

Clinical applications of non-invasive ventilation in critical care



GBS McNeill MBChB MRCP

AJ Glossop BMedSci, BM, BS, MRCP, FRCA, DICM

Key points

Reducing the time patients spend on mechanical ventilation (MV) may decrease the risk of several serious complications.

The strongest evidence for use of non-invasive ventilation (NIV) is in patients with respiratory failure secondary to either chronic obstructive pulmonary disease or cardiogenic pulmonary oedema.

NIV is emerging as an alternative to MV in a number of different clinical situations.

When NIV is commenced outside critical care, a defined plan should already be in place if NIV is unsuccessful.

NIV should not delay intubation and MV in those patients who fail to respond to or deteriorate on NIV.

Tracheal intubation and mechanical ventilation (MV) are supportive interventions that may be life saving in critically ill patients but also involve a significant risk of morbidity and mortality. Averting the need for MV, or reducing the time patients spend on MV, may decrease the risk of several serious problems such as ventilator-associated pneumonia, sedation-related problems, and sinusitis and may also improve patient mortality in several different clinical situations.

Non-invasive ventilation (NIV) is defined as 'delivery of ventilatory support via the patient's upper airway using a mask or similar device' and includes both continuous positive airway pressure (CPAP) and non-invasive positive pressure ventilation (NPPV). NIV was initially used to treat type II respiratory failure and prevent the need for MV and the attendant complications associated with invasive ventilation but is now emerging as a useful alternative treatment strategy to MV in a number of different clinical situations.

Worldwide, the use of NIV has more than doubled in the past 10 yr. In the UK where the previous decade has seen a disproportionate increase in level 2 critical care beds, NIV use has risen steadily. Yet, large international geographical variations remain and NIV use remains relatively low in areas such as North America.

General considerations

Although the likelihood of successful application of NIV will largely depend on the particular clinical setting in which it is applied, some general considerations can aid success. The importance of explaining the procedure to the patient, paying close attention to skin integrity, and appropriate mask interface selection can play a large role in the success of the intervention. The setting in which NIV is used is also crucial. It must be appreciated that the scope for the safe use of NIV in the ward environment is inherently less than that of critical care,

where escalation to invasive ventilation is rapidly available.

The evidence base for the use of NIV in a number of different clinical situations has increased greatly in recent years; however, there remain a number of contraindications to its use. These are described in Table 1. While these general indications and cautions may act as a guide, the role of NIV in specific clinical syndromes is inherently more complex. Guidance based on the available evidence is outlined below.

Type II respiratory failure

Chronic obstructive pulmonary disease

In acute exacerbations of chronic obstructive pulmonary disease (COPD), NIV has been demonstrated in numerous randomized controlled trials (RCTs) and meta-analyses to significantly reduce mortality and complications when compared with standard medical therapy.¹ As such, it is now considered the first-line therapy in COPD and there is growing evidence that its use may be applicable in patients with severe acidaemia (pH < 7.25) and hypercarbic coma, conditions previously considered as contraindications to NIV. This growing evidence base is reflected in the latest BTS guidelines on the use of NIV in acute exacerbations of COPD. This recently published guidance emphasizes the need to consider the most appropriate clinical area for NIV to be commenced. Those with severe acidaemia (pH < 7.25) should be managed within a critical care area. Any possible treatment limitations should be considered at the time NIV is commenced. Although dedicated respiratory support units will be suitable for most patients with acute exacerbations of COPD, if the need for intubation is anticipated, it may be more appropriate to initiate NIV within a critical care area.

However, some caution should be exercised in patients with COPD and additional

GBS McNeill MBChB MRCP

Advanced Trainee in Intensive Medicine
Department of Critical Care
Sheffield Teaching Hospitals NHS
Foundation Trust
Sheffield
UK

AJ Glossop BMedSci, BM, BS, MRCP, FRCA, DICM

Consultant in Anaesthesia and Intensive
Care Medicine and NICE Scholar 2010–
2011 for Evaluation of the Health
Economic Benefits of NIV
Department of Critical Care
Northern General Hospital
Sheffield Teaching Hospitals NHS
Foundation Trust
Sheffield S5 7AU
UK
Tel: +44 114 271 4195
Fax: +44 114 226 9342
E-mail: alastair.glossop@sth.nhs.uk
(for correspondence)

Table 1 Indications and contraindications for NIV in acute care (reproduced from Hill and colleagues).¹ NIV, non-invasive ventilation; P_{aCO_2} , arterial partial pressure of carbon dioxide; P_{aO_2} , arterial partial pressure of oxygen; F_{IO_2} , fraction of inspired oxygen

Indications	
Bedside observations	
Increased dyspnoea—moderate to severe	
Tachypnoea (>24 bpm in obstructive, >30 min ⁻¹ in restrictive)	
Signs of increased work of breathing, accessory muscle use, and abdominal paradox	
Gas exchange	
Acute or acute on chronic ventilatory failure (best indication), P_{aCO_2} >6.0 kPa, pH <7.35	
Hypoxaemia (use with caution), P_{aO_2}/F_{IO_2} ratio <200	
Contraindications	
Absolute	
Respiratory arrest	
Unable to fit mask	
Relative	
Medically unstable—hypotensive shock	
Uncontrolled cardiac ischaemia or arrhythmia	
Uncontrolled copious upper gastrointestinal bleeding	
Agitated, uncooperative	
Unable to protect airway	
Swallowing impairment	
Excessive secretions not managed by secretion clearance techniques	
Multiple (i.e. two or more) organ failure	
Recent upper airway or upper gastrointestinal surgery	

acute pathology. Although there is evidence that patients with COPD and bronchopneumonia have a clearer benefit from NIV than patients with bronchopneumonia alone, a recent large UK audit of NIV use in COPD² documented an inappropriate use of NIV and an associated high inpatient mortality. This study's conclusions emphasized the need for timely initiation of NIV once respiratory acidosis develops. It also suggests that outcomes may be poorer if there is co-existing metabolic acidosis.

Asthma

The use of NIV in asthma remains a contentious area.¹ Some small RCTs suggest that using NPPV in acute exacerbations of asthma may improve respiratory parameters and reduce intubation rates. However, a Cochrane review of the available evidence published in 2005 failed to find robust evidence of benefit. The BTS guidelines on management of asthma are non-committal on the use of NIV, suggesting that a 'trial' may be considered. In this setting where clinical judgement appears crucial, there is evidence that particular caution should be used when there is a presence of altered mental status or exhaustion. Indeed, trials of NIV in acute asthma should only be commenced in a critical care area, where in the event of NIV failure, intubation can be rapidly undertaken.

Morbid obesity

Obesity is one of the fastest growing health burdens in the western world. It is strongly associated with certain respiratory syndromes

such as obstructive sleep apnoea and chronic alveolar hypoventilation. These patients are increasingly presenting to critical care environments with acute on chronic type II respiratory failure. There is increasing evidence that when this presentation is *de novo*, NIV is the initial treatment of choice.³ It also appears useful in obese patients in the postoperative period. When the syndrome is associated with other pathology such as bronchopneumonia, the evidence remains less clear.

Neuromuscular disorders

There is a lack of evidence for the use of NIV in acute neuromuscular disorders such as Guillain-Barré syndrome (GBS) and acute myasthenia.⁴ These disorders are often associated with upper airway dysfunction and there is concern that NIV may increase the already high incidence of pulmonary aspiration. In addition, respiratory compromise due to GBS is often associated with a prolonged period of MV and a recommendation for early tracheostomy. Given this, NIV is often felt to be inappropriate and its routine use cannot presently be recommended in acute neuromuscular disorders.

Chronic neuromuscular disorders, notably motor neurone disease (MND), are characterized by an irreversible decline in respiratory function due to respiratory muscle atrophy. Dyspnoea is a common and subjectively distressing feature of advanced MND and death from respiratory failure is common. The use of NIV has been demonstrated to improve quality of life and survival in patients with advanced neuromuscular disorders⁵ and its use is recommended by National Institute for Health and Clinical Excellence (NICE) and also by the American Association of Neurologists (AAN) in advanced MND. In amyotrophic lateral sclerosis in particular, even if there is a presence of severe bulbar dysfunction, there is trial evidence that NIV confers a symptomatic if not survival benefit.

Type I respiratory failure

The role of NIV in this group is less clear due to the heterogenous nature of hypoxic respiratory failure, and the success of NIV may vary greatly according to the underlying aetiology (Fig. 1). Caution is still strongly advised in certain patient groups, especially those with haemodynamic instability or reduced conscious level.

Cardiogenic pulmonary oedema

There is good evidence to support the use of both CPAP and NPPV in acute pulmonary oedema.¹ Theoretical benefits include a reduction in both preload and afterload and improved oxygenation and reduced work of breathing. This appears to translate into strong RCT evidence of CPAP improving patient mortality. Evidence from the 3CPO trial⁶ suggested that there was no additional benefit for the use of CPAP or NPPV in acute cardiogenic pulmonary oedema. However, this conflicts with evidence from a

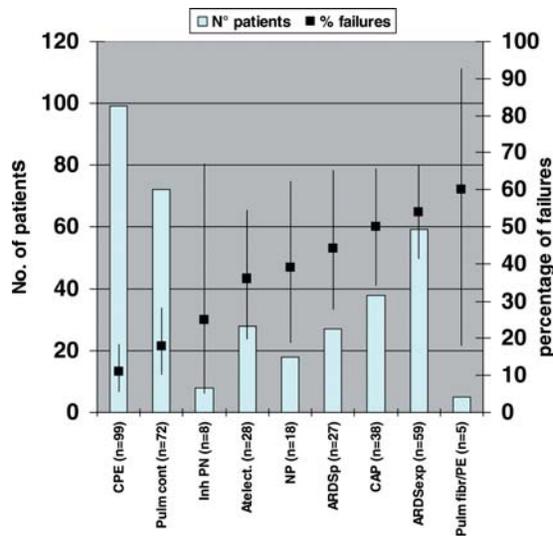


Fig 1 Causes of acute respiratory failure and frequency of NIV failure.

recent Cochrane review which confirmed the above clinical benefits and failed to demonstrate an increased incidence of myocardial infarction associated with NIV. The use of NIV is now widely accepted in CPE with a greater body of mortality benefit for use with CPAP. In addition, NPPV may have a role in faster resolution of dyspnoea.

Pneumonia

The use of NIV as a treatment for pneumonia remains controversial. Data registry statistics suggest that pneumonia as a cause of respiratory failure predicts failure of NIV. In patients with pneumonia and underlying COPD, or immunocompromise, there may actually be a mortality benefit to treatment with NIV.¹ The latest BTS pneumonia guidance outlines the lack of evidence for CPAP or NPPV in pneumonia but also acknowledges its widespread use in patients managed specifically within critical care. It concludes that if a trial of NIV is undertaken, it should be advised that this is done in an area where escalation to invasive ventilation is readily available.

Acute lung injury/acute respiratory distress syndrome

There is a lack of clinical evidence regarding the use of NIV in acute lung injury (ALI)/acute respiratory distress syndrome (ARDS).¹ The limited studies that have been performed suggest that it is not effective in the presence of multiple organ system failure, although there may be a role in isolated respiratory compromise. The majority of these studies have been conducted in single centres with extended expertise in the use of NIV. It is therefore likely that even in specialist centres, any NIV use in ALI/ARDS will depend on a very restricted patient selection policy, and thus the use cannot currently be recommended.

Lung contusion/chest trauma

Respiratory failure due to chest trauma or contusions responds well to NIV and may improve mortality compared with 'standard treatment'. Indeed, recent evidence suggests that when combined with an effective analgesic regime, outcomes after NIV compare favourably to the use of MV with reduction in mortality and infective complications.⁷

Immunocompromised patients with acute respiratory failure

Intubation and ventilation of patients with solid organ or bone marrow transplants and respiratory failure carries a very high risk of mortality. After intubation, incidence of ventilator-associated pneumonia is high and outcomes are poor. Intubation rates, mortality, and intensive care unit (ICU) length of stay can all be significantly reduced by the use of NIV in this group with the reduction in infective complications such as ventilator-associated pneumonia thought to be the most important factor in this.¹ In particular, it is noted that these patients often require fiberoptic bronchoscopy as part of their diagnostic work-up. This patient group is at risk of respiratory decline after this procedure. There is growing evidence that the pre- and post-procedure use of NIV may prevent this decline in respiratory function and reduce rates of emergency post-procedure intubation.

Post-extubation use of NIV

Removal of patients from MV reduces the risk of several serious problems. However, premature extubation may be equally detrimental to patient outcomes with the need for reintubation associated with a mortality of up to 40% in some patient groups. The use of NIV in recently extubated patients provides an attractive alternative to MV and may improve outcomes and mortality. The use of NIV post-extubation may be divided into three main areas.

NIV post-extubation in critical care

NIV has been used as both a rescue therapy and a preventative measure in recently extubated patients thought to be high risk for reintubation to reduce the need for a period of further MV. Predictably, this approach was initially described in patients with COPD who developed type II respiratory failure post-extubation.

However, a landmark study demonstrated that instigation of NIV once post-extubation respiratory failure had developed did not prevent reintubation and actually increased patient mortality due to a delay in time to reintubation of patients receiving NIV. This trial included only a very small number of patients with COPD and the NIV group had a significantly increased time to reintubation compared with the control group, but nonetheless led to re-evaluation of the role of NIV post-extubation.⁸

Although the use of NIV to treat established post-extubation respiratory failure is not recommended, the evidence for using

NIV prophylactically immediately after extubation to prevent the development of respiratory failure is more compelling. Several groups have focused on the use of NIV as a preventative measure in ICU patients who have been extubated but are deemed to be at high risk of developing post-extubation respiratory failure. The evidence suggests that the use of NPPV early after extubation and before the onset of respiratory failure may avert the onset of respiratory failure and potentially reduce the need for reintubation and mortality in selected patient groups.

Weaning from MV

NIV has also been studied in patients who are difficult to wean as an alternative to ongoing MV, with the aim of reducing the risks associated with prolonged tracheal intubation. In particular, ventilator-associated pneumonia is a significant cause of morbidity and mortality that hinders weaning from MV and may be prevented by extubation onto NIV. It has been suggested that NPPV could be used as a tool to help wean patients deemed not suitable for extubation from MV, by providing respiratory support without the need for sedation, neuromuscular block, and tracheal intubation in place of MV.

RCTs have compared the use of NPPV against conventional weaning methods in patients who are felt ready to begin weaning from MV but are not felt suitable for extubation. A large meta-analysis of these studies has highlighted that although there is good evidence that NIV may reduce mortality, length of stay, and rates of ventilator-associated pneumonia, the study populations often include disproportionately large numbers of COPD patients.⁹ The applicability of this evidence to the general critical care population remains uncertain.

Postoperative patients

After abdominal surgery, basal atelectasis, prolonged supine position, and diaphragmatic splinting may all contribute to the development of postoperative respiratory failure. The use of CPAP both prophylactically and as a treatment for hypoxic respiratory has been demonstrated to reduce reintubation rates and mortality in a wide variety of patients after open abdominal visceral surgery. The use of NIV in patients who have undergone upper gastrointestinal procedures remains controversial, although there is growing evidence for the safe use of NIV after gastric and bariatric surgery.

In cardiac surgery, a recent RCT has supported previous findings that the postoperative use of continuous positive airways pressure in cardiac surgical patients may reduce postoperative complications such as pneumonia, need for reintubation, and readmission to critical care. Postoperative prophylactic CPAP has also been demonstrated to improve oxygenation, reduce pulmonary complications, and reduce reintubation rates after abdominal and thoracic aortic aneurysm repair.

In thoracic surgery, acute respiratory failure (ARF) after pneumonectomy or lobectomy confers a significant risk of poor outcome. Reintubation is associated with a mortality risk of between 60% and 80%. Those at highest risk of ARF include those with raised BMI, a history of COPD, and those who continue to smoke. Theoretical risks of any positive pressure ventilation in this postoperative group include bronchial stump disruption and air leakage. RCT evidence suggests that NIV is safe and may reduce both reintubation rates and mortality in this at-risk surgical group.¹⁰

Conclusion

NIV is a useful alternative therapy to MV in many different situations where patients may be experiencing ARF. It may also have roles in preventing the development of respiratory failure in recently extubated ICU patients and in the postoperative period and also in palliation of patients with progressive neurological conditions. Particularly, when NIV is commenced outside critical care, a defined plan should already be in place if NIV is unsuccessful. Within critical care, although NIV may be applied to potentially sicker populations, the importance of the need for a 'trial of NIV' should be emphasized. Set goals should be defined at the time of treatment initiation. Particularly, in high-acuity patients, if after 1–2 h there is no improvement in pH, respiratory rate, or patient co-operation, consideration should be given to escalation to MV. Thus, despite increasing interest in its use, NIV should not be considered as a replacement for MV and should not delay intubation and MV in those patients who fail to respond to or deteriorate on NIV.

Declaration of interest

A.G. was awarded a scholarship by NICE in 2010 to examine the health economic benefits of NIV in post extubation patients but received no financial incentives.

References

1. Hill NS, Brennan J, Garpestad E, Nava S. Noninvasive ventilation in acute respiratory failure. *Critical Care Medicine* 2007; **35**: 2402–7
2. Roberts CM, Stone RA, Buckingham RJ, Pursey NA, Lowe D. Acidosis, non-invasive ventilation and mortality in hospitalised COPD exacerbations. *Thorax* 2011; **66**: 43–8
3. BaHammam A. Acute ventilatory failure complicating obesity hypoventilation: update on a 'critical care syndrome'. *Curr Opin Pulm Med* 2010; **16**: 543–51
4. Mehta S. Neuromuscular disease causing acute respiratory failure. *Respir Care* 2006; **51**: 1016–21, discussion 21–3
5. Bourke SC, Bullock RE, Williams TL, Shaw PJ, Gibson GJ. Noninvasive ventilation in ALS: indications and effect on quality of life. *Neurology* 2003; **61**: 171–7
6. Gray A, Goodacre S, Newby DE *et al*. Noninvasive ventilation in acute cardiogenic pulmonary edema [see comment]. *N Engl J Med* 2008; **359**: 142–51
7. Gunduz M, Unlugenc H, Ozalevli M, Inanoglu K, Akman H. A comparative study of continuous positive airway pressure (CPAP) and

intermittent positive pressure ventilation (IPPV) in patients with flail chest. *Emerg Med J* 2005; **22**: 325–9

8. Agarwal R, Aggarwal AN, Gupta D, Jindal SK. Role of non invasive positive-pressure ventilation in postextubation respiratory failure: a meta-analysis. *Respir Care* 2007; **11**: 1472–9
9. Burns KEA, Adhikari NKJ, Keenan SP, Meade M. Use of non-invasive ventilation to wean critically ill adults off invasive ventilation: meta-analysis and systematic review [see comment]. *Br Med J* 2009; **338**: b1574
10. Jaber S, Chanques G, Jung B. Postoperative noninvasive ventilation. *Anesthesiology* 2010; **112**: 453–61

Please see multiple choice questions 25–28.