

NON-INVASIVE VENTILATION IN THE INTENSIVE CARE UNIT

ANAESTHESIA TUTORIAL OF THE WEEK 40

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Self assessment

Case 1:

A previously healthy 28-year-old female with HIV has been admitted to hospital with an opportunistic Pneumocystis pneumonia. Despite antibiotics she is deteriorating on the ward and you are asked to consider admitting her to ICU. On assessment she is tiring. Her oxygen saturations are 90% receiving 40% oxygen, her respiratory rate has fallen from 32 to 12 breaths per minute and she is using accessory muscles of respiration. Cardiovascular observations are normal, and she is conscious but drowsy. Arterial blood gases on 40% oxygen show a PaO₂ of 8 kPa (60 mmHg) and PaCO₂ of 9 kPa (68 mmHg). How would you manage this patient?

Case 2:

A 35 year old male is referred to the intensive care unit (ICU) with severe community-acquired pneumonia. He has no other medical problems. On examination he is cyanosed with a respiratory rate of 40 breaths per minute. He is tired but fully conscious. Arterial blood gases taken with the patient on 80% oxygen show a PaO₂ of 7 kPa (53 mmHg) and PaCO₂ of 3 kPa (23 mmHg). How would you manage this patient?

Introduction

Non-invasive ventilation (NIV) is an alternative to mechanical ventilation for patients with respiratory failure. The equipment, indications for use, advantages and disadvantages are discussed below.

Definitions

Respiratory failure

- A state of reduced oxygenation such that PaO₂ is less than 8 kPa (60 mmHg) in the absence intra-cardiac shunting.
- Divided into type I respiratory failure in which the primary problem is one of oxygenation and the PaCO₂ is low or normal, and type 2 in which the patient is also failing to adequately clear CO₂, causing a raised PaCO₂.

Conventional ventilation

- Mechanical ventilation via a tracheal tube (either oral or tracheostomy).

Non-invasive ventilation (NIV)

- A method of providing ventilatory support without the need for tracheal intubation.

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- Different types of NIV include continuous positive airway pressure (CPAP), volume controlled ventilation and pressure controlled ventilation. The term NIPPV (non-invasive positive pressure ventilation) is also widely used.

CPAP (Continuous positive airways pressure)

- The provision of positive airway pressure throughout all phases of spontaneous ventilation.
- This increases the functional residual capacity of the lungs by holding airways open and preventing collapse. The application of CPAP also causes the patient to breathe at higher lung volumes, making the lungs more compliant.
- CPAP is particularly useful for improving oxygenation in type 1 respiratory failure.

Inspiratory positive airway pressure (IPAP) and expiratory positive airway pressure (EPAP)

- These terms are commonly used in reference to BiPAP. IPAP is the pressure set to support the patient on inspiration. EPAP is the pressure set for the period of expiration.
- The actual airway pressure during inspiration is independent from the expiratory airway pressure. For example, BiPAP ventilation using IPAP 15 and EPAP 8 is equivalent to conventional pressure support delivering pressure support of 7 above PEEP of 8.

Bi-level positive airway pressure (BiPAP®)

- This is the trade name for the machines most commonly used in the UK to provide two levels of airway pressure. Positive pressure is maintained throughout the respiratory cycle, with a higher pressure during inspiration.
- BiPAP results in reduced work of breathing and an improvement in tidal volume and CO₂ removal; it is therefore particularly useful in the treatment of type 2 respiratory failure.
- Spontaneous modes are similar to use of pressure support ventilation (or assisted spontaneous breathing) on invasive ventilators, whereas timed modes are analogous to conventional mandatory ventilation.
- Note that **bi-phasic positive airways pressure (BIPAP)** is different to BiPAP and less commonly encountered. The patient breathes at a preset level of CPAP and at timed intervals (not synchronised to the patient's inspiratory efforts) the level of CPAP is reduced to a lower level. The intermittent reduction in CPAP leads to a large expiration and therefore increases CO₂ elimination.

Equipment for Non-invasive Ventilation

NIV requires a machine capable of delivering pressurised, oxygenated gas through a mask to the patient. Modern sophisticated intensive care ventilators may be used if they have been loaded with the appropriate software. However, in practice, since they are not usually designed for this purpose, problems with inadequate flows and poor triggering of spontaneous breaths are common. Less expensive, purpose-built machines are much simpler to use and perform better.

NIV machines must be capable of providing gas flows that can match those generated by the patient during inspiration (30 l/min), otherwise the desired airway pressure will not be maintained. The simplest machines provide CPAP at a set pressure whereas more complex machines allow ventilation (volume or pressure controlled.)

BiPAP® machines (Respironics, Inc) are commonly used in the UK. Different models of varying complexity are available, although all are capable of providing high gas flows to maintain preset airway pressures, as well as sensing the respiratory effort made by the patient. The more advanced machines can deliver up to 100% oxygen, whereas the simpler machines require oxygen to be added to the distal breathing circuit through a side port. With this latter system the inspired oxygen concentration is

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variable, depending on flow within the circuit, and it is not possible to provide more than 60% inspired oxygen. This is important to consider when treating hypoxic patients.

The machine is attached to the patient via a breathing circuit. This tube delivers the inspiratory gas and also allows the sensors to detect the patient's respiratory effort. A vital component of the circuit is the **mandatory expiratory valve**, which allows exhaled gases to escape. Blockage of this valve for any reason may have disastrous consequences as high flow gas is driven towards the patient with no means of escape (critically important if the patient is being ventilated via a tracheostomy)

The circuit is usually attached to the patient via a mask. This may be a full-face mask, a nasal mask or nasal cushions (within the nostrils). The choice depends on the patient's condition and preference. Patients often prefer nasal masks, but must keep their mouths closed for optimal performance. Full-face masks are more effective for severe respiratory failure. Recently a full head helmet has been developed to overcome the problems of pressure sores and claustrophobia. The helmet sits on the shoulders and does tend to be noisy (patients often request earplugs) but is generally very well tolerated.

Humidification of inhaled gases is important if the integrity and function of the respiratory tract is to be maintained and various options exist to humidify gases in non-invasive circuits. The least efficient method involves the placement of a 'wet sponge' within the circuit. More efficient methods include bubbling the gas through a cold, or preferably hot, water bath. This water should be sterile; in order to reduce the risk of bacterial contamination and the temperature needs to be carefully controlled. Care also needs to be taken in order to prevent water collecting within the circuit as this can be delivered to the patient inadvertently.

If the patient is making some effort to breathe, the machine may be set to assist spontaneous breaths. If this is not possible, the machine can be set to provide controlled ventilation at a rate set by the clinician.

Naso-gastric tubes should be considered with NIV in order to drain air introduced into the stomach.

Advantages of NIV compared to conventional ventilation

Compared with conventional ventilation, NIV is a relatively inexpensive and simple technique which prevents the need for conventional ventilation in some patients and improves survival. Major advantages include:

- Avoiding many of the complications associated with conventional ventilation (table 1).
- Avoiding the need for sedation.
- Easier communication with patient.
- Requires less intensive nursing care.

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Table 1. Complications of conventional ventilation

Related to intubation	adverse effects from induction drugs risk of failed intubation risk of aspiration of gastric contents airway trauma
Related to presence of tracheal tube	need for sedation endobronchial intubation difficult communication reduced ciliary activity risk of ventilator associated pneumonia
Long term complications	tracheal stenosis sinusitis vocal cord damage

Disadvantages of NIV compared to conventional ventilation

Conventional ventilation remains the gold standard for treatment of respiratory failure in the ICU. NIV is not appropriate for all patients; it is contraindicated in some (see below) and ineffective in those who are severely ill. Minor problems are common and include air leaks and skin damage from mask pressure. Major complications such as pneumothorax are very rare. Concerns that NIV increases the risk of aspiration have not been demonstrated studies of comparing NIV to conventional ventilation.

Indications for the use of NIV

NIV is commonly used for the treatment of respiratory failure from:

- Exacerbation of chronic obstructive airways disease (COPD)
- Pulmonary oedema
- Respiratory failure in immunocompromised patients. E.g. AIDS, malignancy
- Weaning from conventional ventilation and prevention of need for reintubation in high risk patients
- Chest trauma
- Asthma.

For patients with exacerbations of COPD, NIV results in a significant reduction in mortality and length of hospital stay when compared to conventional ventilation. NIV is now recommended as first line therapy for those requiring ventilatory support.

Research into the use of NIV in asthma has shown promising results, although further trials are required before conclusions can be drawn.

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Immunosuppressed patients with respiratory failure requiring mechanical ventilation are very susceptible to ventilator associated pneumonia and have a mortality rate of over 90 percent. The use of NIV has resulted in significantly improved outcome in these patients.

NIV is also used to wean patients from conventional ventilatory support, resulting in shorter duration of ventilation, reduced complications, reduced hospital stay and reduced mortality.

Contraindications to the use of NIV

These may be **absolute**:

- Non-compliant patient
- Unconscious patient / unable to protect airway.

Or **relative**:

- Facial fractures
- Excessive secretions
- Following oesophagectomy (risk of anastomotic breakdown due to increased pharyngeal/oesophageal pressures)
- Haemodynamic instability.

Practicalities of setting up and using NIV

After deciding to commence NIV, there are a number of issues to consider:

What type of mask to use?

- For acutely unwell patients with respiratory failure, it may be appropriate to start with a full face mask. This allows the use of higher pressure ventilation with less gas leakage.
- For patients who are relatively stable, a nasal mask or helmet may be better tolerated.

How to apply the mask?

- The patient may feel claustrophobic as the mask is applied and should be reassured. It may help if they are allowed to hold it on themselves.
- The mask is then held on the face by a harness which passes around the back of the head. When tightening the straps, it is important to find a balance between leaving the mask so loose that there is an uncontrollable leak and making it uncomfortably tight. Pressure relieving dressings may be used to reduce the chance of sores developing in sensitive areas such as the bridge of the nose.

What mode to use? (Respironics BiPAP[®] machines)

- CPAP is ideal for type I respiratory failure where CO₂ elimination is not a problem.
- BiPAP is used to augment CO₂ removal as well as improving oxygenation (type II respiratory failure). There are three mode options when using BiPAP:

1. **Spontaneous** – the machine will detect and support spontaneous breaths in patients with good respiratory drive (similar to pressure support).

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2. **Timed** – the machine will provide mandatory breaths at a set frequency in patients with inadequate spontaneous respiration (similar to controlled mandatory ventilation).

3. **Spontaneous / timed** – the machine will support spontaneous breaths, but if the patient does not breathe for a set period, they will be given a mandatory breath.

Which initial pressure settings to use for BiPAP® spontaneous mode?

· Commonly the IPAP is set to 10 cmH₂O and the EPAP to 5 cmH₂O. The response to these pressures should determine future changes.

· Most machines can generate maximal pressures of 20-23 cmH₂O. If higher pressures are required leakage around the mask is usually a problem, and conventional invasive ventilation is indicated.

What FiO₂ to choose?

· Choose an initial FiO₂ slightly higher to that the patient received prior to NIV.

· Adjust the FiO₂ to achieve an SaO₂ that you deem appropriate for their underlying disease. Generally SaO₂ above 92% is acceptable.

· If a patient is hypoxic while breathing 100% oxygen on a CPAP circuit, their hypoxia will not improve if they are placed onto a BiPAP circuit (in spite of the increased ventilatory assistance) because the FiO₂ will drop significantly.

· Similarly if a patient starts to work harder on a BiPAP circuit they may become more hypoxic due to a drop in FiO₂ caused by increased gas flow through the breathing circuit.

How to monitor the patient's response to NIV?

· The most useful indicator is how the patient feels. They should be able to tell you if they feel better or worse.

· Where available arterial blood gases (ABG) are useful to assess changes in oxygenation and CO₂ clearance.

How to tell if NIV is not effective?

· Again, this is largely based on how the patient feels and ABG results.

· If the patient is getting increasingly tired, or their ABG deteriorating despite optimal settings, then they will probably need tracheal intubation and mechanical ventilation. It is important to recognise this as soon as possible so that management may be planned before the patient collapses.

How to intubate a patient previously on NIV?

· Patients are likely to be critically unwell at this point - seek experienced help.

· Assume the patient's stomach is full, using a rapid sequence induction.

· Preoxygenate as thoroughly as possible, applying an FiO₂ of 100% with or without CPAP.

· Expect and prepare for cardiovascular collapse on induction (have IV fluids running and vasopressors readily available).

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Self assessment discussion

Case 1

This patient has significant respiratory compromise, with type 2 respiratory failure – her PaO₂ is low and her PaCO₂ is raised. Without ventilatory support she will deteriorate further. It would be reasonable to intubate and mechanically ventilate this patient, but since her illness suggests that she is immunocompromised, her chance of survival will be better with NIV. She is not yet moribund and therefore likely to be responsive and co-operative. She is not profoundly hypoxic (currently only in 40%) but is tiring and so it would be reasonable to start BiPAP in an attempt to improve her CO₂ clearance and modestly improve her oxygenation.

Suggested initial BiPAP settings are: FiO₂ 40%, IPAP 10, EPAP 5 using a spontaneous mode delivered through a full face mask.

You should gauge her response to NIV after 10-15 minutes, by assessing her:

Oxygenation

- If her SaO₂ improves then NIV is a good choice and you can consider reducing her FiO₂. There is little benefit in decreasing EPAP below 5.
- If her SaO₂ fails to improve you can either increase the FiO₂ (up to machine limits of about 60%) or consider increasing her EPAP. A combination of both is also reasonable. Remember that increasing her EPAP alone will reduce the IPAP-EPAP difference (i.e. her pressure support) and increase her work of breathing. This is likely to increase her CO₂ levels. Therefore any increase in EPAP should prompt a similar increase in IPAP in order to maintain her pressure support. Also bear in mind that most machines perform poorly when the EPAP is increased much above 10cmH₂O – if this is necessary consider conventional ventilation.

Work of breathing

- Monitor respiration rate and use of accessory muscles. If these reduce and she reports that her breathing feels easier, then it suggests that NIV is beneficial.

CO₂ clearance

- If the PaCO₂ remains high and the patient feels tired then the IPAP can be increased. This should increase tidal volume and alveolar ventilation; ideally the respiratory rate will also fall.
- If possible monitor the PaCO₂ level and tolerate a mild elevation of PaCO₂.
- If IPAP increases do not help consider using a timed mode where the mandatory breaths have a longer inspiratory time than the patient's spontaneous breaths. This may help, but conventional ventilation is more likely to be required.

Case 2

This patient is clearly very unwell and at risk of rapid deterioration. He has type 1 respiratory failure and has no problem with CO₂ clearance. His high respiratory rate means that he is at risk of tiring. He should be moved to the ICU for intensive monitoring and management.

A small proportion of patients in this clinical state will avoid invasive ventilation. If NIV is available, or if there is a delay in instituting invasive ventilation, it is appropriate to give a trial of CPAP, which may improve oxygenation. BiPAP in this setting is unlikely to help and may exacerbate hypoxia.

However, there is currently little evidence to support the use of NIV in the treatment of severe pneumonia. If used, the patient must be closely monitored. Any sign of deterioration, such as tiring or

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reduced oxygenation should prompt intubation and ventilation. If invasive ventilation is left too late, then the patient may become hypoxaemic and exhausted, necessitating a high-risk emergency induction and intubation in a patient who cannot be pre-oxygenated.

Further reading

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