Airway Management With Noninvasive Positive Pressure Ventilation

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ABSTRACT

Noninvasive positive-pressure ventilation (NPPV) is a form of ventilatory support that does not require the placement of an advanced airway. The authors discuss the use of NPPV on patients who will likely benefit. The use of NPPV has reduced the need for patients to require intubation and/or mechanical ventilation in some cases, as well as benefits.

KEYWORDS: *noninvasive positive-pressure ventilation (NPPV); continuous positive airway pressure (CPAP); bilevel positive airway pressure (BiPAP); noninvasive ventilation (NIV); acute respiratory failure (ARF)*

Introduction

Noninvasive positive-pressure ventilation (NPPV) is a form of ventilatory support that does not require the placement of an advanced airway. NPPV has also been called continuous positive airway pressure (CPAP) or bilevel positive airway pressure (BiPAP). All of these ultimately fall into the category of noninvasive ventilation (NIV), a means of delivering ventilatory support without using an invasive mode of ventilation. The use of NPPV has reduced the need for patients to require intubation and/or mechanical ventilation in some cases, ultimately limiting them from further complications.[1] In addition, NPPV has shown to reduce mortality and intensive level care for patients with chronic obstructive pulmonary disease (COPD) and congestive heart failure (CHF).[1,2]

There are over 100,000 traumatic deaths in the United States every year and chest traumas are the cause of death for over a quarter of polytrauma patients.[3] Pulmonary contusions, interstitial, and intraalveolar fluids are common causes of posttraumatic respiratory failure.[3] The severity of those posttraumatic injuries and their pathology correlate with the development of pulmonary infections, respiratory failure, and mortality.[3] First-line treatment in COPD and acute respiratory failure (ARF) is to use NPPV, as long as there are no contraindications.[3–4] NIPPV was historically limited to in-hospital settings, but it is now a first-line treatment in prehospital medicine, ultimately lowering the need for advanced airway management and mechanical ventilation in higher echelons of care.[4,5]

Development and History

In the 1930s, noninvasive ventilation devices delivered breaths by squeezing the abdomen, gently applying pressure and using gravity's force during inspiration and expiration. The first device developed was the "pneumobelt," which utilized a bladder attached to the patient's abdomen and incorporated a large ventilator that delivered positive pressure. Further into the history of NIV and possibly the most recognizable would be considered the "iron lung." The "iron lung" was a device that was used predominantly during the polio epidemic as support for those with respiratory failure secondary to the disease. This device utilized negative pressure within a closed chamber in an effort to keep the patient's lungs from developing atelectasis and to prevent total failure of the diaphragm. Whenever the pressure within the chamber would decrease, the thorax of the patient would expand, allowing for the intraalveolar pressure to decrease, imitating the action of the diaphragm in a physiologically normal human.

What Is NPPV?

NPPV is a form of mechanical ventilatory support that delivers positive pressure with a mix of atmospheric air and oxygen via a noninvasive device for patients that can maintain their own airway.[4,6–8] The use of NPPV can be delivered via ventilators found in the hospital setting, transport ventilators (i.e., Hamilton T1, Hamilton MR1, Zoll EMV+), and portable devices that can be used via attachment to oxygen tanks. CPAP and BIPAP are specific treatment modalities under the umbrella of NPPV, which is further defined within NIV and respiratory support.[8–10] These are modes that are delivered via facemask, endotracheal tube, or tracheostomy.

CPAP delivers a constant set pressure. This set pressure is commonly referred to as PEEP (positive end expiratory pressure), which may also be referred to as EPAP (expiratory positive airway pressure). By flowing at a constant pressure, the CPAP mode overpowers residual pressure that prevents the lungs from fully emptying on exhalation in reactive airway disease (RAD) and COPD.[11,12] Breaths are triggered by the patient, which drives tidal volume (Vt) to be fully dependent on the effort and compliance of the patient and their lung mechanics.[11, 12] CPAP creates an increase of alveolar pressure, allowing for better oxygenation at the end-alveolar plateau. Some negative impacts of CPAP include decreased patient comfort and increased anxiety due to large amounts of air being forced into their face and increased intra-thoracic volume, potentially causing hypercapnia and baro- and volutrauma.[11] These potential negative impacts can largely be avoided with pharmacologic assistance or utilization of BiPAP when available.[11]

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BiPAP is a form of pressure support (PS) ventilation delivering "bi-level" pressure on both inspiration and expiration. BiPAP is a time or flow-cycled change of the CPAP level.[11,12] This mode delivers both a set inspiratory pressure (IPAP) and expiratory pressure (EPAP), with the set IPAP delivering the higher pressure and cycling to the lower EPAP to improve patient comfort while also maintaining open alveoli. This can also be conceptualized by defining it as CPAP with PS, in which PS is added to the baseline PEEP every time the patient initiates a breath. In initial management of the acutely hypoxemic patient, the gradient between IPAP and EPAP should be kept the same (i.e., increasing the EPAP by 3cmH_2O should be matched by an increase of IPAP by 3cmH_2O) with the target of improving oxygenation.[11,12] In the acutely hypercapnic patient, the end goal would be to improve Vt and minute ventilation to decrease $PaCO_2$, achieved by widening the gradient between IPAP and EPAP.[11–13]

Both modes are to be used on conscious patients with the ability to maintain their own airway and the ability to spontaneously breathe. Patients with impending airway collapse or potential to become apneic should be treated with invasive airway intervention in an effort to protect the airway and breathing process. Additionally, in all patients that are being treated with NPPV, airway pressures must be closely monitored. Patients with PEEP or IPAP exceeding 20 cmH_2O are at increased risk for mask leaks, gastric inflation, increased anxiety, and barotrauma. Increases in gastric inflation put the already unstable airway at risk for aspiration due to vomiting. While using devices without electronic monitoring of airway pressure, the provider should pay close attention to patient comfort, airway resistance/compliance, and breath sounds with frequent reassessment.

When to Use NPPV

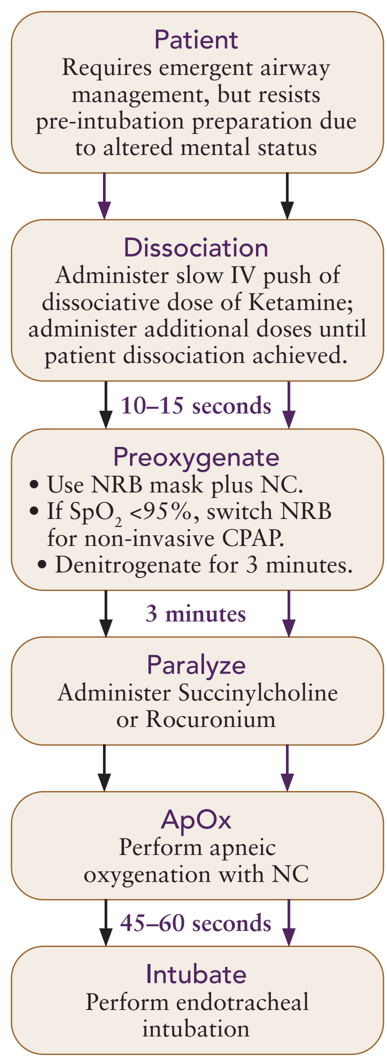
The primary indication for the use of any form of NIV/NPPV is acute respiratory failure (ARF).[1,2,4–6,12] The use of NIV/NPPV is commonly used in the following acute and chronic conditions: chronic obstructive pulmonary disease (COPD), asthma, hypercapnic respiratory failure, hypoxemic respiratory failure, ARDS, pneumonia, nocturnal hypoventilation, and amyotrophic lateral sclerosis (ALS).[1,2,4–6,13] NIV should also be considered postextubation as an effective weaning tool in a subset of patients with acute-on-chronic respiratory failure from COPD.[4–6] Applying immediate NIV to patients at high risk for extubation failure improves outcome by decreasing the need for reintubation.[4–6,11–13] NIV/NPPV should be considered as the first line treatment in any ARF patient when presenting with two or more of these signs and symptoms: accessory muscle use, paradoxical breathing, respiratory rate greater than 25 breaths per min, severe dyspnea or increased dyspnea in COPD, $PaCO_2$ above 45 mmHg, and a P/F (PaO_2/FiO_2) ratio less than 200.[1,2,4–6,14] P/F ratio is used as a predictor for ARDS with the following criteria: 200–300 mild ARDS (27% mortality); 100–200 moderate ARDS (32% mortality); <100 severe ARDS (45% mortality).[1,2,4–6,14] P/F ratio should only be used as a rule of thumb when the $PaCO_2$ is normal and V/Q (ventilation/perfusion) shunt is not suspected.[1–2,4–6,14]

Pharmacological Adjuncts in NPPV

As an additional adjunctive intervention, NPPV may be used in conjunction with medication to delay or forego the need for intubation.[15] The use of NIV and dissociative doses of ketamine, a treatment modality referred to as DSI (delayed sequence intubation), is a clinical algorithm used in the critically ill respiratory patient in an effort to achieve effective preoxygenation prior to intubation or to allow the patient to achieve a level of sedation and comfort to effectively oxygenate without intubation.[15] DSI is functionally procedural sedation with the predicted outcome being an increase in preintubation oxygenation. In an observational study performed with a total of 62 patients, with 39 receiving DSI with CPAP and 23 receiving preintubation oxygenation via nonrebreather, those patients receiving DSI had an increase in SpO_2 > 93% and successful intubation.[15]

Patients receiving dissociative doses of ketamine should receive 1–1.5mg/kg and CPAP or BIPAP with a PEEP of 5–15 cmH_2O and a PS of 5–10 cmH_2O, with both settings titrated to oxygenation, respiratory effort, and compliance.[15] Sedation-dose ketamine is generally a safe practice as long as patients are continuously monitored by advanced airway practitioners.[15]

FIGURE 1 *Elaboration of the DSI procedure used in this prospective observational study.*[15]



Patients That Will Benefit From NPPV

Patients in acute exacerbation of chronic obstructive pulmonary disease (AECOPD) with hypercapnia or a respiratory acidosis ($PaCO_2$ > 45 mmHg or pH < 7.35) are likely to benefit from NPPV.[16–18] In a meta-analysis of 17 randomized trials of patients diagnosed with AECOPD, there was a 50% reduction in mortality as comparted to patients with standalone respiratory treatment.[16–18] Additionally, those patients showed a decreased rate of intubation, ventilator induced injuries, and multiorgan failure.[16–18]

Patients in acute cardiogenic pulmonary edema (ACPE) are likely to improve with NPPV as a result of preload reduction, alveolar recruitment, and decreased left ventricular afterload.[19–26] In a 2013 meta-analysis of 32 studies (2,916 patients), it was reported that NPPV significantly reduced hospital mortality and respiratory failure (dyspnea, hypercapnia, acidosis, etc.).[26] NPPV also reduced the need for intubation and or frequency of intubations in lengthy hospital admissions in the same cohort.[26,27]

NPPV in Trauma Patients

The respiratory management of trauma patients is complex and tied tightly to multiple physiologic factors including intrinsic pulmonary function, respiratory mechanics, airway integrity, and hemodynamic status. It is the responsibility of the clinician to determine the best method of protecting and managing the patient's airway appropriately. In general, there is little evidence showing the efficacy of NPPV in the initial management of the trauma patient.[28–29] Often complex polytrauma patients are intubated for airway protection and during surgical procedures, which would be a contraindication for the use of NPPV. Current Prehospital Trauma Life Support and Advanced Trauma Life Support guidelines suggest early invasive airway intervention for those patients who are in respiratory failure or have significant thoracic trauma.[28] NPPV may be considered for the management of patients that are postsurgical and at risk for development of nosocomial pneumonia during prolonged hospital stays.[29] The goal for these trauma patients should be alveolar recruitment, oxygenation, and avoidance of ventilator-induced lung injury (VILI) or worsening of existing injuries.

Patients Who Will Not Benefit From NPPV

Patients suffering from hypoxemic, nonhypercapnic respiratory failure are less likely to benefit from NPPV and will respond better to individualized approaches to reversing the hypoxemia.[30] The use of high-flow oxygen delivered via nasal cannula (HFNC) is typically a better option in these patients.[30] The targeted approach to correcting the hypoxemia is often the primary cause to later acute respiratory failure, which requires aggressive NPPV and/or intubation.[30]

All patients requiring PPV in either invasive or noninvasive processes should be monitored for VILI. VILI can occur because of ventilation at high lung volumes, leading to alveolar rupture (bleb), air leaks, and gross barotrauma (e.g., pneumothorax, pneumomediastinum, and subcutaneous emphysema).[31] The concern for barotrauma is secondary to lung overdistention, not high airway pressures, which may be measured utilizing plateau pressures (most obtainable in the patient with an advanced airway placed). Lung overdistention may be secondary to high airway pressures, especially in settings of low PEEP. The management and prevention of VILI are well noted in the ARDSNET protocols, seeking a lung protective strategy in all patients receiving positive pressure ventilation.[31]

When Not to Use NPPV

Contraindications include:

- Decreased level of consciousness (Glasgow Coma Scale (GCS) score < 10)
- Cardiac arrest or dysrhythmias
- Acute coronary syndrome
- Hemodynamic instability (systolic blood pressure < 90mmHg)
- Open thoracic wound
- Apnea
- Upper airway obstruction
- Upper gastrointestinal bleeding
- Facial trauma
- Vomiting
- Pregnancy
- Patient refusal
- Patient ability to cooperate
- Excessive secretions
- Inability to protect own airway
- Facial burns
- Abnormal anatomy

Summary

NPPV is a form of positive pressure ventilation that supports patients with ARF. Using NPPV on patients that will likely benefit has shown to lessen mortality, the need for intubation, ventilator management, and later stage organ failure. While the use of NPPV in the initial management of trauma patients lacks evidence, these patients postintubation or in respiratory failure may benefit.

Disclosures
None.

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References
1. **Rose L, Gerdtz MF.** Review of noninvasive ventilation in the emergency department: clinical considerations and management priorities. *J Clin Nurs*. 2009;18(23):3216–3224.
2. **Rose L.** Management of critically ill patients receiving noninvasive and invasive mechanical ventilation in the emergency department. *Open Access Emerg Med*. 2012;4:5–15.
3. **Szucs-Farkas Z, Kaelin I, Flach PM, et al.** Detection of chest trauma with whole-body low-dose linear slit digital radiography: a multireader study. *AJR Am J Roentgenol*. 2010;194(5):W388–W395.
4. **Boldrini R, Fasano L, Nava S.** Noninvasive mechanical ventilation. *Curr Opin Crit Care*. 2012;18(1):48–53.
5. **Antonelli M, Conti G, Moro ML, et al.** Predictors of failure of noninvasive positive pressure ventilation in patients with acute hypoxemic respiratory failure: a multi-center study. *Intensive Care Med*. 2001;27(11):1718–1728.
6. **Chiumello D, Coppola S, Froio S, et al.** Noninvasive ventilation in chest trauma: systematic review and meta-analysis. *Intensive Care Med*. 2013;39(7):1171–1180.
7. **Hernandez G, Fernandez R, Lopez-Reina P, et al.** Noninvasive ventilation reduces intubation in chest trauma-related hypoxemia: a randomized clinical trial. *Chest*. 2010;137(1):74–80.

8. **Hess DR.** The evidence for noninvasive positive-pressure ventilation in the care of patients in acute respiratory failure: a systematic review of the literature. *Respir Care*. 2004;49(7):810–829.
9. **Karcz MK, Papadakos PJ.** Noninvasive ventilation in trauma. *World J Crit Care Med*. 2015;4(1):47–54.
10. **Bauer, E.** *Ventilator Management*. 2nd ed. Scotts Valley: CreateSpace Independent Publishing Platform; 2016.
11. **Keenan SP, Sinuff T, Cook DJ, Hill NS.** Does noninvasive positive pressure ventilation improve outcome in acute hypoxemic respiratory failure? A systematic review. *Crit Care Med*. 2004;32 (12):2516–2523.
12. **Peñuelas O, Frutos-Vivar F, Esteban** A. Noninvasive positive–pressure ventilation in acute respiratory failure. *CMAJ*. 2007;177 (10):1211–1218.
13. **Epstein SK.** Noninvasive ventilation to shorten the duration of mechanical ventilation. *Respir Care*. 2009;54(2):198–211.
14. **Nickson S.** PAO2/FIO2 Ratio (P/F Ratio). *Life in the Fast Lane*. 2020. https://litfl.com/pao2-fio2-ratio/. Accessed 24 January 2022.
15. **Weingart S, Trueger N, Wong N, et al.** Delayed sequence intubation: A prospective observational study. *Ann Emerg Med*. 2015;65(4):349–355.
16. **Rochwerg B, Brochard L, Elliott MW, et al.** Official ERS/ATS clinical practice guidelines: noninvasive ventilation for acute respiratory failure. *Eur Respir J*. 2017;50.
17. **Brochard L, Mancebo J, Wysocki M, et al.** Noninvasive ventilation for acute exacerbations of chronic obstructive pulmonary disease. *N Engl J Med*.1995;333:817.
18. **Osadnik CR, Tee VS, Carson-Chahhoud KV, et al.** Non-invasive ventilation for the management of acute hypercapnic respiratory failure due to exacerbation of chronic obstructive pulmonary disease. *Cochrane Database Syst Rev*. 2017;7(7):CD004104.
19. **Williams JW Jr, Cox CE, Hargett CW, et al.** *Noninvasive positive-pressure ventilation (NPPV) for acute respiratory failure*. Rockville (MD): Agency for Healthcare Research and Quality (US); 2012.
20. **Masip J, Roque M, Sánchez B, et al.** Noninvasive ventilation in acute cardiogenic pulmonary edema: systematic review and meta-analysis. *JAMA*. 2005;294:3124.
21. **Winck JC, Azevedo LF, Costa-Pereira A, et al.** Efficacy and safety of noninvasive ventilation in the treatment of acute cardiogenic pulmonary edema: a systematic review and meta-analysis. *Crit Care*. 2006;10:R69.
22. **Collins SP, Mielniczuk LM, Whittingham HA, et al.** The use of noninvasive ventilation in emergency department patients with acute cardiogenic pulmonary edema: a systematic review. *Ann Emerg Med*. 2006;48:260.
23. **Gray A, Goodacre S, Newby DE, et al.** Noninvasive ventilation in acute cardiogenic pulmonary edema. *N Engl J Med*. 2008;359: 142.
24. **Weng CL, Zhao YT, Liu QH, et al.** Meta-analysis: noninvasive ventilation in acute cardiogenic pulmonary edema. *Ann Intern Med*. 2010;152:590.
25. **Masip J, Betbesé AJ, Páez J, et al.** Noninvasive pressure support ventilation versus conventional oxygen therapy in acute cardiogenic pulmonary oedema: a randomised trial. *Lancet*. 2000;356: 2126.
26. **Vital FM, Ladeira MT, Atallah AN.** Noninvasive positive pressure ventilation (CPAP or bilevel NPPV) for cardiogenic pulmonary oedema. *Cochrane Database Syst Rev*. 2013;:CD005351.
27. **Nouira S, Boukef R, Bouida W, et al.** Noninvasive pressure support ventilation and CPAP in cardiogenic pulmonary edema: a multicenter randomized study in the emergency department. *Intensive Care Med*. 2011;37:249.
28. **Vidhani K, Kause J, Parr M.** Should we follow ATLS guidelines for the management of traumatic pulmonary contusion: the role of non-invasive ventilatory support. *Resuscitation*. 2002;52(3): 265–268.
29. **Ludwig C, Koryllos A.** Management of chest trauma. *J Thorac Dis*. 2017;9(Suppl 3):S172–S177.
30. **Frat JP, Thille AW, Mercat A, et al.** High-flow oxygen through nasal cannula in acute hypoxemic respiratory failure. *N Engl J Med*. 2015;372:2185.
31. **Slutsky AS, Ranieri VM.** Ventilator-induced lung injury. *N Eeng J Med*. 2013;369(22):2126–2136.

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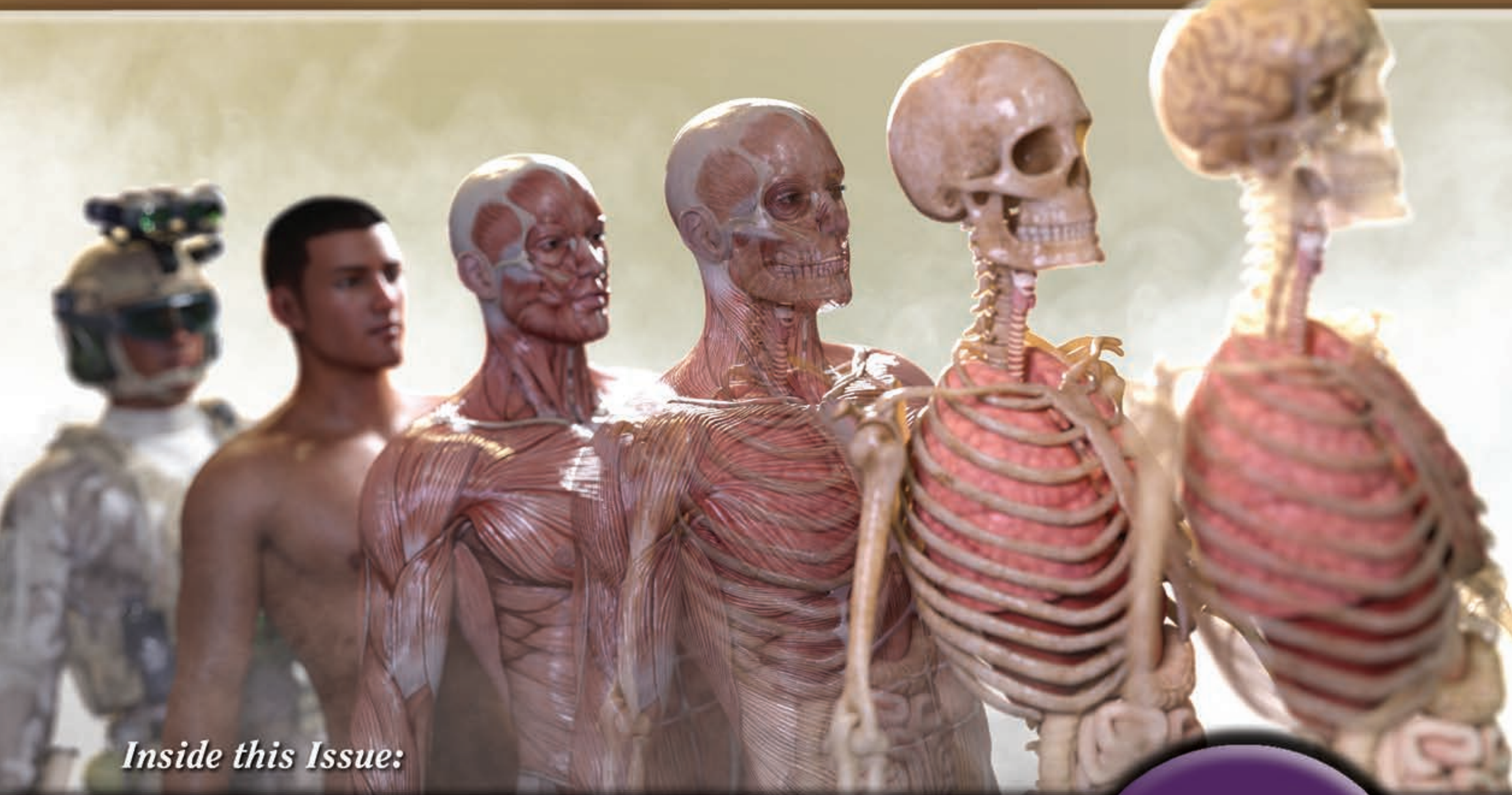

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