$ (which produces acidosis due to the generation of carbonic acid) is to retain sodium bicarbonate and excrete hydrogen ions. This raises the pH, a process that occurs over hours to days. The reverse is true for a respiratory alkalosis, where less carbonic acid is in the blood, due to lower $PaCO_2$ levels.

Compensation

As explained, the lungs and the kidneys contribute to control of the CO_2/H_2CO_3 system, and in simple disorders changes in one are counteracted by the other. This is important in maintaining normal pH. If both mechanisms are impaired, for example, in respiratory and renal failure, then a change in pH may rapidly occur, with secondary organ dysfunction.

Primary disorders

Respiratory acidosis

Respiratory acidosis refers to an accumulation of carbon dioxide with a resultant increase in carbonic acid and finally, a fall in pH. A respiratory acidosis is said to be present is the pH is less than 7.35 and the CO_2 is greater than 45. Respiratory acidosis is the result of alveolar hypoventilation.

Causes of alveolar hypoventilation can be divided into several broad groups:

1. primary pump failure:
    a. CNS—stroke, trauma, drugs (morphine, sedatives)
    b. spinal cord—trauma, demyelination, compression, polio
    c. peripheral nerves—demyelination, drugs, trauma, myasthenia gravis
    d. muscles—myositis
2. excessive work:
    a. parenchymal—pneumonia, cardiac failure, pulmonary fibrosis
    b. airway—asthma, COPD, upper airway obstruction
    c. chest wall—kyphoscoliosis, fractured ribs, pleural thickening/effusions
    d. metabolic—acidosis (DKA, renal failure).

As a consequence of raised CO_2 levels, HCO levels will also rise, and this is often termed 'early compensation'. It is actually just the normal chemical breakdown of carbonic acid to H and HCO_3. Thus, in a respiratory acidosis, the principal findings are a low pH, high CO_2 and a mild elevation of HCO_3. For example:

pH 7.30, pCO_2 56, HCO_3^- 27

pH < 7.40, therefore this is an acidois acidotic

$PaCO_2$ > 40, therefore this is a respiratory acidosis.

Note the small rise in HCO_3, the so-called acute compensation.

Over time, there is renal compensation, with a further rise in bicarbonate and a rise in pH. There are equations for determining how high the bicarbonate should be in a respiratory acidosis, which will be discussed later.

Principal change	Rise in CO_2 with fall in pH
Acute compensation	Rise in bicarbonate
Chronic (renal) compensation	Further rise in bicarbonate and rise in pH

Rules	
Acute	HCO_3^- increases 1 for each 10 increase in CO_2
Chronic	HCO_3^- increases 3 for each 10 increase in CO_2

The importance of a respiratory acidosis is that it signifies respiratory failure. Hypoxia kills, and while supplemental oxygen does not address the underlying problem in ventilatory failure, it is vital that supplemental oxygen is given to prevent tissue hypoxia. Treatment to reverse alveolar hypoventilation depends on the underlying cause. Respiratory depression due to drugs may be reversed with specific antagonists (morphine reversal with naloxone) and hypoventilation due to lung pathology (for example, APO or asthma) may be reversed by specific treatment.

However, alveolar hypoventilation often requires mechanical assistance of the respiratory pump while the underlying problem is treated. This may be non-invasive, via a tight-fitting facemask, or invasive, by tracheal intubation. These techniques allow time for treatments to take effect and the underlying process causing hypoventilation to resolve.

Respiratory alkalosis

Respiratory alkalosis is due to alveolar hyperventilation, and is defined as a pH > 7.45 with a $PaCO_2$ < 35 mmHg. Hyperventilation causes a fall in CO_2 and a resultant increase in pH. The bicarbonate level will drop acutely, due to the lower CO_2 levels, and over time will drop further, with renal compensation and a consequent fall in pH. For example:

pH 7.51, pCO_2 30, HCO_3^- 23

pH > 7.40, therefore this is an alkalosis

pCO_2 < 35, therefore this is a respiratory alkalosis.

Note the small drop in HCO_3^- due to acute compensation.

Causes

Causes can include:

- anxiety, panic or fear
- pain
- hypoxia—lung disease, high altitude
- hypermetabolic states—fever, sepsis, pregnancy.

Respiratory alkalosis rarely causes significant problems, but it is important to recognise, so that inappropriate treatment and investigations are avoided.

Principal change	Fall in $PaCO_2$ with increase in pH
Acute compensation	Decrease in bicarbonate
Chronic (renal) compensation	Further fall in bicarbonate and decrease in pH

Metabolic acidosis

A metabolic acidosis results from loss of bicarbonate or excess acid other than CO_2 in the blood. It is characterised by a bicarbonate level less than 22 and a pH of less than 7.35. Compensation occurs through the lungs by hyperventilation with a reduction in CO_2 and an associated partial return of pH towards normal. For example:

pH 7.25, CO_2 25, HCO_3^- 10

pH is low, so this is an acidosis

CO_2 is low, so this is a metabolic acidosis.

Note the CO_2 is equal to the last two digits of the pH.

Causes

Addition of acid

This can include:

volume resuscitation with normal saline

- renal failure
- lactate in hypoxia or organ ischaemia
- ketoacids in uncontrolled diabetes
- ingested acids—aspirin.

Loss of bicarbonate

This can include:

- renal tubule problems
- diarrhoea.

Principal change	Fall in HCO_3^- with decrease in pH
Acute compensation	Decrease in CO_2 with hyperventilation
Rules	CO_2 = last two digits of the pH
	HCO_3^- + 15 = last two digits of pH
	Base excess is negative

Metabolic alkalosis

Results from loss of acid (or its equivalent) or an excess of bicarbonate and is characterised by an HCO_3 > 26 and a pH > 7.45. Respiratory compensation occurs through hypoventilation with a resultant rise in CO_2. The degree of compensation is variable. The commonest cause is volume depletion due to diuretic use that results in excess NaHCO re-absorption in the kidney. Other causes include corticosteroids, excessive loss of gastric contents (vomiting, nasogastric drainage) or ingestion (antacids) or infusion of bicarbonate. For example:

pH 7.54, CO_2 49, HCO_3^- 40

pH is high, so this is an alkalosis

CO_2 is high so, this is a metabolic alkalosis.

Anion gap

An anion gap is the difference between the sum of the main cations (Na + K) and the main anions (Cl- + HCO_3^-). The anion gap is due to unmeasured anions such as lactate, phosphates and sulphates. The normal anion gap is less than 15. When the anion gap is increased in a metabolic acidosis, it suggests that an excess of some unmeasured anion is causing the acidosis. Common causes include:

- ketoacid overproduction due to fat metabolism (diabetes, alcohol, starvation)
- lactic acid overproduction due to hypoxia, shock or tissue ischaemia
- inability to excrete acids (sulfate and phosphate) due to renal disease (usually with an elevated BUN (blood urea nitrogen) and creatinine)
- an overdose of medications such as salicylates
- toxins such as ethylene glycol, methanol.

Base excess

The base excess refers to the amount of acid required to return the pH to normal, and reflects the metabolic component of the acid–base disorder. A negative number means excess acid, hence a metabolic acidosis; while a positive number indicates excess bicarbonate (lack of acid), hence a metabolic alkalosis. The normal range is -2 to +2 MEq/L. This is a handy tool to help spot mild disorders or mixed respiratory and metabolic disorders.

A simple approach to ABG analysis

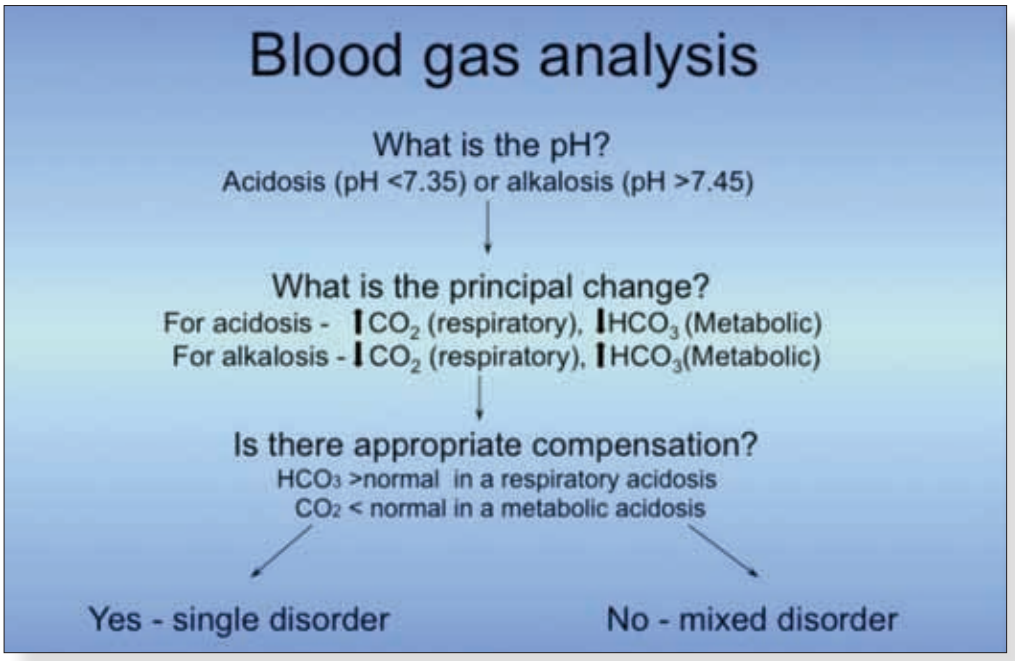


Figure 1: A simple approach to ABG analysis

A systematic approach to blood gases interpretation makes determining the abnormality a relatively simple process.

1. **What is the pH?**
   a. Is there an acidosis (pH < 7.35) or an alkalosis (pH > 7.35)?
2. **What is the principal change?**
   a. For an acidosis:
      i. If the CO_2 is high, then it is a primary respiratory acidosis.
      ii. If the HCO_3^- is low, then it is a primary metabolic acidosis
   b. For an alkalosis:
      i. If the CO_2 is low, then it is a respiratory alkalosis.
      ii. If the HCO_3^- is high, then it is a metabolic alkalosis.
3. **Is there appropriate compensation?**
   a. For a respiratory acidosis, the bicarbonate level should be elevated. If it is not, then there is a coexistent metabolic acidosis. Check the base excess—it will be negative in a metabolic acidosis.
   b. For a metabolic acidosis, the CO_2 should be low. If it is not, then there is a coexistent respiratory acidosis. The CO_2 should equal the last two digits of the pH. If it is higher, then there is a respiratory acidosis.
   c. Mixed acidosis is important to recognise, because there is a lack of compensatory mechanisms, and rapid deterioration is possible.

Primary disorder	pH	CO_2	HCO_3^-
Respiratory acidosis	i	hh	h
Respiratory alkalosis	h	ii	i
Metabolic acidosis	i	i	ii
Metabolic alkalosis	h	h	hh

Double arrows (hh or i) denote principal change.

Central venous gases

Central venous gases are increasingly utilised as a surrogate for cardiac output, and to monitor ventilation where an arterial line is not present. Typical central venous gases have a $PaO_2 \simeq 40$, $PaCO_2$ 45 (or 5 greater than the arterial value) and an oxygen saturation of 65–75%.

Cardiac output

The oxygen content of venous blood returning to the heart is determined by the net difference between oxygen delivery and oxygen consumption. Oxygen delivery is the product of the cardiac output, the oxygen content of the blood and the haemoglobin. For a patient lying resting in bed with normal saturations and haemoglobin, the principal determinant of delivery is the cardiac output. If the cardiac output is low, then less oxygen will be delivered to the tissues and proportionality more will be extracted by the tissues. This results in lower oxygen content in the blood returning to the heart. A low PaO_2 and low saturations (< 65%) in the central venous blood suggests inadequate cardiac output, given that Hb, saturations and consumption are normal.

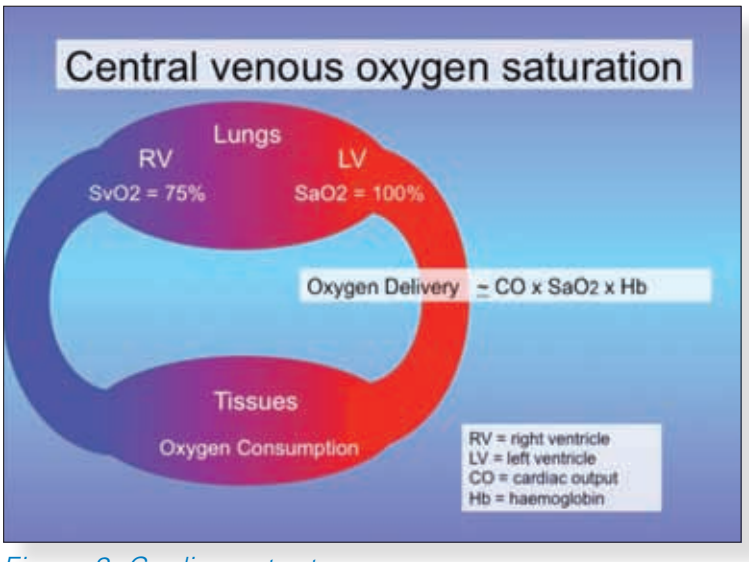


Figure 2: Cardiac output

Learning activities

Suggested learning activities and timetable are outlined below.

Timing	Activity	Objective
30 minutes	Facilitated discussion	1, 2, 3
10 minutes	Case study 1	4
10 minutes	Case study 2	4
15 minutes	Case study 3	4
15 minutes	Case study 4	4
10 minutes	Summary	
5 minutes	Evaluation	

Total time = 1 hour 40 minutes

Facilitated discussion

The facilitator should lead a discussion amongst participants about the issues covered in the background information. The facilitator should not give a didactic lecture, but instead promote open discussion and knowledge sharing amongst participants. Participants should be encouraged to describe any real-life experiences they have encountered.

Case studies

Case study 1 Part A

An 18-year-old insulin-dependent diabetic presents with fever and breathlessness.

- Initial bloods: Na 131, K 4.1, HCO_3 6, Cl 98, Cr 124, Ur 3.1
- Hb 184, WCC 18, Plat 345
- Glucose 37

Case study 1 Part A—Questions

Discuss possible differential diagnosis for breathlessness.

If unnoticed, draw attention to the low bicarbonate.

What does this mean/suggest?

Leads to calculation of anion gap:

Anion gap = (131 + 4.1) - (98 + 6) = 31.

What does the low bicarbonate and wide anion gap suggest?

Case study 1 Part B

Blood gases are performed: pH 6.93, CO_2 10, O_2 154, HCO_3 2, BE -29

Case study 1 Part B—Questions

What is the acid–base disorder?

- There is an acidosis with a low CO_2, so this is a metabolic acidosis.
- The base excess of minus 29 confirms this.
- The CO_2 is low and reflects the respiratory compensation. Although the rule is that the CO_2 should equal the last two digits of the pH, it is not possible to reduce the CO_2 below approximately 8–10 mmHg. This is maximal respiratory compensation.

What is the cause of the acidosis?

- Note the wide anion gap and history of diabetes.
- This is diabetic ketoacidosis with the widened anion gap due to ketoacids.

Why is the patient breathless?

- Acidosis is a strong stimulus for respiration—the patient perceives their respiratory effort to be out of proportion to their activity of lying in bed.

Case study 2

An obese 65-year-old woman post laparotomy on a morphine infusion for pain is admitted to your ward. You review her because of desaturation and drowsiness. Blood gases are taken.

pH 7.20, CO_2 65, O_2 62, HCO_3 28

BE 1.0 on 2 L of oxygen by nasal prongs.

Case study 2—Questions

What is the acid–base disorder?

- There is an acidosis with a raised CO_2, so this is a respiratory acidosis.
- The bicarbonate is 2 above normal, as expected in an acute respiratory acidosis (bicarbonate increases 1 for each 10 increase in CO_2 acutely).
- Base excess is in the normal range, so there is no associated metabolic disorder.

What is the mechanism of the raised CO_2 in this patient?

- CO_2 rises due to alveolar hypoventilation.
- The most likely cause in this patient is depression of the central respiratory drive due to morphine.

Case study 2—Questions (cont.)

- Other factors which may exacerbate: obesity, pain and upper airway obstruction in an obese, drowsy patient.

What is the initial management?

- Ensure the airway is clear, apply oxygen, stop morphine, give naloxone.
- Consider the use of non-invasive ventilation if there is persistent hypercapnia.

Case study 3

A 30-year-old woman is brought to the emergency department following a respiratory arrest due to a heroin overdose. She is intubated and ventilated and has a blood pressure of 110/60.

Bloods are taken:

U and E: Na 144, K 6.1, HCO_3 13, CL 110, Cr 88, Ur 6.1

ABGs: pH 7.10, CO_2 37, O_2 204, HCO_3 12, BE -17.3

Case study 3—Questions

What is the acid–base disorder?

- There is an acidosis with the CO_2 in the normal range, so this is a primary metabolic acidosis.
- The base excess of minus 17.3 confirms this as a metabolic acidosis.
- Normal compensation hyperventilation, so the CO_2 should be low (from the rule the CO_2 should equal the last two digits of the pH). There is therefore an associated respiratory acidosis—that is, there is failure of respiratory compensation.

What is the cause of the acidosis?

- Calculate the anion gap (144 + 6.1 - 12 - 110 = 28).
- The anion gap is widened, so there is an extra anion—in this case, lactate that was 8.4, due to tissue hypoxia.

How would adjust the ventilation to correct the acidosis?

- Increasing the rate or volume to increase minute ventilation, and hence alveolar ventilation, should be discussed. The lactic acidosis should resolve unless there is ongoing tissue ischaemia.
- Bicarbonate should not be given.

Case study 4 Part A

A 72-year-old smoker who lives alone presents in respiratory distress. He has been unwell for three days with cough productive of yellow sputum, wheeze and progressive breathlessness. He is sweaty and confused.

ABGs: pH 7.18 CO_2 68 pO_2 58 HCO_3 22 BE -4.7.

Case study 4 Part A—Questions

What is the acid–base disorder?

- There is an acidosis with an elevated CO_2, so this is a respiratory acidosis. However, the bicarbonate is low-normal.
- We know that the bicarbonate should rise 1 for each 10 increase in CO_2, so it should be 27 or 28. Therefore, there is an associated metabolic acidosis. The negative base excess confirms this.

Why is there a respiratory acidosis?

- This patient is a smoker with wheeze and a history of a productive cough, so he is likely to have an infective exacerbation of COPD. If the work of breathing becomes too great, there will be alveolar hyperventilation due to rapid shallow breathing.

How would you manage this man's respiratory acidosis?

- Oxygen, bronchodilators and steroids with non-invasive ventilation.

Case study 4 Part B

U and Es are taken: Na 144, K+ 5.1, HCO_3 23, Cl 112, Cr 133, Ur 17.2.

Case study 4 Part B—Questions

What is the metabolic acidosis due to?

- The anion gap is 14, which is in the normal range.
- Given there is elevation of the Cr and urea, this is most likely an acidosis due to renal failure. Renal failure may have occurred because of dehydration while he has been sick over the last three days.

Resource list

Resource	Quantity	Additional comments
Facilitators	2:12	
PowerPoint presentation	1	
Case study handouts		As per group size

Evaluation

A formal evaluation has been specifically developed for this module. It incorporates the objectives of the module and the perceptions of the participants about whether they have increased their understanding by working through the module. It is highly recommended that this formal evaluation be copied and completed by all participants at the completion of the module.

A range of informal evaluation tools may also be used in conjunction with this evaluation throughout the module, including those available in the Department of Human Services' *Clinical Skills Facilitators Manual* from the basic course conducted in 2007.

Resources

Facilitator feedback form

The following form should be used to assist you in giving feedback after each participant has practised their ABG skills at the skills station.

Feedback using the Pendleton model

Pendleton's model of feedback assists learners to maximize their potential at different stages of training, raise their awareness of strengths and areas for improvement, and identify actions to be taken to improve performance. Pendleton's rules are structured in such a way that the learner identifies the positives first, in order to create a safe environment. This is followed by the facilitator or group reinforcing these positives and discussing skills to achieve them. Different techniques are then suggested. The advantage of this method is that the learner's strengths are discussed first. Avoiding a discussion of weaknesses right at the beginning prevents defensiveness and allows reflective behaviour in the learner.

Below is a series of questions to assist you in this technique:

1. Ask the learner how they feel.
2. Ask the learner what went well and why (this can be combined with question 1 and 3).
3. Tell the learner what went well and why.
4. Ask the learner what could have been done better and why.
5. Tell the learner what could have been done better and why.
6. Summarise the learner's strengths and identify up to three things to concentrate on.

Note: This form does not need to be given to the participant — it is a guide for you, the group facilitator.

Module 8: Arterial blood gases—evaluation

Thank you for participating in this module. As part of our commitment to quality improvement the following questionnaire will be used to plan future implementation of this module. We appreciate your time completing this evaluation.

1. Overall

How would you rate this module?

☐ poor ☐ fair ☐ good ☐ very good ☐ outstanding

2. Learning objectives

Please consider whether this module was successful in meeting the following learning objectives:

Respiratory 2 Learning objectives of Module 8: Arterial blood gases	Strongly disagree	Disagree	Slightly agree	Agree	Strongly agree
Identified the normal physiological parameters for ABGs	☐	☐	☐	☐	☐
Identified how normal ABG vales are maintained	☐	☐	☐	☐	☐
Identified and discussed abnormal ABG values: ■ respiratory acidosis ■ respiratory alkalosis ■ metabolic acidosis ■ metabolic alkalosis	☐	☐	☐	☐	☐
Participated in four case studies and practised ABG analysis	☐	☐	☐	☐	☐

3. Important learning outcomes

What are the three most important things you have learned from this module?

4. Module implementation

Please indicate to what extent you agree or disagree with each of the following statements in relation to the implementation of the module.

	Strongly disagree	Disagree	Slightly agree	Agree	Strongly agree
The facilitator respected my experience	☐	☐	☐	☐	☐
The facilitator encouraged my participation	☐	☐	☐	☐	☐
I was able to ask the facilitator questions	☐	☐	☐	☐	☐
The facilitator was able to answer my questions	☐	☐	☐	☐	☐
The feedback I received was clear	☐	☐	☐	☐	☐
The feedback I received will assist me my future performance	☐	☐	☐	☐	☐
There was adequate time for the skills stations	☐	☐	☐	☐	☐
There was adequate time for the facilitated discussions	☐	☐	☐	☐	☐
There was adequate time for the simulations	☐	☐	☐	☐	☐
I have increased my confidence in performing ABG analysis	☐	☐	☐	☐	☐
I have identified future learning needs in this topic area	☐	☐	☐	☐	☐

5. Future module implementation

Do you think the module should be altered in any way? ☐ yes ☐ no

If yes, what recommendations do you have?

Thank you

PowerPoint Presentation

1.

Clinical Skills in Hospitals Project

Package Name
MODULE 8
'Arterial Blood Gases (ABG)'

StV

A Victorian Government initiative

2.

Arterial Blood Gases

- Introduction and Overview

	Normal Range
pH	7.35 – 7.45
PaO2	85 – 105 mmHg
PaCO2	36 – 44 mmHg
HCO_3^-	22 - 26
SaO2	95 – 100%
Base Excess	-2 – 2 mmol/L
Na^+	135 – 145
K^+	3.5 – 5.0
Cl^-	97 – 107
Lactate	0.5 – 2.0 mmol/L

3.

Arterial Blood Gases

- Maintenance of pH
- Primary Disorders
  - Respiratory Acidosis
  - Respiratory Alkalosis
  - Metabolic Acidosis
  - Metabolic Alkalosis
- Anion Gap & Base Excess

4.

Arterial Blood Gases

- Blood Gas Analysis
  1. What is the pH?
  2. What is the principle change?
  3. Is there appropriate compensation?

Primary Disorder	pH	CO_2	HCO_3^-
Respiratory Acidosis	↓	↑↑	↑
Respiratory Alkalosis	↑	↓↓	↓
Metabolic Acidosis	↓	↓	↓↓
Metabolic Alkalosis	↑	↑	↑↑

Double arrows (↑↑or ↓↓) denote principal change.

5.

Arterial Blood Gases

- Central venous gasses
- Cardiac Output

6.

Arterial Blood Gases

- Skills Station

Module 9: Non-Invasive Ventilation (NIV)

Introduction

Respiratory 2 was developed as a teaching and learning tool for Victorian clinical educators. The information contained in each module was developed using evidence-based resources and examples of best practice. Where expert opinion varies, a discussion section is included. However, it is not within the scope of *Respiratory 2* to address the full spectrum of local variations. Variations can occur in several areas, including practices relating to types of equipment used, infection control processes, practice guidelines and so on. Therefore, educators should, where appropriate, adapt content to reflect their local policies, procedures and protocols. This will ensure the relevancy of the package content to your learners.

The modules are designed to be discrete courses in their own right. They are timetabled so they can be completed in a 1–2 hour timeframe. This timeframe was chosen after we received feedback from clinical educators requesting shorter courses, because health professionals often have limited time to educate away from patients. However, the packages may also be combined into a one- or two-day course.

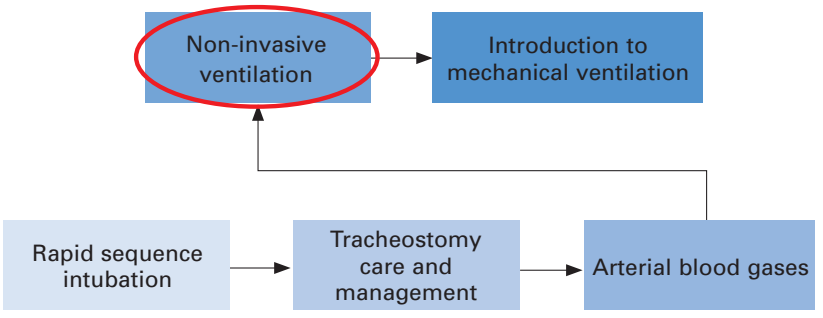
Respiratory 2 should be used as an educational tool to assist in the teaching of clinical skills. It is structured as a guide to assist clinical educators, and uses many concepts taught in the *Clinical Skills in Hospitals Project* (Train-the-Trainer courses). Educators are encouraged to build on this resource by adding their own scenarios which incorporate hospital/health service protocols, policies and other resources. Each module is designed as a lesson plan to incorporate the simulations into the teaching of clinical skills.

Aims

Respiratory 2 aims to make participants confident in their application of respiratory knowledge and skills on adults in different environments and settings.

Package structure

Respiratory 1 is the first of the two respiratory packages, and contains five modules that provide learning opportunities for health professionals at all levels of experience and from all health disciplines. Modules 1, 2 and 3 in *Respiratory 1* are regarded as fundamental, while Modules 4 and 5 are more difficult and are regarded as intermediate. *Respiratory 2* contains Modules 6–10, which are considered intermediate to complex. These modules focus on more complex respiratory management strategies that require participants to have completed *Respiratory 1*.

Level of complexity	Package structure
Complex For participants with more than 4 years experience or who have completed Modules 1–4	
Intermediate For participants in postgraduate years 3–4 or who have completed Modules 1 and 2	
Fundamental For participants in postgraduate years 1–2	

Respiratory 2 consists of: *Module 6: Rapid sequence intubation, Module 7: Tracheostomy care and management, Module 8: Arterial blood gases, Module 9: Non-invasive ventilation* and *Module 10: Introduction to mechanical ventilation*.

Respiratory 2 was designed to develop participants' knowledge, skills and behaviours in the use of respiratory skills and practices, as well as expose them to increasingly complex scenarios aimed at testing their ability to combine these individual skills, work as a team and problem solve in more difficult situations.

Educators delivering these modules should be aware of participants' level of experience and choose appropriate modules. Modules presume an increasing level of knowledge as they progress, ranging from a fundamental knowledge of anatomy and physiology for the fundamental modules, up to detailed knowledge of respiratory practices for the complex modules. Novice participants (such as first-year graduates) are expected to start with the fundamental modules, and only move onto intermediate and more complex modules as they demonstrate proficiency. More experienced participants may start at the intermediate level if the educator is satisfied that they have the prior knowledge and skills. Individual educators are responsible for assessing each participant's baseline knowledge and determining which modules they should complete. More specific descriptions of presumed knowledge are outlined in each module.

The design of these packages presumes that the clinical educators using them have knowledge and expertise in current best practice regarding the teaching of clinical skills and conducting facilitated discussions. Knowledge and expertise are presumed commensurate with the Department of Human Services' basic and advanced Train-the-Trainer programs. Clinical educators are encouraged to refer to the *Department of Human Services' Clinical Skills Facilitators Manual* for theory on:

1. Peyton's model for teaching clinical skills
2. leading small group discussions
3. giving feedback
4. crisis resource management skills.

Module 9: Non-Invasive Ventilation (NIV)

Author: Dr. Antony Tobin

Aims

This module gives participants an overview of non-invasive ventilation (NIV) and opportunities to practise the use of this advanced clinical skill.

Presumed knowledge

Participants are expected to have completed all modules in *Respiratory 1* and *Respiratory 2—Module 6: Rapid sequence intubation*, *Module 7: Tracheostomy care and management* and *Module 8: Arterial blood gases*.

Objectives

By the end of this module, participants should have:

1. identified and discussed NIV terminology
2. discussed the clinical indications for NIV
3. reviewed patient monitoring requirements while on NIV therapy
4. identified and review your relevant health service policy pertaining to the use of NIV
5. practised setting up NIV circuits relevant to that health service
6. participated in four clinical skills stations.

Background information for educators

Introduction

This module presents a practical approach to implementing NIV. It concentrates on the use of NIV in acute pulmonary oedema and exacerbations of COPD, because for these two disease states, overwhelming evidence exists that NIV is helpful. The settings and titration for these two disease states are quite different, reflecting their different pathophysiology.

NIV definition

NIV is the provision of ventilatory support via a facemask, as distinct from invasive ventilation, where the upper airway is bypassed by endotracheal tube.

Terminology

NIPPV: **N**on-Invasive **P**ositive **P**ressure **V**entilation

- Positive pressure ventilation via a mask using an inspiratory pressure (IPAP) and an expiratory pressure (EPAP).
- The difference between the two pressures is the level of pressure support (PS).

CPAP: **C**ontinuous **P**ositive **A**irway **P**ressure

- Airway pressure is maintained at the same level throughout the respiratory cycle
- CPAP does not provide ventilation.

BiPAP: **B**ilevel **I**nspiratory **P**ositive **A**irway **P**ressure

- Proprietary name for a specific bilevel NIV machine.
- It is commonly used interchangeably with NIV and NIPPV, but this practice should be discouraged, because it can confuse.

Respiratory failure

- Refers to alterations in gas exchange by the lungs that results in serious derangement of blood oxygen and carbon dioxide levels.

Hypoxic respiratory failure

- Refers to a reduction in arterial oxygen levels due to reduced oxygen uptake by the lungs, and is primarily due to mismatch between ventilation and blood flow in the lungs. Examples of causes are pulmonary oedema and pneumonia.
- Hypoxic respiratory failure is generally defined as an arterial oxygen tension of < 60 mmHg.

Hypercapnic respiratory failure

- Refers to elevated arterial carbon dioxide levels resulting from reduced alveolar ventilation. This occurs in lung diseases such as severe exacerbations of COPD and severe asthma, where the work of breathing is exceeds the individual's ability to maintain adequate ventilation. It may also be due to non-pulmonary causes, such as drug toxicity or neurological disease.
- Hypercapnic respiratory failure is generally defined as an arterial carbon dioxide tension > 45 mmHg.

Basics of bilevel NIV

Ventilation refers to the movement of air in and out of the lungs. Ventilation occurs due to alternating changes in intrathoracic pressure generated by the respiratory muscles.

NIV is used to assist ventilation by providing an alternating pressure to the airways via a mask. The machine alternates between an inspiratory pressure (IPAP, or high pressure) and an expiratory pressure (EPAP, or low pressure). The difference between the two pressures is the level of pressure support (PS). The greater the pressure support the more assistance to inspiration.

By varying flow into the tubing and mask system, the NIV machine alternates pressure in the mask and hence the airways of the patient. The patient's respiratory effort triggers cycling between the two pressures.

When the machine senses inspiratory effort, this triggers an increase in pressure to a high level (IPAP). When the machine senses expiratory effort, this triggers a drop in pressure to a low level (EPAP). The cycling from a high to a low pressure in time with the respiratory cycle augments ventilation.

Inspiratory pressure, or high pressure: reduces work of breathing, which helps to prevent respiratory muscle fatigue and augments alveolar ventilation, thus reducing $PaCO_2$.

Expiratory pressure, or low pressure: depending on the condition being treated, the expiratory pressure recruits collapsed lung, which improves oxygenation and reduces the work of breathing by improving lung mechanics. The patient must have an adequate intrinsic respiratory rate for NIV to work.

By comparison, **c**ontinuous **p**ositive **a**irway **p**ressure (CPAP) maintains the airway pressure at the same level throughout the inspiratory cycle. While improving lung mechanics and oxygenation, CPAP does not provide ventilation.

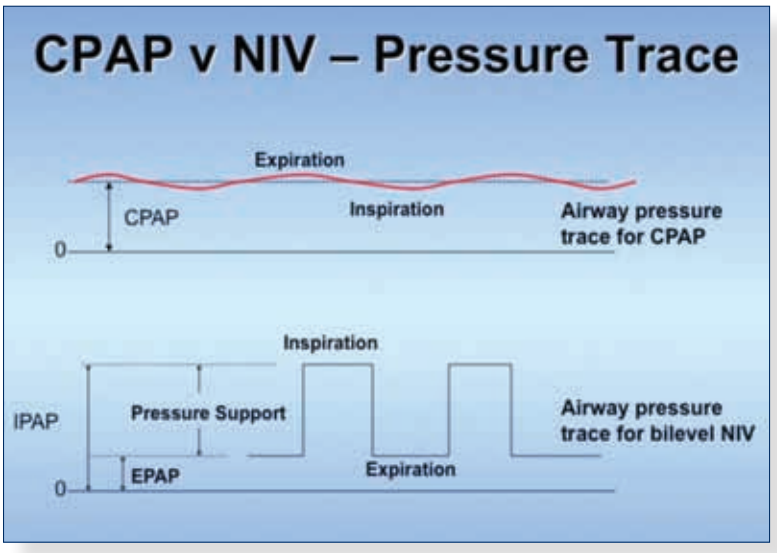


Figure 1: Basics of bilevel NIV

Indications

Hypercapnic respiratory failure:

- exacerbation of COPD with hypercapnia and acidosis
- obesity hypoventilation syndromes
- post-extubation respiratory failure
- pain/surgery-related hypoventilation
- chest trauma with hypoventilation
- neuromuscular disease.

Hypoxic ventilatory failure:

- acute pulmonary oedema
- pneumonia
- diffuse interstitial lung disease.

Contraindications

- respiratory arrest
- inability to clear secretions
- coma
- confusion/agitation
- unstable circulation
- untreated pneumothorax
- uncontrolled upper GI bleeding or vomiting.

While NIV is used for a wide variety of causes of respiratory failure—both hypoxic and hypercapnic—there is only strong evidence for its use in hypercapnic respiratory failure, due to exacerbations of COPD and acute pulmonary oedema.

While NIV may be beneficial in other conditions, the response to therapy is variable and less predictable. Given this, NIV should only be considered for conditions other than hypercapnic COPD and APO when alternative strategies for management have been clearly explored, appropriate monitoring and supervision are in place and a clear directive for further management exists in the event that NIV fails. In general, this means that patients who are candidates for invasive ventilation should NIV fail are better managed in an ICU if one is available.

Bilevel NIV implementation

- Record baseline observations (HR, RR, BP, SpO_2) and perform blood gases if possible.
- Monitor the patient. $SpO_2$and blood pressure monitoring are a minimum; continuous cardiac monitoring is desirable.
- Plug in your machine and set up a circuit (viral filter, tubing, oxygen nipple and tubing and exhalation valve (if needed) and select an appropriate-sized mask.
- A full-face mask should be used, because it is better tolerated in the acute setting.
- **NIV breathing circuits do not have an exhalation limb, so that CO_2 levels will increase if an expiratory leak is not introduced into the circuit. An exhalation valve must be placed in the circuit for masks that do not have exhalation holes. Alternatively, a mask with built-in exhalation holes can be used.**

- Set the inspiratory pressure to 10 cm H_2O and expiratory pressure to 5 cm H_2O (that is, 5 cm H_2O of pressure support).
- Hold the mask to patient's face and encourage slow, relaxed breathing.
- Once the patient is comfortable with the mask, use a head strap to secure the mask.
- The mask should be fitted with the least amount of tension that prevents large leaks.
- Titrate the oxygen to achieve desired saturations. How much oxygen is needed depends on the clinical problem and the patient's respiratory pattern.
- Adjust the NIV machine pressure setting according to the patient's disease and their response to therapy.
- A heated humidifier can be added to the circuit for patients who require NIV for more than 12 to 24 hours.

Figure 2: Bi-level NIV implementation

Patient review

Successful NIV is characterised by patient tolerance of the therapy and improvement in their clinical condition. Clinical signs to monitor include:

- improved mental state
- reduced respiratory rate
- reduced heart rate and blood pressure
- improved oxygenation
- reduced use of accessory muscles of respiration
- improved patient comfort
- falling $PaCO_2$ and rising pH—blood gasses taken an hour after implementation are a good indicator of likely success/failure.

Failed NIV

This is characterised by:

- inability to tolerate mask
- rising pCO_2 or falling pH or refractory hypoxia
- reduction in conscious state
- increasing respiratory rate
- agitation/confusion.

Cessation of NIV

NIV can be stopped when the patient is comfortable without it and oxygen saturations and blood gases are satisfactory. In general, there is no need to wean the pressures.

Periodic trials off NIV for drinks/meals allow you to assess whether the patient still requires NIV.

Complications

Facial pressure areas can occur with prolonged NIV, but can be minimised:

- The head strap should be as loose as possible while still maintaining a seal.
- A duoderm over the nasal bridge may prevent pressure areas.
- Use a better fitting mask if available, for example, a soft silicon mask.
- Intolerance of NIV is common but often can be overcome:
- Talk to the patient. Hold the mask on by hand until the patient has settled.
- Try reducing the inspiratory pressure.
- Loosen straps.
- Try a different mask.

Dry mouth:

- Use a humidifier.
- Minimise leaks from the circuit.
- Give frequent breaks for sips of water.

Treating acute pulmonary oedema

NIV improves oxygenation and reduces the need for intubation in acute pulmonary oedema. The principal problem in APO is lung oedema, resulting in stiff lungs and poor oxygenation due to alveolar collapse.

NIV helps in APO by:

- the recruitment of collapsed lung, resulting in improved oxygenation
- reduced work of breathing through recruitment of collapsed lung
- improved heart function through a reduction in afterload and preload.

When bilevel NIV is used in APO, the focus should be on setting the low pressure (EPAP) to the level at which better oxygenation and symptom control is obtained.

- Start with EPAP at 6 cm H_2O and IPAP at 10 cm H_2O.
- EPAP should be gradually increased until adequate oxygenation is achieved or EPAP is 12 cm H_2O.
- IPAP should be adjusted to be always 5 greater than EPAP.
- If, after optimum EPAP is set, the patient still has considerable respiratory distress or hypercapnia, IPAP can be slowly increased further. This will increase the patient's pressure support and further reduce WOB.
- IPAP should not exceed 20 cm H_2O.
- Oxygen should be entrained into the circuit at sufficient flows to maintain saturations > 92% (range: 10–30 L per minute).
- NIV is one aspect of treatment and the patient should also receive adequate pharmacological treatment, including loop diuretics, vasodilators and morphine.
- Often, NIV is only required for a period of a few hours in pulmonary oedema.

NIV can be discontinued when:

- breathing is comfortable
- diuresis is achieved
- BP is controlled
- saturations are satisfactory on wall oxygen alone.

NIV may be used intermittently once the patient is stable to allow relief from mask pressure, eating and drinking.

Alternatively, CPAP may be used, because it has a similar efficacy to NIV in APO:

- For CPAP, commence at a pressure of 6 cm H_2O.
- CPAP should be increased until the patient is comfortable and adequate saturations are obtained, up to a maximum pressure of 12 cm H_2O.
- If the patient remains hypercapnic or breathless on 12 cm H_2O of CPAP, consider changing to bilevel NIV.

Summary

The summary session reinforces content covered in the learning activities, and is an opportunity for participants to reflect on what they have covered. No new material should be introduced.

Important points to include in the summary are:

- STarting pressures are IPAP 10 cm H_2O and EPAP 6 cm H_2O with maximal oxygen delivery.
- Increase the EPAP to the level at which better oxygenation is achieved (usually 8 to 12 cm H_2O).
- Keep IPAP 4 cm H_2O above EPAP.
- if the patient remains tachypnoeic on EPAP = 12 cm H_2O, then IPAP can be slowly increased to a maximum of 20 cm H_2O to reduce work of breathing further.
- An IPAP of greater then 18 to 20 cm H_2O is rarely tolerated.
- CPAP may be used as an alternative to bilevel NIV, starting with 6 cm H_2O and titrating the pressure up, based on saturations and respiratory rate to a maximum of 12 cm H_2O.

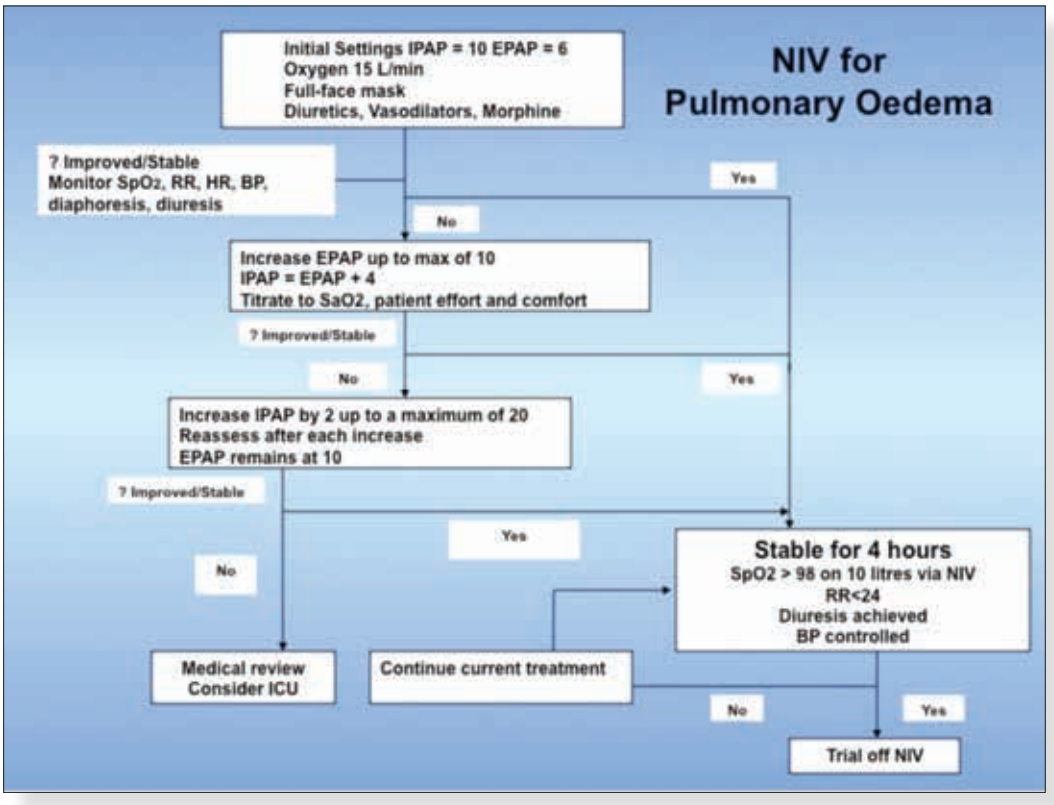


Figure 3: Algorithm for the titration of NIV in acute pulmonary oedema

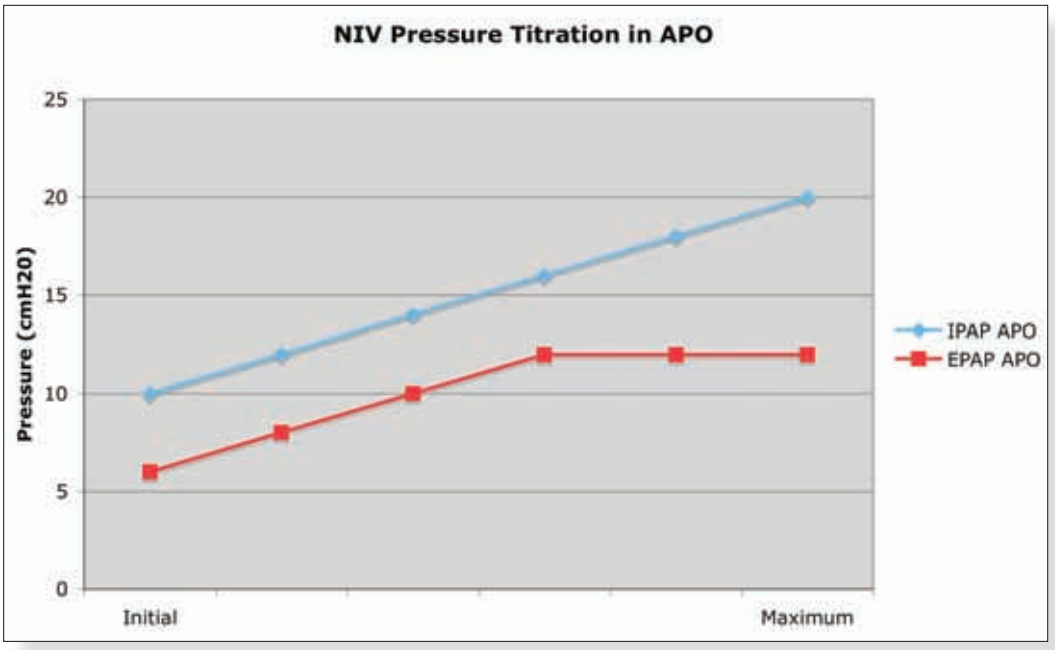


Figure 4: Pressure titration graph for NIV in acute pulmonary oedema

Exacerbations of COPD with hypercapnia

NIV has been shown to reduce intubation and mortality in selected patients with severe exacerbations of COPD. The principal problem is reduced alveolar ventilation due to excessive work of breathing.

Both EPAP and IPAP are important in reducing work of breathing (WOB) and improving alveolar ventilation.

The level of pressure support is the difference between IPAP and EPAP.

The higher the pressure support, the greater the potential reduction in WOB and $PaCO_2$, but patient discomfort and intolerance also increases with increasing pressures.

Initial settings are IPAP = 10 cm H_2O and EPAP = 5 cm H_2O.

IPAP should be increased to the maximal pressure tolerated (patient discomfort or mask leaks) or until there is a satisfactory response in RR, HR, use of accessory muscles and pH and $PaCO_2$. Commonly used IPAP pressures are 14–18 cm H_2O. Few patients or mask systems can cope with pressures above 20 cm H_2O.

EPAP should always remain at 5.

Failure to improve (within 1–2 hours of commencing adequate NIV) is a good predictor of NIPPV failure. The need for intubation and mechanical ventilation should be considered if there is failure to improve after 2 hours of NIPPV.

The potentially detrimental effects of oxygen on respiratory drive must always be considered in these patients. For machines without an oxygen blender, oxygen should be bled into the circuit at the lowest flow rate sufficient to keep saturations at 88 to 92%. This may mean flows as low as 1–2 L per minute.

In a severe exacerbation of COPD, it is common to require NIV for 12 to 24 hours, with intermittent NIV continuing for a further 24 to 48 hours.

In addition to NIV, appropriate pharmacological treatment should be given at the same time, including inhaled B2 agonists/anticholinergics, parenteral corticosteroids and antibiotics.

Most patients will have had an adequate trial of aggressive inhaled bronchodilator therapy before NIV, so time between nebulisers should be at least every 1–2 hours initially, to allow adequate periods of uninterrupted NIV.

Consider using a heated humidifier, because high flow rates quickly lead to drying of airway secretions.

Summary

The summary session reinforces content covered in the learning activities, and is an opportunity for participants to reflect on what they have covered. No new material should be introduced.

Important points to include in the summary are:

- Starting pressures are EPAP 5 cm H_2O and IPAP 10 cm H_2O.
- Use the lowest flow of oxygen that keeps SpO_2 > 90%.
- IPAP is increased in increments of 2 until there is a satisfactory clinical response or the patient becomes intolerant or IPAP = 20.
- EPAP should remain at 5 cm H_2O and should not be increased, because higher levels may worsen hyperinflation.
- A satisfactory response is a reduction in pCO_2, RR, HR and accessory muscle use.

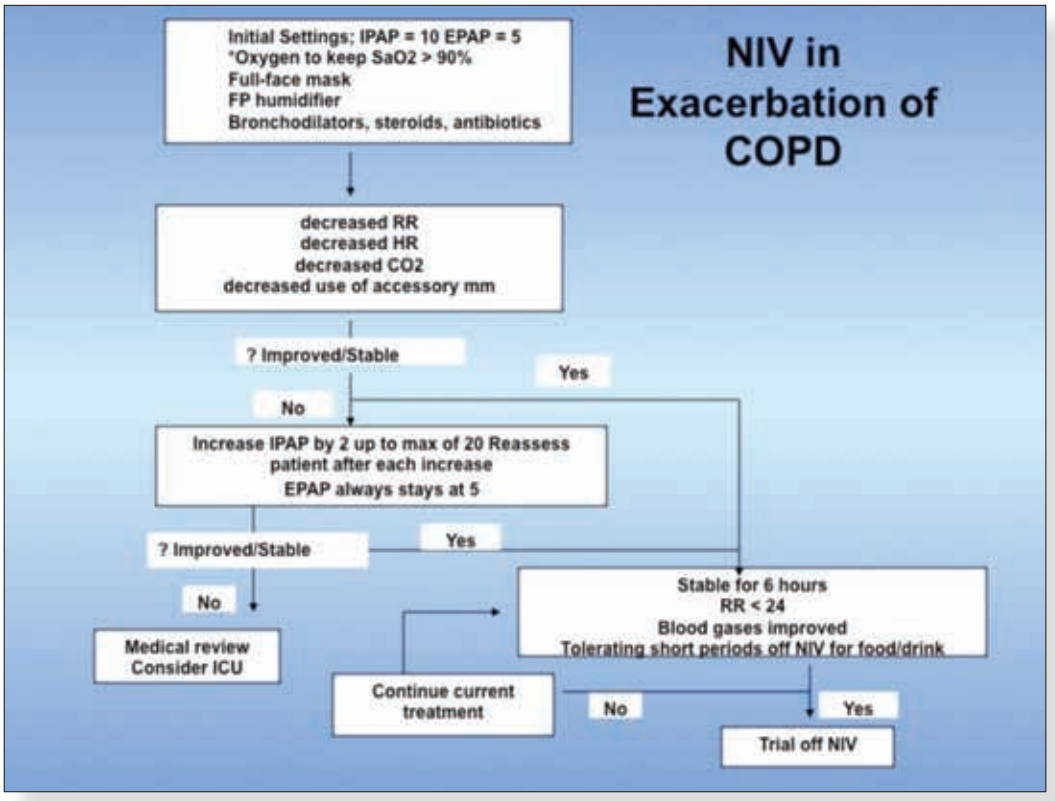


Figure 5: Algorithm for titration of pressure in exacerbations of COPD

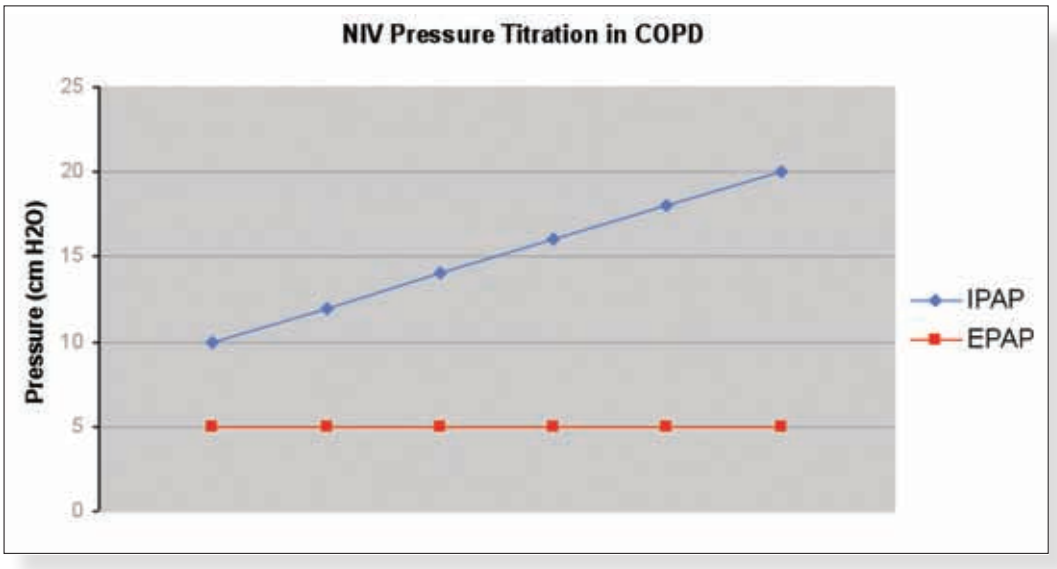


Figure 6: Pressure graph in NIV for exacerbations of COPD

Treating hypoxic respiratory failure (not due to APO)

This includes:

- ARDS
- pneumonia
- pulmonary fibrosis
- post-operative atelectasis
- interstitial pneumonitis.

A major problem is hypoxia with fatigue, due to increased work of breathing.

Atelectasis with hypoxia occurs due to reduced lung compliance associated with parenchymal inflammation/increase in lung water and/or reduced chest wall compliance due to abdominal distension and pain. EPAP in this situation will recruit lung units improving oxygenation and will contribute to reduced work of breathing.

EPAP should be commenced at 6 cm H_2O, and may be increased to 10 cm H_2O. The final level should be where better oxygenation is achieved without discomfort to the patient or adverse cardiovascular effects.

IPAP should initially be kept 6 cm H_2O above the EPAP level. Once the optimum EPAP is set, then the IPAP can be increased to reduce the work of breathing further, and thus diminish the risk of fatigue developing before lung function improves. Maximum IPAP settings are 18–20 cm H_2O.

Use a heated humidifier, because high flow rates quickly lead to drying of airway secretions.

These conditions do not reverse quickly as they do in pulmonary oedema, so NIV may be needed for several days.

NIV has a high failure rate, so clear documentation of resuscitation status and suitability for ICU admission is needed.

Learning activities

Suggested learning activities and timetables are outlined below.

Timing	Activity	Objective
40 minutes	Facilitated discussion	
15 minutes	Skills stations 1	
15 minutes	Skills stations 2	
15 minutes	Skills stations 3	
15 minutes	Skills stations 4	
5 minutes	Summary	
5 minutes	Evaluation	

Total time = 1 hour 50 minutes

Facilitated discussion

The facilitator should lead a discussion amongst participants about the issues covered in the background information. The facilitator should not give a didactic lecture, but instead promote open discussion and knowledge sharing amongst participants. Participants should be encouraged to describe any real-life experiences they have encountered.

Skills stations

The four skills stations allow participants to demonstrate and practise:

- NIV circuit setup
- patient assessment
- ongoing patient assessment for a patient currently receiving NIV therapy.

The skills stations can be worked through sequentially or broken up into four stations, should resources allow.

A full body manikin and airway trainer are required. If the clinical educators' health service has access to a high fidelity manikin that can be ventilated, this is considered optimum for Skills station 4. However, any manikin that has an interactive airway will suffice.

Skills station 1

Put together an NIV circuit. This should include viral filter, tubing, oxygen nipple, +/-exhalation valve and mask. The subject should the explain purpose of each component.

Skills station 2

Demonstrate the setup of the NIV machine for a patient with an acute exacerbation of COPD, including the placement of the mask on the manikin.

The subject should explain the settings they choose (IPAP, EPAP, oxygen flow rate) and demonstrate how they would talk to the patient while placing the mask and then applying the head strap.

Skills station 3

Demonstrate the review of a patient with APO one hour after implementation of NIV.

The subject should check HR, BP, RR, SpO_2, mask leak, patient comfort, whether they are feeling better and check ABGs if available.

Skills station 4

A patient with APO has been on NIV for 30 minutes and you review them. Vital signs are RR 36, BP 180/110, HR 120 and SpO_2 89 on 15 L O_2 and IPAP 10 EPAP 6.

The subject should demonstrate how they would respond to the manikin (ask questions about pain, comfort), check NIV settings and adjust. Explain how and why adjustments are made.

Summary

- Starting pressures are IPAP 12 cm H_2O and EPAP 6 cm H_2O with 15 L per minute oxygen.
- Increase the EPAP to the level at which better oxygenation is achieved (usually 6 to 10 cm H_2O).
- Keep IPAP 6 cm H_2O above EPAP.
- When the patient is settled on the mask, slowly increase the IPAP to the maximum tolerated pressure to reduce further the work of breathing.
- An IPAP of greater than 18 to 20 cm H_2O is rarely tolerated.

Resource list

The following resource list assumes two facilitators for every eight participants, a ratio of 1:4. As a minimum, the following resources are needed to conduct this module.

Resource	Quantity	Additional comments
Facilitators	Up to 2	Group size up to 8
Manikins	Up to 3	If available
3 NIV circuits	3	Or one, if working through each skills station sequentially
NIV machine	1–2	A machine that your health service uses

Evaluation

A formal evaluation has been specifically developed for this module. It incorporates the objectives of the module and the perceptions of the participants about whether they have increased their understanding by working through the module. It is highly recommended that this formal evaluation be copied and completed by all participants at the completion of the module.

A range of informal evaluation tools may also be used in conjunction with this evaluation throughout the module, including those available in the Department of Human Services' *Clinical Skills Facilitators Manual* from the basic course conducted in 2007.

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Resources

Facilitator feedback form

The following form should be used to assist you in giving feedback after each participant has practised their NIV—ventilation skills at the skills station.

Feedback using the Pendleton model

Pendleton's model of feedback assists learners to maximize their potential at different stages of training, raise their awareness of strengths and areas for improvement, and identify actions to be taken to improve performance. Pendleton's rules are structured in such a way that the learner identifies the positives first, in order to create a safe environment. This is followed by the facilitator or group reinforcing these positives and discussing skills to achieve them. Different techniques are then suggested. The advantage of this method is that the learner's strengths are discussed first. Avoiding a discussion of weaknesses right at the beginning prevents defensiveness and allows reflective behaviour in the learner.

Below is a series of questions to assist you in this technique:

1. Ask the learner how they feel.
2. Ask the learner what went well and why (this can be combined with question 1 and 3).
3. Tell the learner what went well and why.
4. Ask the learner what could have been done better and why.
5. Tell the learner what could have been done better and why.
6. Summarise the learner's strengths and identify up to three things to concentrate on.

Note: This form does not need to be given to the participant — it is a guide for you, the group facilitator.

Module 9: Non-invasive ventilation—evaluation

Thank you for participating in this module. As part of our commitment to quality improvement the following questionnaire will be used to plan future implementation of this module. We appreciate your time completing this evaluation.

1. Overall

How would you rate this module?

☐ poor ☐ fair ☐ good ☐ very good ☐ outstanding

2. Learning objectives

Please consider whether this module was successful in meeting the following learning objectives:

Respiratory 2 Learning objectives of Module 9: Non-invasive ventilation	Strongly disagree	Disagree	Slightly agree	Agree	Strongly agree
Identified and discussed NIV terminology	☐	☐	☐	☐	☐
Discussed clinical indications for NIV	☐	☐	☐	☐	☐
Reviewed patient monitoring requirements while on NIV therapy	☐	☐	☐	☐	☐
Identified and reviewed your relevant health service policy pertaining to the use of NIV	☐	☐	☐	☐	☐
Practised setting up NIV circuits relevant to that health service	☐	☐	☐	☐	☐
Participated in four clinical skills stations	☐	☐	☐	☐	☐

3. Important learning outcomes

What are the three most important things you have learned from this module?

4. Module implementation

Please indicate to what extent you agree or disagree with each of the following statements in relation to the implementation of the module.

	Strongly disagree	Disagree	Slightly agree	Agree	Strongly agree
The facilitator respected my experience	☐	☐	☐	☐	☐
The facilitator encouraged my participation	☐	☐	☐	☐	☐
I was able to ask the facilitator questions	☐	☐	☐	☐	☐
The facilitator was able to answer my questions	☐	☐	☐	☐	☐
The feedback I received was clear	☐	☐	☐	☐	☐
The feedback I received will assist me my future performance	☐	☐	☐	☐	☐
There was adequate time for the skills stations	☐	☐	☐	☐	☐
There was adequate time for the facilitated discussions	☐	☐	☐	☐	☐
There was adequate time for the simulations	☐	☐	☐	☐	☐
I have increased my confidence in using NIV therapy	☐	☐	☐	☐	☐
I have identified future learning needs in this topic area	☐	☐	☐	☐	☐

5. Future module implementation

Do you think the module should be altered in any way? ☐ yes ☐ no

If yes, what recommendations do you have?

Thank you

PowerPoint Presentation

1.

Clinical Skills in Hospitals Project

MODULE 9

'Non-Invasive Ventilation (NIV)'

StV

A Victorian Government initiative

2.

Non-Invasive Ventilation

- Introduction and Overview
- Terminology
  - NIPPV
  - CPAP
  - BiPAP
  - Respiratory Failure

3.

Non-Invasive Ventilation

- Basics of Bi-Level NIV
  - Indications
  - Contraindications
  - Implementation
- Patient Review
  - Failure of NIV
- Cessation of NIV
- Complications

4.

Non-Invasive Ventilation

- Treating Acute Pulmonary Oedema
- Exacerbations of COPD with hypercapnia
- Treating Hypoxic Respiratory Failure

5.

Non-Invasive Ventilation

- Skills Stations

6.

Module 10: Introduction to mechanical ventilation

Introduction

Respiratory 2 was developed as a teaching and learning tool for Victorian clinical educators. The information contained in each module was developed using evidence-based resources and examples of best practice. Where expert opinion varies, a discussion section is included. However, it is not within the scope of *Respiratory 2* to address the full spectrum of local variations. Variations can occur in several areas, including practices relating to types of equipment used, infection control processes, practice guidelines and so on. Therefore, educators should, where appropriate, adapt content to reflect their local policies, procedures and protocols. This will ensure the relevancy of the package content to your learners.

The modules are designed to be discrete courses in their own right. They are timetabled so they can be completed in a 1–2 hour timeframe. This timeframe was chosen after we received feedback from clinical educators requesting shorter courses, because health professionals often have limited time to educate away from patients. However, the packages may also be combined into a one- or two-day course.

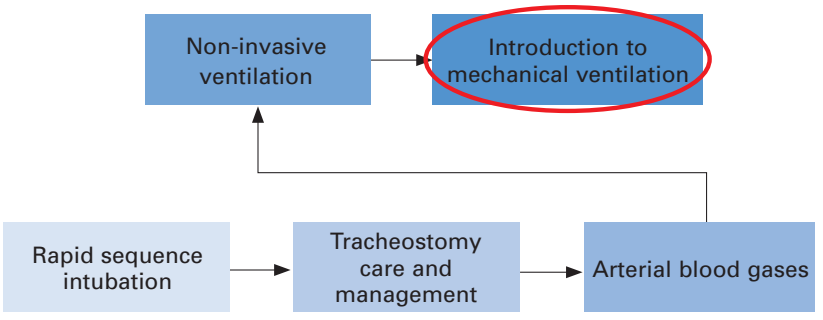
Respiratory 2 should be used as an educational tool to assist in the teaching of clinical skills. It is structured as a guide to assist clinical educators, and uses many concepts taught in the Clinical Skills in Hospitals Project (Train-the-Trainer courses). Educators are encouraged to build on this resource by adding their own scenarios which incorporate hospital/health service protocols, policies and other resources. Each module is designed as a lesson plan to incorporate the simulations into the teaching of clinical skills.

Aims

Respiratory 2 aims to make participants confident in their application of respiratory knowledge and skills on adults in different environments and settings.

Package structure

Respiratory 1 is the first of the two respiratory packages, and contains five modules that provide learning opportunities for health professionals at all levels of experience and from all health disciplines. Modules 1, 2 and 3 in *Respiratory 1* are regarded as fundamental, while Modules 4 and 5 are more difficult and are regarded as intermediate. *Respiratory 2* contains Modules 6–10, which are considered intermediate to complex. These modules focus on more complex respiratory management strategies that require participants to have completed *Respiratory 1*.

Level of complexity	Package structure
Complex For participants with more than 4 years experience or who have completed Modules 1–4	
Intermediate For participants in postgraduate years 3–4 or who have completed Modules 1 and 2	
Fundamental For participants in postgraduate years 1–2	

Mechanical ventilation

Respiratory 2 was designed to develop participants' knowledge, skills and behaviours in the use of respiratory skills and practices, as well as expose them to increasingly complex scenarios aimed at testing their ability to combine these individual skills, work as a team and problem solve in more difficult situations.

Educators delivering these modules should be aware of participants' level of experience and choose appropriate modules. Modules presume an increasing level of knowledge as they progress, ranging from a fundamental knowledge of anatomy and physiology for the fundamental modules, up to detailed knowledge of respiratory practices for the complex modules. Novice participants (such as first-year graduates) are expected to start with the fundamental modules, and only move onto intermediate and more complex modules as they demonstrate proficiency. More experienced participants may start at the intermediate level if the educator is satisfied that they have the prior knowledge and skills. Individual educators are responsible for assessing each participant's baseline knowledge and determining which modules they should complete. More specific descriptions of presumed knowledge are outlined in each module.

The design of these packages presumes that the clinical educators using them have knowledge and expertise in current best practice regarding the teaching of clinical skills and conducting facilitated discussions. Knowledge and expertise are presumed commensurate with the Department of Human Services' basic and advanced Train-the-Trainer programs. Clinical educators are encouraged to refer to the *Department of Human Services' Clinical Skills Facilitators Manual* for theory on:

1. Peyton's model for teaching clinical skills
2. leading small group discussions
3. giving feedback
4. crisis resource management skills.

Module 10: Introduction to mechanical ventilation

Author: Mandy Voss

Aims

Module 10: Introduction to mechanical ventilation enables participants to develop an in-principal understanding of the concepts surrounding mechanical ventilation, and then to discuss its implementation and management.

Presumed knowledge

Participants are expected to have completed all modules in *Respiratory 1* as well as *Respiratory 2—Module 6: Rapid sequence intubation*, *Module 7: Tracheostomy care and management*, *Module 8: Arterial blood gases* and *Module 9: Non-invasive ventilation*. Alternately, participants should be engaged in postgraduate studies where mechanical ventilation is a practice requirement.

Objectives

By the end of this module, participants should have:

1. identified indications for mechanical ventilation
2. discussed the principles of positive pressure ventilation
3. identified and discussed the commonly used modes of ventilation
4. discussed how a mandatory breath is delivered to the patient using volume and pressure control ventilation
5. discussed how the ventilator can be programmed to deliver a mandatory breath in terms of frequency, time for inspiration and breath size
6. discussed the adverse effects of positive pressure on the respiratory and cardiovascular system
7. discussed the alarm settings necessary to prevent barotrauma and volutrauma
8. discussed how carbon dioxide and oxygenation levels can be maintained during mechanical ventilation.

Background information for educators

Mechanical ventilation

Mechanical ventilation is used in a variety of situations where patients have compromised respiratory function. The ventilator may take complete control of the patient's ventilation, it may partially assist the patient's inspiratory breathing effort, or it may allow for the patient to breathe spontaneously through the ventilator and provide a level of inspiratory support.

Indications for mechanical ventilation support

The most common reason for a patient to require mechanical ventilation support is when they have a reversible acute respiratory failure. This may be due to a hypoxic respiratory failure when the patient has inadequate oxygenation, or a hypercapnaeic respiratory failure where alveolar ventilation is inadequate to meet the metabolic needs of the patient. Often the patient has an increase in their work of breathing (WOB) which their body cannot sustain. Other non-respiratory reasons for mechanical ventilation include cardiac arrest, trauma, sepsis, altered mental status, neuromuscular disorders and as a support to perform routine surgical procedures.

Aim of mechanical ventilation

The main aim of mechanical ventilation to ensure the patient has optimal ventilation and oxygenation while the underlying cause for respiratory failure resolves. This involves maintaining gas exchange (O_2 and CO_2), controlling the elimination of CO_2 and reducing the work of breathing.

A brief review of spontaneous breathing

During spontaneous breathing, inspiration is considered an active process which requires contraction of the respiratory muscles. Contraction of the respiratory muscles increases the volume of thorax and lowers the gas pressures within the lungs to less than atmospheric pressure, resulting in the ambient flow of air into the lungs.

Expiration is a passive process and occurs due to relaxation of the respiratory muscles. An elastic recoil of the lungs and chest wall reduces the capacity of the thorax and increases alveolar pressure to greater than atmospheric pressure, so air is ‘forced’ out of the lung,

Positive pressure ventilation

In contrast to spontaneous breathing, mechanical ventilators deliver a breath by forcing air into the lungs to inflate them, and therefore causing a positive pressure. Expiration remains a passive process, and occurs when the ventilator ceases to deliver the breath and allows the breath to be passively exhaled—the ventilator does not ‘suck’ the gas out of the lungs. Often when the patient is receiving mechanical ventilation a small positive pressure may be applied during the expiratory phase to maintain patency of the small airways, called positive end expiratory pressure (PEEP).

Modes of mechanical ventilation

It is often assumed that when a patient is receiving mechanical ventilation the ventilator takes complete control of the patient’s breathing. However, a patient receiving mechanical ventilation may be able to breathe spontaneously. Mechanical ventilators have the capacity to take full control of the patient’s breathing, partially

assist the patient's inspiratory effort, or allow the patient to breathe spontaneously through the ventilator circuit. How much control the ventilator has over the patient's ventilation depends on the mode of ventilation chosen.

A mode of ventilation indicates how the mechanical ventilator ventilates the patient, whether it delivers regular, compulsory breaths and how it responds to the patient's inspiratory effort. The mode selection determines how much the patient participates in their breathing. The choice of mode depends on the clinical condition and needs of the patient and the overall goals of their management.

Control mode

Continuous (or controlled) mandatory ventilation (CMV) is a control mode of ventilation, sometimes referred to as intermittent positive pressure ventilation (IPPV). In this mode the ventilator performs all the work of breathing—it is set to deliver a fixed rate of mandatory ventilator breaths each minute. The actual breath delivered may be controlled by a fixed volume or pressure. In this mode the ventilator does not sense or recognise a patient's intrinsic spontaneous inspiratory effort. This can be potentially harmful and uncomfortable for the patient, and when used, the patient requires sedation and muscle relaxants to enable effective safe ventilation. This mode of ventilation is now rarely used.

Assisted modes

In these modes the mechanical ventilator can recognise when a patient makes an inspiratory effort—it will respond to the patient-initiated breath by assisting their ventilation.

The two main assisted modes seen on mechanical ventilators are assist control (A/C) and synchronised intermittent mandatory ventilation (SIMV).

Assist control (A/C)

In assist control mode the mechanical ventilator will respond to the patient's inspiratory effort by delivering a preset mandatory breath. This mandatory breath may be a fixed volume or a fixed pressure breath. In this mode the ventilator can be set to deliver a fixed rate of mandatory breaths to the patient each minute, but will still respond to the patient-initiated breath by delivering the mandatory breath, thereby assisting their inspiratory effort.

The total respiratory rate may be higher than the ventilator preset rate if the patient is making inspiratory effort, but all the delivered breaths will be the same. If the ventilator does not have a set rate of breaths to deliver each minute, all the ventilated breaths will be patient initiated.

Synchronised intermittent mandatory ventilation (SIMV)

In SIMV mode the mechanical ventilator can be set to deliver a preset rate of mandatory breaths to the patient. When a patient makes an inspiratory effort in this mode the ventilator will respond in one of two ways. If the patient's inspiratory effort occurs near the time that the mandatory breath will be delivered, the ventilator synchronises the delivery of the mandatory breath with the patient's inspiratory effort. However, if a patient-initiated breath occurs when the ventilator is not due to deliver the preset mandatory breath, it allows the patient to make their own spontaneous breath. The ventilator can also be set to deliver extra support to the spontaneous breath by providing pressure support to augment the size of the patient's spontaneous breath.

In this mode the patient always receives the preset rate of mandatory breaths, and these are synchronised with the patient's inspiratory effort. Any additional breaths initiated by the patient are their own spontaneous breaths and may be augmented in size by the addition of a pressure support. The total respiratory rate may be higher than the ventilator preset rate if the patient makes inspiratory effort.

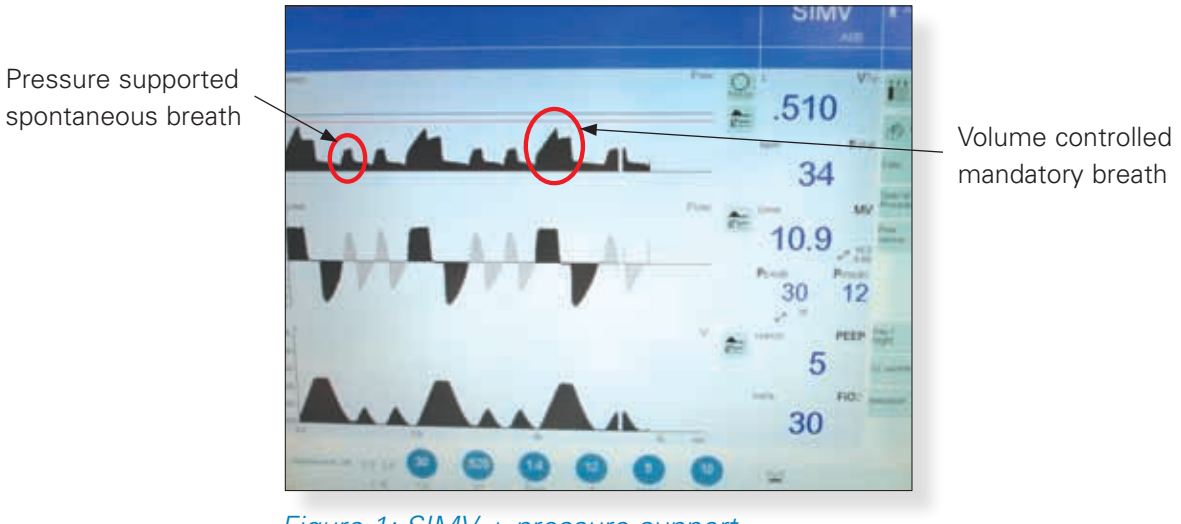


Figure 1: SIMV + pressure support

Spontaneous modes

When the ventilator is set in a spontaneous mode the patient initiates all their breaths. Unlike the other modes, there is no preset fixed rate of mandatory breaths to be delivered to the patient. In spontaneous modes there is usually a parameter set to support the patient's breath. This support can be given in the form of a continuous positive airway pressure (CPAP) or pressure support (PS).

Continuous positive airway pressure (CPAP)

In this mode the patient breathes spontaneously through the ventilator with a continuous positive pressure applied throughout the respiratory cycle.

Pressure support (PS)

In this spontaneous mode the patient initiates all their breaths and breathes spontaneously through the ventilator. A level of positive pressure, that is, a level of pressure support, is applied by the ventilator to the patient when they initiate their breath. Pressure support is applied and maintained at a set level during their inspiration phase, and ceases when patient begins expiration. The aim of the pressure support is to augment the size of the patient's spontaneous breath and reduce the work of breathing. Pressure support can be used as the sole measure of ventilation support as in spontaneous breathing, or can be used in conjunction with SIMV.
A pressure support level is usually set between 10 and 20 cm H_2O. Pressure support is sometimes referred to as assisted spontaneous breathing (ASB).

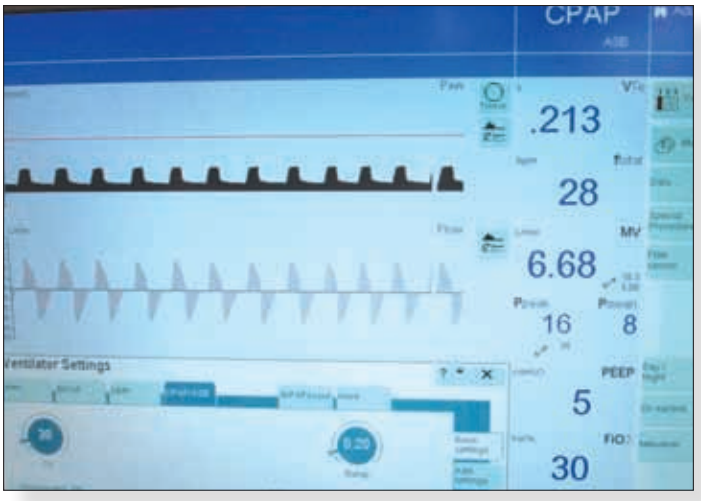


Figure 2: Wave forms for CPAP and pressure support

Setting the ventilator controls

When using the control and assisted modes of ventilation, the mechanical ventilator needs to be programmed to deliver the mandatory breath. It is important to control the amount of gas delivered as a mandatory breath during the inspiratory phase. If the volume is too large, or the positive pressure too high, there is a potential for damage to the lung tissue. Large tidal volumes overstretch alveoli and injure the lungs. If the mandatory breath volume is too small, there is a potential for inadequate ventilation (hypoventilation).

The size of the breath delivered to the patient is known as the tidal volume. Generally, the aim is to deliver a tidal volume of approximately 8 mL per kg body weight of the patient's lean body mass.

Example

If the patient weighs 70 kg and we use 8 mL per kg body weight, the desired tidal volume is 560 mL:

70 kg x 8 mL = 560 mL.

Selecting the size of the tidal volume is partly determined by the patient's ideal body weight, but is also influenced by the patient's presenting respiratory problem. A lower Vt may be required in patients with a severe respiratory failure that has caused:

- a significant reduction in the lung compliance,
- or an increase in airways resistance

This works as a lung protective strategy to prevent further damage to the lung with the commencement of mechanical ventilation. For most patients, 8 mL per kg body weight is an appropriate starting volume, with an upper limit of 10 mL per kg body weight.

How to achieve the desired tidal volume—volume, pressure and dual control cycle

The mandatory ventilator breaths are delivered by setting a volume or pressure control parameters, sometimes referred to as volume cycle and pressure cycle ventilation.

Volume control

When using volume control to deliver the breath, the ventilator is set to deliver a fixed volume of gas to the patient during the inspiration phase (a tidal volume). Every mandatory breath delivered by the ventilator is the same volume. Once the preset volume has been delivered, the ventilator ceases to deliver gas to the patient, and is ready for passive expiration to occur. Expiration can follow immediately after the mandatory tidal volume has been delivered, or if the ventilator has a time-cycling capacity, it may hold the tidal volume in the lungs until it is ready to cycle to expiration (sometimes referred to as the inspiratory pause time).

A positive pressure is generated in the lungs as the tidal volume is delivered to the patient. The pressure continues to rise during inspiration and peaks at the point that the full tidal volume has been delivered to the patient. This is measured as the peak inspiratory pressure (PIP). This peak inspiratory pressure cannot be predicated before the tidal volume is delivered, and can be of varying pressure. The peak pressure is influenced by:

- the size of the mandatory tidal volume
- the speed of the gas flow (measured in L per minute)
- the patient's lung compliance and resistance.

For example, the larger the tidal volume, the higher the peak inspiratory pressure. A patient with a condition that reduces their lung compliance (for example, pulmonary oedema) or that increases airway resistance (for example, asthma) will also generate higher peak inspiratory pressures. The greater the speed of gas delivered, the higher the peak pressure generated.

Excessive pressure generation (high PIP) during the inspiratory phase increases the potential for lung damage and needs to be avoided. A peak inspiratory pressure greater than 40 mmHg in volume control ventilation is considered a high pressure. If there is an inspiratory pause time, (when there is a period after the volume has been delivered and before expiration commences) a plateau pressure can be monitored. The plateau pressure should be monitored and maintained below 30 mmHg.

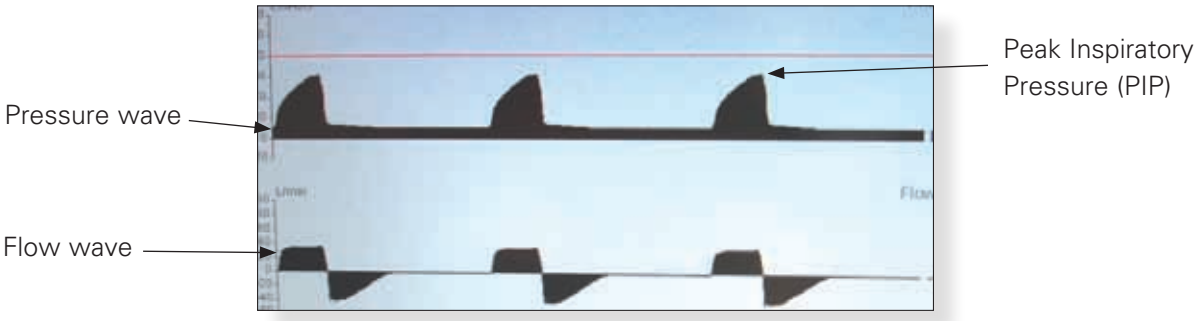


Figure 3: Volume control breath without inspiratory pause

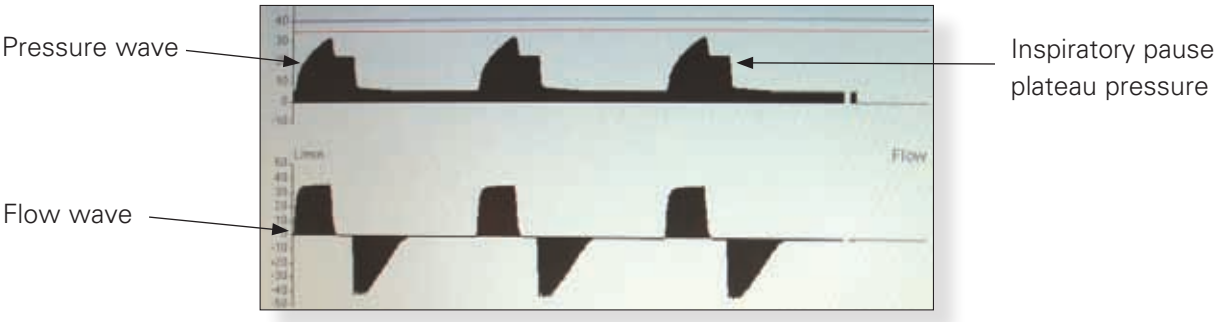


Figure 4: Volume control breath with inspiratory pause

Alarm settings

A peak inspiratory pressure alarm (pMax) setting is one of the various safety mechanisms available on mechanical ventilators that can be set to prevent high positive pressure generation and to warn that the pressure is increasing. If the alarm is activated, the ventilator will terminate the delivery of the tidal volume to prevent excessive pressures. More sophisticated ventilators can continue to deliver the tidal volume even when the alarm has been activated by delivering the volume at a lower pressure.

An increase in the airway pressure can occur if there is obstruction of the endotracheal tube (ETT) or large airways, (for example, if the patient bites on the tube, or sputum is in the ETT), or if there is a deterioration in the lung characteristics (for example, bronchospasm, or acute pulmonary oedema) which changes the airway resistance and lung compliance.

Pressure control ventilation

In this type of ventilation the mandatory breath is delivered to a preset level of pressure. The ventilator delivers the same level of pressure for each breath. Unlike volume control ventilation, in pressure control, the pressure remains constant, but the volume of each breath may vary. The size of the breath is influenced by:

- the set level of pressure (the higher the pressure, the larger the volume)
- the patient's lung compliance and resistance
- the time that the pressure is held during the inspiratory phase.

To achieve the desired tidal volume for the patient, the inspiration pressure is manipulated—increasing the pressure level increases the size of the tidal volume, and decreasing the pressure level decreases the volume size. The actual tidal volume size will not be known until it is measured (by the ventilator) at the end of expiration.

The pressure level can be set safely between 20 cm H_2O and 30 cm H_2O, and is manipulated to achieve the desired tidal volume. In some circumstances the medical team may prescribe a higher pressure level, but never above 40 cm H_2O.

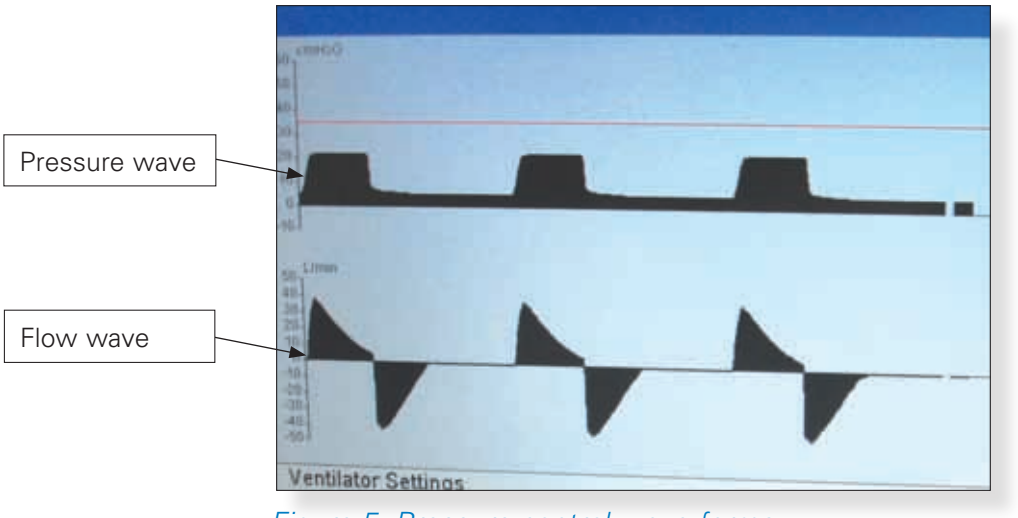


Figure 5: Pressure control wave forms

Alarm settings

In pressure control ventilation the expired tidal volumes should be monitored to ensure that the desired volume is achieved. The volume alarm parameters need to be set at a level that alerts staff if the volume is either too large or has decreased.

A drop in tidal volume with no change in the preset pressure level may indicate that there is an obstruction in the ETT, or that there has been an alteration in the patient's respiratory resistance and compliance.

Dual control ventilation

This option of breath delivery is a reasonably new innovation and is not available on all ventilators. When using dual control (commonly called autoflow or pressure regulated volume control, or PRVC) the ventilator is programmed to deliver a predetermined tidal volume (as for volume control); however, the ventilator delivers the breath in the same way as it would for a pressure control breath. The aim is to deliver the desired tidal volume at the lowest possible positive pressure level. The ventilator regulates the positive pressure by adjusting the pressure level to achieve the desired volume.

The upper level of pressure in dual control is not necessarily at a constant pressure level as it is for pressure control ventilation—it may vary from breath to breath to achieve the desired preset tidal volume size. For this reason it is important to set a maximum pressure alarm parameter to prevent the occurrence of high pressure levels.

Any changes of pressure may indicate that there is an obstruction in the ETT or an alteration in the patient's lung compliance and resistance. It is possible that the tidal volumes desired will not be achieved if the pressure alarm is activated.

Volume versus pressure control breath delivery

The choice of whether to use a volume or pressure control breath depends on the patient's presenting problems and medical opinion. However, traditionally, the first choice (especially when initially commencing mechanical ventilation) is volume control breaths. This is because of the ease with which a consistent and appropriately sized tidal volume can be delivered to the individual patient and, together with the rate, can provide a satisfactory per-minute ventilation to achieve alveolar ventilation and a desired CO_2 level.

Controlling the time for each mandatory breath delivered by the mechanical ventilator

Most ventilators have a time-cycling mechanism set to control the duration of the inspiratory phase of ventilation. It determines the length of time for the volume to be delivered in volume control, and the length of time that the pressure level is maintained in pressure control ventilation. Inspiration ends once the set inspiration time elapses, and the ventilator then cycles into the expiration phase to allow for passive expiration.

Different mechanical ventilators have various control settings to determine the time for inspiration, but the principle remains the same. The following settings influence the time for each inspired breath:

- inspiratory time (measured in seconds)
- respiratory rate per minute
- inspiration-to-expiration ratio (I:E ratio)
- the gas flow rate (speed at which the gas is delivered).

Because expiration remains a passive process, it is essential that enough time is allowed for the breath to be expired before the next ventilator breath is delivered.

Inspiratory time

In most circumstances the inspiratory time for a mandatory ventilator breath can be set anywhere between 1 and 1.5 seconds. Inspiration ends once the preset time elapses and the ventilator cycles to the expiration phase. The inspiratory time remains constant for each mandatory breath.

Some ventilators do not have an inspiratory time setting. In these circumstances the inspiratory time is determined indirectly by using the I:E ratio and respiratory rate.

Inspiration-to-expiration ratio (I:E ratio)

An I:E ratio is the ratio of the duration of inspiration to the duration of expiration, and is generally set to a ratio of 1:2.

The I:E ratio can be manipulated to allow a proportionally longer duration for expiration, for example, an I:E ratio of 1:3 or 1:4. This is only done in special circumstances when the patient requires a longer period to fully expirate, for example, when a patient has an acute exacerbation of asthma or COAD.

The I:E ratio can also be manipulated to allow for a proportionally shorter period for expiration ratios of 1:1 or 2:1. Again, this is done only in special circumstances—usually in the intensive care unit when patients have an acute lung injury.

Flow rate

Also referred to as 'peak flow', the flow rate is the speed or velocity at which the gas flow is delivered during inspiration. Depending on the mechanical ventilator and the choice of mandatory breath delivery, the flow rate may be manipulated directly or determined automatically by the ventilator. The flow is measured in L per minute and on average, in normal circumstances, is set somewhere between 20 and 60 L per minute.

Flow wave patterns

The flow of gas may be delivered in variable waveforms. The pattern determines if the flow rate is delivered at a constant or variable speed. The four main configurations are the rectangle, sinusoidal, decelerating and accelerating. The pattern can be set manually, or automatically by the ventilator.

Respiratory rate

Respiratory rate is the number of mandatory breaths to be delivered by the mechanical ventilator each minute, often referred to as a set frequency (f). It is set anywhere between 8 and 20 breaths per minute, depending on the patient's per-minute ventilation requirements.

Minute ventilation

The minute ventilation is the total volume delivered to the patient each minute:

frequency x tidal volume = minute ventilation.

Manipulating the minute ventilation will directly effect alveolar ventilation, it therefore will influence CO_2 levels.

Trigger sensitivity

Mechanical ventilators should be able to sense and recognise when a patient is making an inspiratory effort in order to respond by delivering a mandatory breath or allow for spontaneous breathing. Setting the trigger sensitivity on the ventilator ensures that the machine can detect the patient's respiratory effort. If the ventilator trigger to set too low, self-triggering may occur, increasing the minute volume. If the trigger is set too high, the patient may attempt to breathe, and the ventilator will not be able to recognise the effort. This is distressing and uncomfortable for patients. The trigger sensitivity should be set as sensitive as possible without causing self-triggering. The sensitivity may be set as a pressure trigger or a flow trigger.

Oxygen

Mechanical ventilators can deliver from 21% to 100% oxygen, and are titrated to individual patient needs. 100% oxygen is usually given when the patient first commences mechanical ventilation, and then it is gradually weaned according to the patient's oxygen saturations. There is a potential for oxygen toxicity if the patient remains on 100% oxygen for long periods; therefore, the percentage must be reduced at the earliest possible time to less than 60%.

Positive end expiratory pressure (PEEP)

PEEP is a positive pressure that is actually applied throughout the respiratory cycle; however, its physiological effects occur during the expiration phase of mechanical ventilation. When PEEP is applied, the pressure does not return to zero (atmospheric pressure) during expiration, and therefore the pressure within the patient's lungs remains positive. It is used to prevent the collapse of the alveoli and smaller airways and to increase the functional residual capacity (FRC). Therapeutically, it is indicated to improve the patient's oxygenation. Increasing the PEEP level to improve oxygenation can aid in lowering the FiO_2 level and decrease the chance of oxygen toxicity. In general, the PEEP should be set at a minimum of 5 cm H_2O and adjusted according to oxygenation/medical orders.

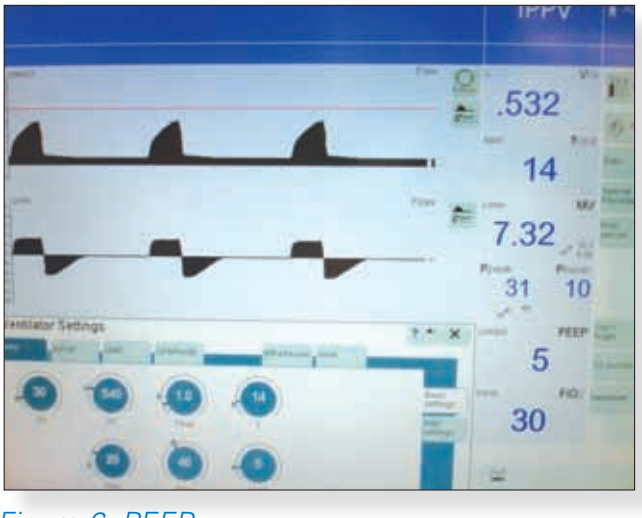


Figure 6: PEEP

Control of carbon dioxide (CO_2) levels

Manipulation of the minute ventilation controls alveolar ventilation and therefore the CO_2 levels. Minute ventilation is controlled by manipulation of the tidal volume and respiratory rate of the ventilator.

Manipulating minute ventilation to achieve desired CO_2 levels

The following equation can be used to assist in determining appropriate minute ventilation for the patient.

$$\text{Desired minute ventilation} = \frac{\text{actual } CO_2 \times \text{actual minute volume}}{\text{Desired } CO_2}$$

The normal range of $PaCO_2$ is 35–45 mmHg. Aiming for a $PaCO_2$ of 40 mmHg is acceptable in the absence of a metabolic acidosis or metabolic alkalosis. For example:

- a patient is receiving Vt 500 x frequency 16 = 8 L per minute
- the ABGs reveal pH 7.50, $PaCO_2$ 30, PaO_2 100, HCO_3 24, SaO_2 100%.

Analysis reveals that the patient has a respiratory alkalosis and demonstrates that the minute ventilation is greater than it should be for 'normal' pH and PCO_2. In this situation the following applies:

$$\text{Desired minute ventilation} = \frac{\text{actual } CO_2 \times \text{actual minute volume}}{\text{Desired } CO_2}$$

$$= \frac{30 \text{ mmHg} \times 8.0 \text{ L per Minute}}{40 \text{ mmHg}}$$

Therefore the desired MV is 6 L per minute.

If the Vt is the appropriate size for the patient, then the frequency can be manipulated to achieve the desired minute volume.

$$\frac{\text{Minute ventilation}}{\text{Vt}} = \text{respiratory rate}$$

$$\frac{8.0 \text{ L per minute}}{500 \text{ mL}} = 12$$

Reducing the frequency of breaths should increase the CO_2 to the desired level.

Maintaining adequate oxygenation

Improvement of the patient's oxygenation can be achieved through titration of the FiO_2 and the application of PEEP.

Humidification

Patients who are intubated and mechanically ventilated require an alternative method of humidification, because the endotracheal tube bypasses the normal humidification process in the upper airways. The effects of this are drying of the airways and the potential for retained respiratory secretions. A heat moisture exchanger (HME) or heated water humidifier may be employed. Use of an HME is appropriate when ventilation is first commenced.

Setting	Definition	Normal ranges/Settings
Tidal volume (Vt)	The volume of gas (mL) inhaled and exhaled with each breath	8 mL per kg body weight, for example, 70 kg x 8 mL = 560 mL
Respiratory rate or frequency (f)	Number of breaths the ventilator is set to deliver per minute	Normal frequency for an adult is 8—20 breaths per minute
Minute volume (MV)	The volume of gas (litres) inhaled and exhaled per minute: MV = frequency x Vt	Depends on Vt and f and patient requirements to achieve a CO_2 level
Oxygen concentration (FiO_2)	The amount of oxygen set to be delivered to the patient Aim to maintain FiO_2 at < 50% where possible	Range: 21–100%
Trigger sensitivity	Determines the amount of effort the patient must generate to initiate a breath	Low as possible without causing self-triggering
Positive end expiratory pressure (PEEP)	A positive pressure applied during the expiration phase of mechanical ventilation	5–10 cm H_2O, depending on the patient's oxygenation requirements
Pressure support (PS)	A positive pressure is delivered as the patient makes an inspiratory effort, with the aim of augmenting the size of the patient's spontaneous breath	10–20 cm H_2O, depending on the patient's spontaneous volume size
Peak inspiratory pressure (PIP)	Highest pressure reading during mechanical inspiration	The aim to keep PIP less than 40 cm H_2O in a volume control mandatory breath Less than 30 cm H_2O in pressure control breaths

Adverse effects of mechanical ventilation

Altered respiratory mechanics

During positive pressure ventilation, the gas tends to go to areas of the lung with the least resistance, causing a maldistribution of gas in the lungs.

Maldistribution of gas can cause:

- progressive atelectasis with reduced functional residual capacity and reduction in surfactant, which will decrease lung compliance
- increased alveolar dead space and shunting
- change in the ventilation-to-perfusion (V/Q) ratio.

Lung injury

The maldistribution of gas in the lungs during positive pressure ventilation can cause trauma and injury to the lung. Excessive inflation pressures can injure or rupture the alveoli (barotrauma), causing conditions such as pneumothorax to occur. Excessive inflation volumes can cause overdistension of the alveoli and cause further injury (volutrauma).

Oxygen toxicity can also cause lung injury. It tends to occur when the lung is exposed to high concentrations of oxygen (greater than 50%) over a prolonged period.

Increased intrathoracic pressure

Positive pressure ventilation increases intrathoracic pressure, and can cause haemodynamic compromise, reduce renal perfusion and increase intracranial pressure.

Haemodynamic compromise

Raised intrathoracic pressure decreases venous return and reduces right and left ventricular preload, increases pulmonary vascular resistance and increases right ventricular afterload. This reduces stroke volume and cardiac output and the patient becomes hypotensive. This response is further exacerbated with the application of PEEP, or if the patient does not have an adequate circulating volume before commencement of mechanical ventilation.

Reduced renal perfusion

As a consequence of the haemodynamic changes renal blood flow is decreased leading to stimulation of the sympathetic nervous system. This then has the effect of reducing renal perfusion and glomerular filtration rate, leading to increased retention of sodium and water.

Increased intracranial pressure

An increase in intrathoracic pressure can also increase intracranial pressure (reduced venous return) and reduce cerebral perfusion pressure in a patient with cerebral injury, trauma or oedema. Again, this can be further exacerbated with application of PEEP. PEEP must be used with caution in this situation.

Gastrointestinal disturbances

Positive pressure ventilation can cause impairment of hepatic function, distended abdomen, malabsorption, ileus and increased potential for stress ulcers.

Other aspects to consider

The 'golden rule'

The patient who is intubated and ventilated should never be left unattended. Careful observation of the patient is required at all times.

Patient assessment

As with all patients, regular monitoring and assessment is vital. A full physical assessment is always performed, with particular focus on their neurological state, cardiac and respiratory function. Any changes in the patient condition should be identified early.

Ventilator–patient synchrony

Other assessment considerations include assessing if there is synchrony of the ventilator breaths with the patient. Asynchrony with the ventilator can be detrimental to the patient's condition, leading to increased oxygen consumption and increased risk of accidental extubation. Reasons for asynchrony include inappropriate ventilator settings (for example, trigger sensitivity is set so that it is not sensing the patient inspiratory effort) and when the patient is anxious and agitated or ETT intolerant.

Sedation and muscle relaxants

Sedation should be considered when the patient is initially commenced on mechanical ventilation, and at any time when they appear anxious or agitated. When using sedation, the aim is to give the minimum required to keep the patient calm, relaxed and easily roused. Over-sedation should be avoided, because this can prolong the time that the patient receives mechanical ventilation.

Muscle relaxants are sometimes required if sedation alone cannot resolve the problem and it continues to effect their respiratory function.

Airway maintenance

Maintaining the position and patency of the endotracheal tube is essential to support mechanical ventilation. The ETT should be secured and checked to ensure correct position on a regular basis. The cuff should remain inflated at the minimum pressure required for a seal. Clearance of secretions from the ETT should occur as necessary to maintain ETT patency for effective ventilation and oxygenation.

In a mechanically ventilated patient,an increasing peak inspiratory pressure and/or reducing tidal volume may indicate secretions in the chest/ETT, and the patient should be suctioned immediately.

Mouth care

Removal of secretions from the mouth and oropharynx and maintaining good mouth hygiene makes the patient feel more comfortable, and also aids in the prevention of ventilator-associated pneumonia.

Patient positioning

Patients should be repositioned regularly to prevent incidence of pressure areas, and also to maintain effective ventilation of the lungs. Ideally, the bedhead should be elevated to 30° to help prevent ventilator-associated pneumonia.

Documentation

Documentation of the ventilator settings and patient assessment should be performed regularly. This is usually performed hourly and whenever there is a change in the parameters.

Learning activities

Suggested learning activities and timetables are outlined below.

Timing	Activity	Objective
30 minutes	Facilitated discussion	
15 minutes	Case study 1	
15 minutes	Case study 2	
15 minutes	Case study 3	
10 minutes	Summary	All
10 minutes	Evaluation	

Total time = 1 hour 35 minutes

Facilitated discussion

The facilitator should lead a discussion amongst participants about the issues covered in the background information. The facilitator should not give a didactic lecture, but instead promote open discussion and knowledge sharing amongst participants. Participants should be encouraged to describe any real-life experiences they have encountered.

This presentation should be conducted with access to a ventilator, One that will be used by the participants in their own clinical setting is a ideal. The aim is to model skills and knowledge on the appropriate equipment as well as to introduce the general principles of mechanical ventilation.

Topics such as modes of ventilation, settings and calculations used to guide therapy must be covered. The discussion, in combination with a demonstration on a ventilator, should increase both the theoretical understanding and working knowledge of mechanical ventilation.

The overall aim of this module is an introduction to mechanical ventilation, not a session to achieve professions. Topics that should be identified include:

- positive pressure ventilation
- modes of ventilation
- modes of ventilation related to ventilators used at the educators' health service
- ventilator setup requirements
- alarm setting
- desired minute volume calculations
- control of carbon dioxide calculations
- adverse effects of mechanical ventilation.

Case studies

The case studies aim to integrate the facilitated discussion into a practical application based on a patient problem.

The case study can be conducted in two ways:

1. as a tabletop exercise, discussing the various changes required
2. in conjunction with the a working mechanical ventilator, to actively change the setting required for the desired outcome.

Case study 1

A 60-year-old man weighing approximately 80 kg is admitted to the emergency department after suffering a cardiac arrest. He required insertion of an endotracheal tube and mechanical ventilation.

Case study 1—Questions

Discuss the ventilation parameters you would choose to commence him on a mechanical ventilator:

- mode
- Vt
- frequency
- FiO_2
- PEEP
- inspiration time
- I:E ratio
- pressure support
- PIP alarm.

Case Study 1a—Questions

Discuss specific monitoring and observations you would make when attaching this patient to a mechanical ventilator.

Case study 2

A 50-year-old woman (weighing approximately 70 kg) is admitted to hospital with increasing shortness of breath and respiratory failure. She was given sedation and a muscle relaxant for intubation and commencement of mechanical ventilation.

The ventilator settings are: SIMV, Vt 550 mL, frequency 14 breaths, inspiration time 1.3 seconds, I:E ratio 1:2, FiO_2 100%, PEEP 5 cm H_2O.

After 30 minutes an arterial blood gas sample was obtained: pH 7.50, $PaCO_2$ 30, PaO_2 200, HCO_3 24, SaO_2 100%.

Case study 2—Questions

Discuss the changes you would make to the ventilator after analysis of the arterial blood gas sample.

Evaluation

A formal evaluation has been specifically developed for this module. It incorporates the objectives of the module and the perceptions of the participants about whether they have increased their understanding by working through the module. It is highly recommended that this formal evaluation be copied and completed by all participants at the completion of the module.

A range of informal evaluation tools may also be used in conjunction with this evaluation throughout the module, including those available in the Department of Human Services' *Clinical Skills Facilitators Manual* from the basic course conducted in 2007.

References

1. Newmarch C 2006 Caring for the mechanically ventilated patient: Part 1. *Nursing Standard* 20(17): 55–64
2. Pierce LNB 2007 *Management of the Mechanically Ventilated Patient* (second edition) Saunders Elsevier, St Louis
3. Pruitt WC and Jacobs M 2004 Take a Deep Breath and conquer your fear of mechanical ventilation. *Nursing Made Incredibly Easy* July/August 10–15, 17–21
4. Robb J 1997 Physiological Changes occurring with positive pressure ventilation: Part 1. *Intensive Care and Critical Care Nursing* 13: 293–307
5. Robb J 1997 Physiological changes occurring with positive pressure ventilation: Part 2. *Intensive Care and Critical Care Nursing* 13: 357–364

Resources

Facilitator feedback form

The following form should be used to assist you in giving feedback after each participant has practised their mechanical ventilation skills at the skills station.

Feedback using the Pendleton model

Pendleton's model of feedback assists learners to maximize their potential at different stages of training, raise their awareness of strengths and areas for improvement, and identify actions to be taken to improve performance. Pendleton's rules are structured in such a way that the learner identifies the positives first, in order to create a safe environment. This is followed by the facilitator or group reinforcing these positives and discussing skills to achieve them. Different techniques are then suggested. The advantage of this method is that the learner's strengths are discussed first. Avoiding a discussion of weaknesses right at the beginning prevents defensiveness and allows reflective behaviour in the learner.

Below is a series of questions to assist you in this technique:

1. Ask the learner how they feel.
2. Ask the learner what went well and why (this can be combined with question 1 and 3).
3. Tell the learner what went well and why.
4. Ask the learner what could have been done better and why.
5. Tell the learner what could have been done better and why.
6. Summarise the learner's strengths and identify up to three things to concentrate on.

Note: This form does not need to be given to the participant — it is a guide for you, the group facilitator.

Module 10: Introduction to mechanical ventilation—evaluation

Thank you for participating in this module. As part of our commitment to quality improvement the following questionnaire will be used to plan future implementation of this module. We appreciate your time completing this evaluation.

1. Overall

How would you rate this module?

☐ poor ☐ fair ☐ good ☐ very good ☐ outstanding

2. Learning objectives

Please consider whether this module was successful in meeting the following learning objectives:

Respiratory 2 Learning objectives of Module 10: Introduction to mechanical ventilation	Strongly disagree	Disagree	Slightly agree	Agree	Strongly agree
Identified indications for mechanical ventilation	☐	☐	☐	☐	☐
Discussed the principles of positive pressure ventilation	☐	☐	☐	☐	☐
Identified and discussed the commonly used modes of ventilation	☐	☐	☐	☐	☐
Discussed how a mandatory breath is delivered to the patient using volume and pressure control ventilation	☐	☐	☐	☐	☐
Discussed how the ventilator can be programmed to deliver a mandatory breath in terms of frequency, time for inspiration and breath size	☐	☐	☐	☐	☐
Discussed the adverse effects of positive pressure on the respiratory and cardiovascular system	☐	☐	☐	☐	☐
Discussed the alarm settings necessary to prevent barotrauma and volutrauma	☐	☐	☐	☐	☐
Discussed how carbon dioxide and oxygenation levels can be maintained during mechanical ventilation	☐	☐	☐	☐	☐

3. Important learning outcomes

What are the three most important things you have learned from this module?

4. Module implementation

Please indicate to what extent you agree or disagree with each of the following statements in relation to the implementation of the module.

	Strongly disagree	Disagree	Slightly agree	Agree	Strongly agree
The facilitator respected my experience	☐	☐	☐	☐	☐
The facilitator encouraged my participation	☐	☐	☐	☐	☐
I was able to ask the facilitator questions	☐	☐	☐	☐	☐
The facilitator was able to answer my questions	☐	☐	☐	☐	☐
The feedback I received was clear	☐	☐	☐	☐	☐
The feedback I received will assist me my future performance	☐	☐	☐	☐	☐
There was adequate time for the skills stations	☐	☐	☐	☐	☐
There was adequate time for the facilitated discussions	☐	☐	☐	☐	☐
There was adequate time for the simulations	☐	☐	☐	☐	☐
I have increased my confidence in understanding mechanical ventilation principles	☐	☐	☐	☐	☐
I have identified future learning needs in this topic area	☐	☐	☐	☐	☐

5. Future module implementation

Do you think the module should be altered in any way? ☐ yes ☐ no

If yes, what recommendations do you have?

Thank you

PowerPoint Presentation

1.

Clinical Skills in Hospitals Project

MODULE 10
'Mechanical Ventilation'

StV

A Victorian Government initiative

2.

Mechanical Ventilation

- Introduction and Presumed Knowledge
- Mechanical Ventilation
  - Indications
  - Aims
- Review of Spontaneous Breathing & Positive Pressure Ventilation

3.

Mechanical ventilation

- Modes of Mechanical Ventilation
  - Control Mode
  - Assisted Modes
  - Spontaneous Modes
- Setting the Ventilator Controls

4.

Mechanical Ventilation

- Control of Carbon Dioxide Levels
- Maintaining Adequate Oxygenation
- Humidification

5.

Mechanical Ventilation

- Adverse Effects of Mechanical Ventilation
- Other aspects to Consider

6.

Mechanical Ventilation

- Skills Station

Acronyms, abbreviations and measurements

Acronyms

A/C	assist control
AAFB	acid and alcohol fast bacilli
ABG	arterial blood gas
ACS	acute coronary syndromes
AEDs	automated external defibrillator(s)
AF	atrial fibrillation
AHA	American Heart Association
ALS	advanced life support
AMI	acute myocardial infarction
APO	acute pulmonary oedema
APTT	activated partial thromboplastin time
ARC	Australian Resuscitation Council
ASB	assisted spontaneous breathing
AV node	atrioventricular node
BBB	bundle branch block
BiPAP	bilevel positive airway pressure
BLS	basic life support
BUN	blood urea nitrogen
CABG	coronary artery bypass graft
cath lab	catheterisation laboratory
CE	cardiac enzymes
CHB	complete heart block
CK	creatine kinase
CKMB	creatine kinase Mb
CMV	controlled mandatory ventilation
CNS	central nervous system
COAD	chronic obstructive airways disease
COPD	chronic obstructive pulmonary disease
CPAP	continuous positive airway pressure
CPR	cardiopulmonary resuscitation
CRM	crisis resource management
CVA	cerebrovascular accident
CVC	central venous catheter
CVS	cardiovascular system
CXR	chest X-ray
DIC	disseminated intravascular coagulation
DKA	diabetic ketoacidosis
DKS	Damus-Kaye-Stansel [procedure]

DRABC	D: danger R: response A: airway B: breathing C: circulation
DVT	deep vein thrombosis
ECF	extracellular fluid
ECG	electrocardiogram
ED	emergency department
EMD	electromechanical dissociation
ENT	ear, nose and throat
EPAP	expiratory positive airways pressure
ET	endotracheal
FBE	full blood examination
FFP	fresh frozen plasma
FRC	functional residual capacity
g	gram
GCS	Glasgow Coma Scale
GI	gastro-intestinal
GIT	gastro-intestinal tract
GTN	glyceryl trinitrate
Hb	haemoglobin
HIV	human immunodeficiency virus
HME	heat moisture exchanger
HPS METI	a brand (Human Patient Simulator) of fully automatic, high-fidelity patient simulator
HR	heart rate
I:E ratio	inspiration-to-expiration ratio
ICF	intracellular fluid
ICP	intracranial pressure
INR	international normalised ratio
IO	intraosseous
IPAP	inspiratory positive airways pressure
IPPV	intermittent positive pressure ventilation
IV	intravenous
LBBB	left bundle branch block
LDH	lactate dehydrogenase
LMA	laryngeal mask airway
mA	milliampere
MET	medical emergency team
NBM	nil by mouth

NGT	nasogastric tube
NIMC	national inpatient medication chart
NIPPV	non-invasive positive pressure ventilation
NIV	non-invasive ventilation
NP airways	nasal prong airways
NSEACS	non-ST elevation acute coronary syndrome
NSR	normal sinus rhythm
OP	oropharyngeal airway
OTC	over-the-counter medications
PCA	patient-controlled analgesia
PCI	percutaneous coronary intervention
PEA	pulseless electrical activity
PEEP	positive end expiratory pressure
pH	the measure of the acidity or alkalinity of a solution
PICC	peripherally inserted central catheter
PIP	peak inspiratory pressure
PRVC	pressure regulated volume control
PS	pressure support
PTX	pneumothorax
QRS	wave form seen on electrocardiogram
RA	room air
RBBB	right bundle branch block
RIC line	rapid infusion catheter exchange set
RMO	registered medical officer
rPA	retaplase
RR	respiration rate
RSI	rapid sequence induction
rt-PA	alteplase
RV	right ventricular
SIMV	synchronised intermittent mandatory ventilation
SK	streptokinase
SR	Sinus rhythm
STEMI	ST elevation myocardial infarction
SVC	superior vena cava
TPN	total parenteral nutrition
UWSD	underwater seal drainage
V/Q mismatch	ventilation/perfusion mismatch
VF	ventricular fibrillation
VT	ventricular tachycardia
WCC	white cell count
WOB	work of breathing
WPW	Wolf-Parkinson-White syndrome

Chemical formulae

$CaCl_2$	calcium chloride
CO_2	carbon dioxide
$ETCO_2$	end-tidal carbon dioxide
FiO_2	fraction of inspired oxygen
H_2CO_3	bicarbonate
$MgCl_2$	magnesium chloride
$MgSO_4$	magnesium sulphate
$PaCO_2$	partial pressure of carbon dioxide in arterial blood
PaO_2	partial pressure of oxygen in arterial blood
SpO_2	percentage of oxygen saturation in blood
SaO_2	saturation of oxygen in arterial blood flow

Units of Measurement

abbreviation	unit
mmHg	millimetres of mercury
L	litre
mL	millilitre
µg	microgram — one-millionth (10-6) of a gram
mmol	millimole
J	joule
mg	milligram
cm	centimetre
m	metre