Use of non-invasive ventilation for respiratory failure in acute care

In respiratory failure, blood oxygen, carbon dioxide or both cannot be maintained at normal levels.

Non-invasive ventilation delivers positive pressure to a patient’s airway and lungs via a face mask.

The equipment should be adapted depending on the patient, device used and mode of treatment.

Patients receiving treatment require regular monitoring for a number of complications.

Therapy duration varies and patients need to be weaned off the treatment.

Non-invasive ventilation (NIV) has been used in practice for many years. During the early 20th century negative-pressure ventilators were used to support the breathing of patients with respiratory failure caused by polio. These devices – or ‘iron lungs’ as they were termed – were large tanks that, although effective, were not easily manoeuvred and were impractical for long-term use (Fig 1). There are still some in use today, as well as more modern cuirasses or negative-pressure vests that are more commonly used for children.

Over the last 40 years, due to its ease of use and practical application, positive-pressure NIV has become the more common method of NIV that is used to treat patients who have respiratory failure. In the acute setting, early use of NIV for patients who have chronic obstructive pulmonary disease (COPD) and mild-to-moderate acidosis has been shown to reduce the need for invasive mechanical ventilation, as well as rapidly improve physiological variables and reduce in-hospital mortality (Plant et al, 2000).

More recently, the National Confidential Enquiry into Patient Outcome and Death reviewed the quality of care provided to patients receiving acute NIV and highlighted a need for improved ventilator management; its report – NCEPOD (2017) – also noted a wide variation in both the organisation of acute NIV services and the clinical care they provide, as well as outlining key recommendations that would improve the care received by patients receiving acute NIV in hospital. This article discusses the treatment’s indications, contraindications, terminology, settings, and practical management.
Clinical Practice

Review

What is NIV?
NIV is a method of ventilating a patient without using invasive endotracheal tubes or requiring tracheostomy. Air, or a combination of oxygen and air, is delivered by a mechanical pump that provides positive pressure to a patient’s airway and lungs via a face mask.

Modern NIV devices have several modes (Table 1). The main therapy delivered by NIV is called bi-level positive airway pressure, because it uses two levels of pressure:

- **Inspiratory positive airway pressure (IPAP)** – this increases the tidal volume per minute (the amount of air that moves in or out of the lungs with each respiratory cycle) and alveolar ventilation, as well as enabling carbon dioxide (CO₂) removal;
- **Expiratory positive airway pressure (EPAP)** – this opens the alveolar to allow for more gas exchange by increasing the surface area; it prevents dynamic airway collapse, decreases auto-positive end expiratory pressure and increases functional residual capacity of the lungs.

This is illustrated in Fig 2.

Indications for NIV

Acute respiratory failure
There are a number of reasons why a patient may develop acute respiratory failure (Fig 1), in which blood oxygen, CO₂, or both cannot be maintained at normal levels. Respiratory failure is classified into two types:

- **Type I** – hypoxaemia (a drop in the blood-oxygen level), defined as PaO₂ <8kPa;
- **Type II** – both hypoxaemia (PaO₂ <8kPa) and hypercapnia (an elevated CO₂ level in the blood), defined as PaCO₂ >6.5kPa.

NIV is indicated when a patient’s blood-gas test results identify a pH level of <7.35 and a PaCO₂ of >6.5kPa, despite optimising medical therapy (Davidson et al, 2016). Once a blood gas test has been taken that indicates a patient would benefit from NIV, therapy should be started:

- **Within one hour for inpatients** (NCEPOD, 2017);
- **Within two hours of hospital arrival for patients who present acutely** (Davies et al, 2018).

NCEPOD (2017) recommends patients are treated in an appropriate clinical area, with appropriate staffing and competency levels; before commencing NIV, the plan should be discussed with a specialist who is competent in its management. It is paramount to consider both the patient’s wishes and their general health and well-being when their condition is stable (Davies et al, 2018). Discussions and care decisions should be documented.

Chronic respiratory failure
A patient may have had a degree of chronic respiratory failure but been compensating for some time – for example, patients with COPD. However, a complication such as pneumonia may cause the balance to shift and the patient to decompensate. Patients

![Fig 2. Intra-alveolar pressure during bi-level positive airway pressure non-invasive ventilation](image-url)

**Table 1. Common NIV modes and CPAP**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Spontaneous timed</td>
<td>Bi-level positive airway pressure ventilation (IPAP and EPAP) that spontaneously triggers a breath, with a timed back-up breath if an apnoea period occurs; the value determined by the difference between IPAP and EPAP (pressure support) is used to create sufficient tidal volume to aid the removal of carbon dioxide</td>
</tr>
<tr>
<td>Spontaneous</td>
<td>Bi-level positive airway pressure that is patient triggered without a timed back-up breath</td>
</tr>
<tr>
<td>CPAP</td>
<td>A continuous flow of air pressure (also called positive end-expiratory pressure or EPAP)</td>
</tr>
<tr>
<td>Volume-targeted modes (average volume-assured pressure support)</td>
<td>The delivery of a pre-set average assured volume, normally based on ideal patient weight (8-10ml/kg), that is delivered between a range of IPAP upper and lower settings and a fixed EPAP setting</td>
</tr>
<tr>
<td>Average volume-assured pressure support auto-EPAP</td>
<td>The delivery of a preset average assured volume, normally based on ideal patient weight (8-10ml/kg), delivered between a range of IPAP upper and lower settings with the added variable auto-EPAP range (which has upper and lower settings)</td>
</tr>
<tr>
<td>Pressure control</td>
<td>Ventilator-timed breaths with IPAP and EPAP, with a set inspiratory time</td>
</tr>
</tbody>
</table>

CPAP = continuous positive airway pressure; EPAP = expiratory positive airway pressure; IPAP = inspiratory positive airway pressure; NIV = non-invasive ventilation.
who present with chronic respiratory failure may benefit from long-term NIV.

**Contraindications**

Absolute contraindications for NIV are severe facial deformity, facial burns and fixed upper-airway obstruction. Other contraindications are relative and, in some circumstances in which plans of care have been made, NIV can be considered. These include patients with:

- pH of <7.15 (pH <7.25 with additional adverse features);
- Glasgow Coma Scale score of <8;
- Confusion or agitation;
- Cognitive impairment (warranting enhanced observation if they have NIV) (Davidson et al, 2016).

For patients undergoing NIV, indications for referral to intensive care include:

- Impending respiratory arrest;
- The NIV failing to augment chest-wall movement or reduce the level of CO₂;
- An inability to maintain an arterial blood oxygen level of 85-88%;
- A need for intravenous sedation, or other adverse features requiring closer monitoring;
- The patient is difficult to intubate in the event of NIV failure (Davidson et al, 2016).

Other considerations that require monitoring include:

- Vomiting;
- Recent upper gastrointestinal surgery;
- Haemodynamic instability;
- Undrained pneumothorax;
- Severe comorbidity;
- Bowel obstruction;
- Copious secretions that require frequent expectoration or clearance using suction.

### Setting up NIV treatment

The modes available on NIV devices vary between manufacturer. Table 1 shows the most common modes; continuous positive airway pressure (CPAP) is also shown although this is not technically an NIV mode as it does not provide respiratory support through back-up breaths or assisted inspiratory pressure.

The equipment required for NIV should be adapted depending on the type of NIV device and its accompanying consumables. Before use, it is essential to prepare the equipment, including:

- Non-invasive ventilator;
- Hose (single- or dual-limb, depending on the device);
- Face mask and sizing gauge;
- Oxygen port if the NIV does not have piped oxygen;
- Exhalation port for CO₂ clearance if this is not built into the face mask;
- Bacterial and viral filter.

If a patient is suspected or confirmed to have an infectious respiratory disease, such as Covid-19, the number of bacterial and viral filter placements need to be increased so there is a filter on the device’s outlet port and one close to the mask’s connection or exhalation port (Fig 4). A huge range of masks is available to use for acute NIV, although hospital departments usually use a select few. An oronasal facemask (Fig 5) is recommended as a patient’s initial interface (Davidson et al, 2016); the benefit of using this, or a full face mask, is that it reduces leakage from the mouth that would be experienced with a nasal mask.

Some masks are vented, meaning they have an integrated exhalation port and are used with a single-limb circuit; for non-vented masks, an exhalation valve needs to be added to the circuit. The exhalation valve allows for CO₂ removal so should never be intentionally obstructed. Some masks also have an anti-asphyxiation valve; if the NIV device’s power fails, the valve opens to allow the patient to breathe via the mask.

If a setting uses a variety of NIV devices that require differing circuits, it is imperative that practitioners are familiar with the mask that accompanies each device.
Many acute hospital wards have guidelines for initial NIV settings; these often start on a spontaneous timed mode (Table 1) with conservative pressures such as IPAP 10–12cmH₂O and EPAP 4–5cmH₂O. Starting NIV at these pressures introduces the patient to the treatment, as it can be a challenging and frightening experience. There may also be differing pressures or modes depending on the patient’s condition – for example, a patient with a neuromuscular condition may start on a low IPAP setting (10cmH₂O), a patient who has COPD may start on a higher one (15cmH₂O), and a patient with obesity hypoventilation syndrome and a body mass index of >35 may be on a higher IPAP setting (15cmH₂O) as well as a higher EPAP (8cmH₂O) setting (Davidson et al, 2016). NIV settings should be prescribed by staff who have had training and maintain competence appropriate for their role (Davies et al, 2018). Initial settings and any changes should be documented on a standardised proforma (NECPOD, 2017).

If a patient is receiving inhaled bronchodilators via NIV, a T-piece nebulisation adapter should be:

- Used as close to the NIV mask as possible;
- Maintained in a horizontal position so that the nebuliser solution does not drain out.

Nebulisers may be driven by piped oxygen, air, a compressor or another method – this should be considered when monitoring the patient. The use of nebulisation can alter the ventilator readings, and the pressures and volumes shown, which can cause alarms. Some NIV devices have a nebuliser setting to accommodate this, which should be activated when using one.

**Monitoring**

To receive NIV, patients should be sitting upright in a comfortable position; once established on the treatment, repositioning to alleviate sacral pressure is possible. Patients should receive continuous electronic monitoring of oxygen saturation and electrocardiogram, as well as regular observations for ACVPU (Alertness, Confusion, Voice, Pain, Unconsciousness), respiratory rate, temperature and blood pressure (Davidson et al, 2016). They should also receive physiological monitoring using the National Early Warning Score (NEWS2) system (Royal College of Physicians, 2017).

NIV alarms should be set to provide an audible alert of any issues: a circuit-disconnect alarm is particularly useful if a patient removes their NIV mask, and other available alarms monitor apnoea, tidal or minute volume (upper and lower levels), and low and high respiratory rate.

All patients should be reviewed by a specialist health professional within four hours of starting acute NIV and by a consultant with expertise in NIV within 14 hours (Davies et al, 2018). A blood-gas test is recommended in the first hour of starting NIV, with additional sampling after four hours and if the patient shows signs of deterioration (Davies et al, 2018).

Treatment is likely to be more successful if there are improvements in pH and PaCO₂, values and a reduction in respiratory rate after two hours of NIV (Roberts et al, 2011). If pH and PaCO₂ do not show any improvement, the NIV treatment should be reviewed and, if appropriate, IPAP pressure titrated. Optimising a patient’s tidal volume by altering IPAP to increase the pressure support range between IPAP and EPAP, with the aim of achieving 8ml/kg (based on ideal body weight), should help reduce PaCO₂ levels. An increase in IPAP pressure is often undertaken in 2cmH₂O increments. In acute settings, titration may be fairly fast, with pressure increased over 10–30 minutes after the initial set-up.

**Complications**

Possible complications of NIV are listed in Table 2, with suggested remedial actions.

An additional consideration is nutrition: patients receive NIV for varying degrees of time and many experience increased work of breathing and hypoxia in the 24 hours after treatment, making adequate nutritional intake difficult. Patients may benefit from a nutritional review and, potentially, from a nasogastric (NG) tube to aid feeding. Although this improves nutritional intake, it also creates a gap between the mask and the patient’s face; careful positioning and securing are therefore required to minimise mask leak. As the NG tube and mask put pressure on the skin, it is also important to pay close attention to skin integrity. However, some masks have an NG tube gap that reduces the pressure on this area.

Another consideration is the positioning of patients: this should optimise chest expansion and take account of areas at risk of pressure damage, such as the heels, hips, the base of the spine and the sacrum. A risk assessment should be carried out and a personalised plan of care put in place; this may require the use of pressure-relieving equipment and regular changes in position.

During the coronavirus pandemic, Basconi et al (2020) observed that some patients receiving NIV have benefitted from being treated in the prone position – that is, lying on their front; in this position or a modified side-prone position, airways can open that may not be able to do so while a patient is in the upright or supine position. However, the prone position can put pressure on parts of the body that are not commonly under such pressure, such as the knees and iliac crests; as such, these should be included in a plan for pressure relief and the skin should be closely monitored for discoloration. Patients should receive information about proning and have the process explained to them (Jiang et al, 2020).

**Weaning patients off NIV**

The duration of NIV treatment depends largely on resolution or improvement of a patient’s blood gases and clinical signs. NIV...
should be maximised in the first 24 hours and can be tapered thereafter, once the patient has stabilised. If a patient remains dependent on NIV, a common weaning protocol begins with breaks for meals and then works towards a routine of NIV only being used overnight and for two hours in the morning and two hours in the afternoon.

Progressively reducing NIV use during the day but continuing its use overnight is the primary objective until the patient is weaned off daytime use. Some patients may need longer weaning times than others, so individual weaning plans should be created. Once a patient is no longer using NIV during the day, night-time use can be reduced.

If a patient is receiving oxygen via NIV, the British Thoracic Society/Intensive Care Society guidelines – Davidson et al (2016) – recommend reducing the oxygen gradually, but maintaining an arterial blood oxygen level of 88-92% saturation in all causes of acute hypercapnic respiratory failure; the duration of NIV is individual to each patient, but normalisation of pH and a PaCO₂ level of <6.5kPa are often used as a guide.

If a patient is successfully weaned off NIV during the day but, when not receiving NIV overnight, continues to have a morning PaCO₂ of >7kPa, other causes should be considered – for example, whether they take any sedating medication such as opiates in the evening. Once other causes have been ruled out, they may be assessed for their suitability to receive NIV at home (Murphy and Hart, 2018).

Table 2. Complications of NIV

<table>
<thead>
<tr>
<th>Complication</th>
<th>Suggested actions</th>
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<tbody>
<tr>
<td>Pressure ulcers or skin breakdown on the nasal bridge or cheeks</td>
<td>Ensure the appropriate mask interface, including accurate sizing and fit. Consider a full face mask. Apply a nasal bridge dressing if a grade 1 pressure ulcer (non-blanching erythema) is developing. Reduce mask-strap tightness if that is the cause. Provide a planned and managed NIV treatment programme with regular breaks.</td>
</tr>
<tr>
<td>Mask leak (eye irritation)</td>
<td>Ensure the appropriate mask interface, including accurate sizing and fit.</td>
</tr>
<tr>
<td>Oral dryness</td>
<td>Consider humidification. Ensure regular mouth care.</td>
</tr>
<tr>
<td>Gastric distention or vomiting</td>
<td>Where appropriate, consider a nasogastric tube for gastric decompression. If there is a risk of vomiting, consider how rapidly a mask can be removed.</td>
</tr>
<tr>
<td>Discomfort</td>
<td>Where appropriate, consider using a nasal mask or a full face mask. Ensure the appropriate mask interface. Reduce mask-strap tightness.</td>
</tr>
<tr>
<td>Haemodynamic instability, hypotension</td>
<td>Monitor blood pressure and electrocardiogram. Provide intravenous hydration or adequate oral hydration.</td>
</tr>
<tr>
<td>Non-compliance, fear or claustrophobia</td>
<td>Discuss the treatment and its benefits with the patient. Involve them in decision making. Allow limited mask application time, then build up. Be persistent. Arrange consultant review. Review ceilings of care.</td>
</tr>
<tr>
<td>Inadequate ventilation</td>
<td>Review NIV pressures and arterial blood gas. Adjust NIV settings.</td>
</tr>
<tr>
<td>Non-synchronisation with NIV</td>
<td>Adjust rise-time setting and inspiratory time. Check for mask leak. Check trigger sensitivity.</td>
</tr>
</tbody>
</table>

NIV = non-invasive ventilation.


For patients with neuromuscular conditions, the PaCO₂ threshold may be lower – namely 6.5kPa. Early initiation of NIV in such patients has been shown to improve survival (Sheers et al, 2014; Lechtzin et al, 2007). In some patients, receiving NIV at home overnight can also reduce readmission due to acute hypercapnic respiratory failure (Tuggey et al, 2003).

Patout et al (2020) found survival is dependent on NIV adherence (of more than four hours per night) and diagnostic categories: for example, patients with progressive neuromuscular conditions have a survival rate of one year while that for those with COPD-obstructive sleep apnoea overlap syndrome is 6.6 years. NT.

References


National Confidential Enquiry into Patient Outcome and Death (2017) Inspiring Change: A Review of the Quality of Care Provided to Patients Receiving Acute Non-invasive Ventilation. NCEPOD.


Royal College of Physicians (2017) National Early Warning Score (NEWS) v2. RCP.

