Non-invasive ventilation

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Key points
Non-invasive ventilation (NIV) is a method of respiratory support that is commonly used for the management of a wide range of causes of respiratory failure, both within and without the intensive care unit (ICU). This review will discuss the advantages of this mode of ventilation over more traditional methods, its indications and contra-indications and the equipment required, as well as reviewing the available literature for evidence of its efficacy. NIV is also used in the management of chronic respiratory failure caused by either pulmonary disease or neurological conditions – this will not be considered further by this review.

Disadvantages of conventional ventilation

Conventional invasive positive-pressure ventilation (IPPV) has been the routine method of respiratory support in the majority of intensive care units (ICU) since the Copenhagen polio outbreak in 1952. Its efficacy is well accepted and it is undoubtedly lifesaving in severe acute respiratory failure. There are, however, many complications and disadvantages associated with its use. These are summarised in Table 1. Many of these complications are associated with the presence of the endotracheal tube (ETT) which is avoided by using NIV. For example, a postulated mechanism for the development of ventilator associated pneumonia (VAP) is pooling of secretions above the ETT cuff which then leak past the cuff, colonise the trachea and cause pneumonia. VAP is implicated in causing excess ICU mortality, length of stay and cost, all of which should be avoided by providing respiratory support without an ETT.

Few patients receiving NIV will require sedation, compared with the majority of patients receiving IPPV, so the many side-effects of these drugs are avoided. Inability to talk is a major disadvantage of IPPV, causing frustration and depression in patients. Communication is difficult but possible while receiving NIV and some patients may cope with temporary cessation of NIV in order to eat and drink or communicate with visitors. However, some complications, such as the cardiovascular effects of positive end-expiratory pressure (PEEP), will also occur during NIV.

Certain groups of patients – e.g. the immunosuppressed or those with haematological malignancies – have mortality rates approaching 90% when treated with IPPV for acute respiratory failure. It has been postulated that NIV may be more successful in these patients. Similarly, those with acute exacerbations of chronic respiratory diseases often have long and complicated ICU stays if managed with IPPV and, in this group, NIV may prove to be a superior method of support. The results of trials of patients with these conditions are discussed later.

Table 1 Complications of conventional ventilation

| Insertion of ETT | Difficult intubation |
| Presence of ETT | Ventilator associated pneumonia |
| Presence of ETT | Sinusitis |
| Presence of ETT | Impairment of ciliary function |
| Presence of ETT | Inability to talk |
| Presence of ETT | Inability to eat and drink |
| Post-extubation | Vocal cord dysfunction |
| Post-extubation | Tracheal stenosis |
| Need for sedation | Cardiovascular instability |
| Need for sedation | Delayed weaning |
| Need for sedation | Reduced coughing |
| Need for sedation | Decreased bowel motility |
| Presence of PEEP | Cardiovascular instability |
| Presence of PEEP | Fluid retention |
Equipment required
The basic requirements are a ventilator, ventilator tubing and an interface to connect the system to the patient. Most modern ICU ventilators will function well as non-invasive ventilators but are much more complicated than is necessary. Their advantages are that they have gas mixers capable of providing high oxygen concentrations and extensive monitoring and alarm systems. Portable non-invasive ventilators are widely used, both on the ICU and respiratory wards. These much simpler machines rarely have specific gas mixers and provide high flows using venturi air entrainment. Therefore, their use is limited to those patients with lower oxygen requirements.

Both volume-controlled and pressure-controlled devices are available. Volume-controlled machines cannot compensate for leaks, so may be difficult to use in patients who cannot tolerate tight masks. The most popular machines are those providing bi-level positive airway pressure (BiPAP). These ventilators administer both PEEP and either pressure support or pressure-controlled ventilation, depending on the level of patient effort. The simplest form of NIV is continuous positive airway pressure (CPAP). Portable, briefcase-sized generators, suitable for home use, can administer this.

There are three major types of interface available: full-face masks, nasal masks and nasal pillows. Nasal masks are said by patients to be the most tolerable, but they require a cooperative patient who can keep their mouth closed in order to be effective. In most patients with acute respiratory failure, full-face masks are a more appropriate choice and have been shown to be more effective in lowering arterial carbon dioxide concentrations. A major disadvantage of both types of mask is that they exert pressure on the nasal bridge in order to maintain a seal and occasionally cause severe ulceration. This can be avoided by sticking a hydrocolloid dressing (e.g. Granuflex) to the nasal bridge before fitting of the mask.

Nasal pillows are soft rubber or silicone bungs that fit inside the nose. These may be used in patients who are claustrophobic or who cannot tolerate a tight mask. However, their efficacy remains unproven.

Indications
The indications for NIV are shown in Table 2. There are varying amounts of evidence to support the use of NIV in different conditions and this is discussed below.

Chronic obstructive pulmonary disease
NIV is extremely effective in the management of exacerbations of chronic obstructive pulmonary disease (COPD). The major mechanism causing acute respiratory failure in COPD is dynamic hyperinflation as a result of the increased airways resistance which prevents complete exhalation before the next inspiration starts. This change in lung mechanics, with a greatly increased level of intrinsic PEEP, causes an increased work of breathing, resulting in early respiratory muscle fatigue and rapid, shallow respiration. There is significant wasted ventilation, resulting in carbon dioxide accumulation. NIV acts by using extrinsically applied PEEP to offset the intrinsic PEEP and reduce dynamic hyperinflation, so reducing the work of breathing; the pressure support helps to overcome increased airways resistance. NIV thus results in an increased tidal volume, reduced respiratory rate, rapid clearance of carbon dioxide and normalisation of pH.

NIV has been successfully used in a wide range of locations, from the ICU or specialised respiratory support unit to the general respiratory ward. It has recently been suggested that the use of NIV should be a standard of care in COPD – its use compared with standard medical management reduces the need for intubation by 50–80% and mortality rates by up to 60%. There is a reduced rate of complications and both ICU and hospital stay are shorter. Those who respond best to NIV are symptomatic patients with established moderate respiratory acidosis (pH 7.25–7.35) who are treated at a relatively early stage in their exacerbation.

Asthma
There has been little research into the use of NIV in severe acute asthma, but many of the trials of NIV in hypoxaemic respiratory failure have included patients with asthma. The results in these patients have been encouraging, but the numbers are very small and a prospective, randomised, controlled trial is now underway.
Cardiogenic pulmonary oedema

Trials have consistently shown that CPAP at levels of 10–12.5 cmH₂O improves oxygenation, decreases the need for intubation and shortens ICU stay. Initial studies showed NIV to be very effective in improving oxygenation, normalising pH and reducing the need for intubation by about 50%. However, 4 of 29 patients in the first study and 5 of 26 patients in the second study died (3 and 4, respectively, with myocardial infarctions).

In a recent controlled trial of BiPAP versus CPAP in cardiogenic pulmonary oedema, rates of intubation and mortality were similar between the two groups. However, there was a significantly increased myocardial infarction rate in the BiPAP group (71% BiPAP versus 31% CPAP). This led the investigators to stop the trial early and counsel against the use of NIV in pulmonary oedema associated with acute cardiac conditions. However, there are concerns about the comparability of the two groups in this trial, as 10 patients in the BiPAP group had chest pain on study entry compared with only 4 in the CPAP group. The mechanism behind any potential adverse cardiac effect of NIV is unclear and more research is required into the haemodynamic effects of BiPAP.

In view of its efficacy, CPAP remains the respiratory support mode of choice in cardiogenic pulmonary oedema. Full NIV is reserved for those patients who require rapid correction of blood gas abnormalities in an attempt to avoid invasive ventilation.

Hypoxaemic respiratory failure

The conditions represented by this category are wide-ranging, from atelectasis or pneumonia to acute respiratory distress syndrome. Initial studies showed NIV to be useful in patients with hypoxaemia and hypercapnia – reducing intubation rate, ICU stay and ICU mortality. Efficacy in those with normocapnia was unclear.

More recent studies have been encouraging. In these uncontrolled studies, NIV reduced the need for intubation by up to 65% and reduced predicted mortality by up to 50%. In a recent controlled trial comparing NIV with conventional ventilation, NIV was found to be as effective in normalising gas exchange as IPPV. Only 31% of patients treated with NIV required intubation – an incidence similar to previous uncontrolled trials. Patients who received NIV had significantly reduced septic complications and there were trends towards reduced mortality and ICU stay. These results have been confirmed by a further randomised controlled trial. Unfortunately, a recent trial of NIV in the accident and emergency department showed no reduction in intubation rate and even a trend towards increased mortality. There are concerns regarding the methodology and conduct of this trial but it casts doubt on the use of NIV in this group of patients.

In summary, for patients with hypoxaemic respiratory failure, NIV is an effective alternative to conventional ventilation, with the proviso that 30–40% of patients will require intubation. It is most effective in those patients who also have hypercapnia and is very helpful in the management of those patients with chest trauma.

Weaning of ventilatory support

Several uncontrolled studies have examined the use of NIV as an aid to weaning. In these trials, patients were extubated before they met standard extubation criteria (e.g. oxygen requirement, PEEP level, respiratory rate) and were then treated with NIV. The majority of patients (60–70%) coped very well with this and did not require re-intubation.

The rationale behind this form of weaning is that, by reducing the duration of invasive ventilation, the incidence of complications should be reduced. This was tested in a controlled trial involving COPD patients who were randomised after 48 h conventional ventilation to either extubation and NIV or routine weaning. NIV treated patients required a shorter duration of ventilatory support, reduced ICU stay and reduced 60-day mortality (8% versus 28%). There was no incidence of VAP compared with 28% in the conventionally managed group.

Patients who fail trials of extubation have been shown to have higher mortality and complication rates than those who are successful and NIV has been proposed as a strategy to avoid re-intubation. Several case series have been published describing success rates of up to 65% in avoiding re-intubation and shorter ICU stays. The technique is most successful in patients with hypercapnic respiratory failure due to COPD, acute pulmonary oedema or mild post-extubation glottic oedema.

Respiratory failure in immunosuppressed patients

Immunosuppressed patients have extremely poor outcomes if they develop respiratory failure requiring ventilatory support – their susceptibility to VAP is high, resulting in mortality rates > 90%. It is proposed that the use of NIV in patients with single organ system failure as a result of opportunistic chest infection may improve their outcome by avoiding superadded VAP. Those patients with multiple organ failure are extremely
unlikely to survive and are thus poor candidates for critical care support.

Several uncontrolled trials have shown NIV to be successful in about two-thirds of patients with AIDS, haematological malignancies and pneumonia following lung transplantation. A larger randomised, controlled study in patients with respiratory failure following solid organ transplantation showed a 60% reduction in intubation rate and lower ICU mortality with NIV. Hospital mortality was unchanged. There was, however, a significant reduction in the incidence of sepsis in the NIV group and other trials have demonstrated up to 75% reduction in the incidence of VAP. It is, therefore, the initial treatment of choice for immunosuppressed patients with respiratory failure.

**Contra-indications to NIV**

**Absolute contra-indications**

Absolute contra-indications include respiratory arrest, severe cardiovascular instability and life-threatening dysrhythmias, as the patient requires intubation as part of resuscitation. Reduced level of consciousness, bulbar palsy and the inability to protect the airway leave the patient at risk of aspiration of gastric contents. Patient co-operation is also essential for NIV to be effective, so it should not be attempted in uncooperative patients.

**Relative contra-indications**

The relative contra-indications fall into three groups: (i) factors that may make it difficult to create a seal with the mask, *e.g.* facial trauma, facial deformity or recent surgery; (ii) conditions where air swallowing may cause problems, *e.g.* after oesophagectomy (risk of swallowed air causing anastamotic breakdown); and (iii) cases where frequent interruption of ventilation is required in order to clear copious secretions.

**Complications of NIV**

Minor complications are common and include air leaks and mask problems such as discomfort, nasal bridge ulceration and facial erythema. Pressure and flow related complications include nasal congestion and eye irritation. Aerophagia occurs in up to 25% of patients and, because of this, all patients receiving NIV should have a nasogastric tube *in situ*. Major complications such as aspiration of gastric contents, cardiovascular instability and pneumothorax are fortunately very rare.

**Assessment of the need for intubation**

The factors involved in the assessment of the need for intubation have been categorised into major factors (require immediate intubation) and minor factors (indication that the respiratory failure is not improving). They are shown in Table 3. It has been suggested that the presence of one major factor at any time, or two minor factors after 1 h of NIV, should lead to intubation.

**Key references**


See multiple choice questions 91–93.