

Recent advances in the role of non-invasive ventilation in acute respiratory failure

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ABSTRACT

Non-invasive positive pressure ventilation (NIPPV) is the technique of delivering mechanical ventilation without endotracheal intubation or tracheostomy. This is increasingly being utilised in both acute and chronic conditions. Strong evidence supports the use of NIPPV for acute respiratory failure (ARF) to prevent endotracheal intubation (ETI) and to facilitate extubation in patients with acute exacerbations of chronic obstructive pulmonary disease, to avoid ETI in acute cardiogenic pulmonary oedema (ACPO), and in immunocompromised patients. Weaker evidence supports the use of NIPPV for patients with ARF due to asthma exacerbations, with postoperative ARF, pneumonia and acute lung injury/acute respiratory distress syndrome. NIPPV should be applied under close monitoring for signs of treatment failure and, in such cases, ETI should be promptly available. A trained team, at an appropriate location, with careful patient selection and optimal choice of devices can optimise the outcome of NIPPV.

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Key Words: acute respiratory failure; endotracheal intubation; non-invasive ventilation

INTRODUCTION

Non-invasive ventilation is the technique of augmenting alveolar ventilation without introducing endotracheal tube or doing tracheostomy, hence avoiding the complications due to endotracheal intubation/tracheostomy.¹ NIPPV is one of the most important developments in the field of respiratory medicine over the past two decades because of its many benefits (Table 1). Recent developments in the application of NIPPV in the treatment of acute and acute-on-chronic respiratory failure are being discussed in this article.

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Strong evidences (Table 2) supporting the role of NIPPV in the treatment of different conditions leading to acute or acute-on-chronic respiratory failure include four conditions as follows:

- (a) Prevention of intubation in patients with acute exacerbations of chronic obstructive pulmonary disease (AECOPD)
- (b) Acute cardiogenic pulmonary oedema (ACPO)

Table 1 Benefits of non-invasive positive pressure ventilation.

- Preservation of airway defence mechanism
- Early ventilation support
- Intermittent ventilation
- Patient can eat, drink, and communicate
- Ease of application and removal
- Improved patient comfort
- Reduced sedation requirement
- Avoidance of complication of intubation
- Ventilation outside of ICU setup possible

Table 2 Effectiveness of non-invasive positive pressure ventilation in acute respiratory failure from different causes.

Cause of acute respiratory failure	Level of evidence
Acute exacerbation of COPD	A
Cardiogenic pulmonary oedema	A
Weaning (AECOPD)	A
Immunocompromised patient	A
Endoscopy	B
Postoperative respiratory failure	B
Post-intubation oxygenation	B
Asthma exacerbation	C
ARDS/acute lung injury	C
Extubation failure	C
Do not intubate status	C
Pneumonia	C
Neuromuscular disorders	C
Thoracic trauma	C
Obesity hypoventilation syndrome	C
Airborne diseases (SARS, Tuberculosis)	C
During fibre-optic bronchoscopy (FOB)	C

Evidence A: Multiple randomised controlled trials and meta-analysis. Evidence B: More than one randomised controlled trial, case control series or cohort studies. Evidence C: Case series or conflicting data.³

- (c) Immunocompromised patients (ICP)
- (d) Weaning from invasive mechanical ventilation in patients with AECOPD who undergo ETI

Weaker evidence supporting the use of NIPPV includes:

- (a) Postoperative ARF
- (b) ARF due to asthma exacerbations
- (c) Pneumonia
- (d) Acute lung injury (ALI)/acute respiratory distress syndrome (ARDS)
- (e) Pre-oxygenation before intubation in patients with severe hypoxaemia²

CONDITIONS WHERE NON-INVASIVE POSITIVE PRESSURE VENTILATION IS USEFUL

Acute Exacerbations of Chronic Obstructive Pulmonary Disease

There is a good level of evidence for the clinical efficacy of NIPPV in the treatment of acute-on-chronic respiratory failure due to AECOPD.^{3,4} Compared with standard medical therapy alone, NIPPV improves survival, reduces the need for intubation and the rate of complications. NIPPV also shortened the hospital length of stay.

In patients with mild-to-moderate ARF (pH: 7.30–7.35), NIPPV was successfully administered in different settings, including ICU, respiratory and acute medical ward.⁴ In more severely ill patients (pH < 7.25), the rate of NIPPV failure is inversely related to the severity of respiratory acidosis. Even in severe patients, an NIPPV trial may be given, if it is not contraindicated (Table 3).³

Severe hypercapnic encephalopathy is not considered a contraindication to NIPPV at present. An initial cautious NIPPV trial should be given in patients of AECOPD with hypercapnic encephalopathy, provided most of the other predictors of success of non-invasive ventilation are favourable (Table 4).⁵

Asthma

Less evidence supports use of NIPPV in severe exacerbations of asthma leading to ARF. A retrospective non-controlled study reported favourable outcomes in 22 patients with status asthmaticus treated with NIPPV due to persistent hypercapnia.⁶ Another RCT has reported inconclusive result.⁷ NIPPV should not be used routinely in acute asthma; but a trial may be given to the patients not responding to standard treatment.⁸

Acute Cardiogenic Pulmonary Oedema

Both continuous positive airway pressure (CPAP) and bi-level positive airway pressure (BiPAP) reduce rate of intubation, and the mortality rate, compared with standard medical therapy.^{9,10} However, there had been a debate regarding the role of CPAP versus BiPAP in ACPO. A meta-analysis suggests that CPAP has a greater efficacy in reducing mortality.¹¹ However, some other study¹² suggests that BiPAP may be preferable for patients with persisting dyspnoea or hypercapnia after initiation of CPAP. Though there was an early concern about possible greater risk of myocardial infarction with NIPPV, subsequent study has not confirmed the same.¹³ In a multicentre randomised controlled

Table 3 Contraindications to non-invasive positive pressure ventilation.^{2,3}

- Cardiac or respiratory arrest
- Severe haemodynamic and cardiac instability (unstable angina, acute myocardial infarction)
- Serious cardiac arrhythmias
- Facial surgery or trauma
- Inability to clear secretions
- Upper airway obstruction
- Severe upper gastrointestinal bleeding

Table 4 Predictors of success in non-invasive positive pressure ventilation use.

- Better neurological status (more cooperative patients)
- Ability to protect airways
- Ability to coordinate breathing with ventilation
- Less air leakage, intact dentition
- Less severe illness (low APACHE II score)
- Hypercarbic, but not too severe (PaCO₂: 45–92 mmHg)
- Acidaemic, but not too severe (pH: 7.1–7.35 mmHg)
- Improvement in gas exchange, heart and respiratory rates within the first two hours

trial¹⁴ that compared BiPAP (12/5 cm H₂O) to CPAP (8 cm H₂O), the two modes were equally effective in reducing respiratory frequency, disposal, and need for invasive mechanical ventilation, and in improving arterial blood gases. NIPPV benefits these patients by causing decreased left ventricular pre- and after-load owing to increased intrathoracic pressure, resulting in improved cardiac performance. Inotropic effect of raised intrathoracic pressure also helps by augmentation of cardiac contractility. Re-opening of collapsed alveoli increases the functional residual capacity (FRC). This improves oxygenation and reduces work of breathing. However, by reduction of pre-load, NIPPV can sometimes be counter-productive by decreasing cardiac output.

Pneumonia

Non-invasive positive pressure ventilation is not very useful in ARF owing to pneumonia. There is a failure rate of more than 65% in patients with severe community-acquired pneumonia (CAP). Routine use of NIPPV in patients with severe pneumonia is not recommended; though, a cautious trial of NIPPV may be considered in these patients in the ICU setting.¹⁵

Acute Lung Injury/Acute Respiratory Distress Syndrome

Non-invasive positive pressure ventilation may be used as a first-line intervention in patients with early ARDS.¹⁶ The technique improves gas exchange and help in avoiding ETI in more than 50% of patients. Need for ETI is more likely in older patients and severe hypoxaemia, or when a higher level of positive end-expiratory pressure (PEEP) and pressure support is needed.¹⁶

NIPPV is not recommended as routine therapy for all cases of ALI/ARDS. A cautious trial in highly selected patients with less severe general condition can be attempted in an appropriate location.

Postoperative Respiratory Failure

Non-invasive positive pressure ventilation has been successfully used in the postoperative period. NIPPV used after major abdominal surgery improves hypoxaemia and reduces the complication rate and the need for ETI.¹⁷ Patients with hypoxaemic ARF after lung resection need less ETI and show reduced mortality rates if treated with NIPPV.

Immunocompromised Patients

Randomised controlled trials (RCTs) in immunosuppressed patients and transplant recipients with hypoxaemic ARF have shown decreased ETI and ICU mortality rates and shorter ICU lengths of stay in patients treated with NIPPV as compared with conventional therapy.¹⁸ The reduced mortality rate is probably due to reduced infectious complications associated with NIPPV compared with ETI, including ventilator-associated pneumonia (VAP) and other nosocomial infections. Hence, NIPPV should be included in management protocol for immunocompromised patients as the preferred initial ventilatory modality to avoid ETI and its associated risks.

Weaning from Invasive Mechanical Ventilation in Patients with Acute Exacerbations of Chronic Obstructive Pulmonary Disease

Randomised controlled trials have shown NIPPV to be useful as a means of facilitating weaning from invasive mechanical ventilation in patients with AECOPD and acute on chronic respiratory failure failing a T-piece trial.¹⁹ Patients intubated for hypercapnic ARF due to AECOPD who fail spontaneous breathing trials should be considered for a trial of extubation to NIPPV.

Do-Not-Intubate Patients

Though study has demonstrated that the use of NIPPV offers very low expectations in medium-term survival in do-not-intubate (DNI) patients, NIPPV has been used for patients and families who choose to forego ETI.²⁰

Neuromuscular Disorders

Non-invasive positive pressure ventilation is used for the majority of patients with respiratory insufficiency due to neuromuscular disorders. Patients with respiratory insufficiency due to neuromuscular disorder were randomly assigned to either NIPPV or no nocturnal ventilatory support.²¹ NIPPV improved survival by 205 days in patients without bulbar involvement, while no survival benefit was noted in those with bulbar disease. All patients however had some improvement in quality of life measures.

Chest Trauma

Continuous positive airway pressure is helpful in patients with rib fracture and hypoxaemia. CPAP may be used in conjunction with regional anaesthesia in these cases. This reduces ICU and hospital stay in comparison to conventional mechanical

ventilation. Bi-level pressure support stabilises a flail chest, and minimises basal atelectasis.²²

Obesity Hypoventilation Syndrome (OHS)

Application of positive airway pressure is the mainstay of therapy for OHS. Nocturnal BiPAP therapy is effective at reducing nocturnal PaCO₂ and daytime sleepiness in patients with OHS. In addition, it may stabilise or improve daytime PaCO₂.²³

Severe Acute Respiratory Syndrome (SARS)

Non-invasive positive pressure ventilation, either CPAP or BiPAP, was commonly employed in many hospitals during the epidemic of SARS. Its use can improve oxygenation and tachypnoea within an hour. NIPPV was found to be able to avoid intubation and invasive ventilation in up to two-thirds of SARS patients with deterioration.²⁴

Tuberculosis

Non-invasive positive pressure ventilation is effective in improving prognosis in acute-on-chronic respiratory failure in pulmonary tuberculosis. Tubercular ARDS can occur with miliary disease, and in extensive tubercular pneumonia. NIPPV, if applied early, is an option for ventilatory support in these patients.²⁵

During Fibre-optic Bronchoscopy (FOB)

Non-invasive positive pressure ventilation has been used via facemask during FOB in high-risk hypoxaemic patients. Having demonstrated satisfactory oxygenation following the application of NIPPV, the bronchoscope is inserted into the nose via a T-piece seal attached to a full-face mask. After PaO₂/FiO₂ ratio improves during NIPPV, patients usually tolerate the procedure well and FOB-related complications are minimal.³

METHODOLOGIES OF ADMINISTERING NON-INVASIVE VENTILATION

The patient is made comfortable in the bed at an angle of 30° or more. A full-face mask is positioned over the face in such a way that the nasal portion of the mask fits just above the junction of nasal bone and cartilage (Figure 1). Nasal mask may be used in those patients who do not tolerate full-face mask. The strap of the mask is fastened in such a way that 1–2 fingers can be passed through the headgear and the face. The mask is examined for patient satisfaction, leak and skin abrasion. In case the patient is given CPAP, the default pressure is set at 4–6 cm water. Gradually the pressure is raised in 2–3 cm increments to 10–15 cm water or more. If the patient is given bi-level positive pressure ventilation, initial settings given to the patients are as follows: inspiratory pressure support (IPAP) 10 cm water, and expiratory pressure support (EPAP) 5 cm water. IPAP is gradually increased at increment of 2 cm over next 30–60 minutes to maximum requirement (usually 15–20 cm water).²

Clinical parameters including pulse, respiratory rate, blood pressure, and oxygen saturation (SpO₂) are monitored continuously; and arterial blood gas levels (ABG) are determined



Figure 1 Bi-level positive pressure ventilation through full-face mask.

1 and 12 hours after the start of treatment, and as and when found indicated. Non-invasive ventilation (NIV) is adjusted to maintain $SpO_2 > 90\%$, patient's comfort, minimal air leak, and respiratory rate of less than 25/minute.

Approach to weaning involves increasing periods off-mask ventilation. Once the patient's condition has stabilised, the mask may be removed for short periods, and supplemental oxygen administered. Patient is closely monitored for signs of respiratory distress and fatigue. Periods off the ventilator lengthen as the underlying condition improves and the patient shows acceptable vital signs, good gas exchange, and no respiratory distress. Another approach to NIPPV weaning involves gradually reducing CPAP or EPAP to a minimum level (less than 5 cm water). Once the minimum level has been reached, NIPPV can be discontinued.

Patient ventilation asynchrony is observed when there is a major air-leak, or when the ventilator fails to sense inspiratory effort or onset of expiration. Asynchrony should be dealt with patience and persistence. Patient is reassured and encouraged to let the machine breath for him.

The modes that can be used with both conventional mechanical ventilator and non-invasive ventilator include assist-control ventilation (ACV) and pressure-support ventilation (PSV). Controlled mandatory ventilation (CMV) and synchronised intermittent mandatory ventilation (SIMV) cannot be used in NIPPV. Similarly, bi-level positive airway pressure (BiPAP) ventilation can be used by NIPPV, but not with conventional mechanical ventilation.

SUCCESSFUL NON-INVASIVE POSITIVE PRESSURE VENTILATION

Successful use of NIPPV in ARF depends on several factors, as listed below.

Clinical Conditions

Clinical judgment is important for decision-making. An improvement in arterial blood gases and in sensorium, or the response of a combination of several clinical and physiological parameters

to NIPPV after the first 1–2 hours of NIPPV, are used as predictors of success or failure in COPD patients.²⁶

Trained Team

Non-invasive positive pressure ventilation application follows a learning curve. As caregivers become more confident with NIPPV, success rates remain stable despite increasing severity of ARF.

Monitoring and Location

Close monitoring is crucial, especially during the initial period of NIPPV. NIPPV has been found effective in the ICU, the RICU, and general ward and in the emergency department.²⁷

Interface

The interface is one of the crucial issues affecting NIPPV outcome. Poor mask tolerance, skin lesions and leaks are the important factors causing NIPPV failure. Although the facemask is usually considered as the first choice interface for delivering NIPPV in the acute setting, nasal masks have been found to have similar success rates but higher tolerability than facemasks in ARF.²⁸ "Helmet interface" is a relatively new interface, which is effective and well tolerated in ARF patients receiving continuous ventilation for many days.

Humidification

Heated humidification during nasal NIPPV attenuates the adverse effects of mouth leak on effective tidal volume and nasal resistance, and improves overall comfort.

Helium–Oxygen Mixture

The use of helium–oxygen mixture (heliox) during NIPPV in AECOPD seems promising in further reducing dyspnoea and work of breathing, as well as hospital length of stay, but not in improving the success rate. The use of heliox is difficult due to the lack of availability of an approved heliox-delivery system.²⁹

Sedation

Despite the advantages of NIPPV, in ARF a large number of failures are due to patient refusal to continue the often-uncomfortable sessions. Therefore, sedation might have a role in the success of this procedure. Most physicians infrequently use sedation and analgesic therapy for NIPPV to treat ARF. Remifentanyl-based sedation has been found to be safe and effective in the treatment of NIPPV failure due to low tolerance.³⁰

CONCLUSION

Non-invasive positive pressure ventilation is an important development in managing patients with acute respiratory failure. However, it should always be remembered that even in conditions in which NIPPV has strong evidence of success; patients should be monitored closely for signs of treatment failure and should be promptly intubated before a crisis develops. The application of non-invasive positive pressure ventilation by a trained and experienced team, with careful patient selection

and choice of appropriate location and setting, should optimise patient outcomes. However, it cannot replace endotracheal intubation in all circumstances.

CONFLICTS OF INTEREST

None.

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