

# NONINVASIVE POSITIVE PRESSURE VENTILATION: RESOURCE DOCUMENT FOR THE NATIONAL ASSOCIATION OF EMS PHYSICIANS POSITION STATEMENT

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## ABSTRACT

The National Association of EMS Physicians (NAEMSP) believes that noninvasive positive pressure ventilation (NIPPV) is an important treatment modality for the prehospital management of acute dyspnea. This document serves as a resource to the NAEMSP position on prehospital NIPPV.

**Key words:** NIPPV; dyspnea; EMS; resource

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## INTRODUCTION

Noninvasive positive pressure ventilation (NIPPV) is a form of mechanical ventilatory support delivered through a face or nasal mask, without the use of an endotracheal tube or other invasive airway device.<sup>1</sup> Hospital clinicians commonly use NIPPV to treat acute respiratory failure in patients with intact mental status and airway reflexes. In many cases, NIPPV may obviate the need for endotracheal intubation (ETI) and its associated risks. New portable systems permit NIPPV application in the prehospital setting. This resource document summarizes the rationale for NIPPV use in the prehospital setting.

## NONINVASIVE POSITIVE PRESSURE VENTILATION MECHANISMS

Noninvasive positive pressure ventilation improves pulmonary function through a variety of mechanisms.<sup>1,2</sup> It reduces the work of breathing and improves pulmonary compliance. It recruits atelectatic alveoli, increasing the area available for gas exchange and reducing ventilation–perfusion mismatch. Noninvasive positive pressure ventila-

tion increases hydrostatic pressure, shifting edema fluid into the vascular system. In addition, positive pressure increases intrathoracic pressure, decreasing venous return to the heart, transmural pressure, and afterload. Positive pressure may keep small pliable airways open, decreasing air trapping and facilitating exhalation. Because it matches and enhances the patient's spontaneous respiratory drive, in select patients NIPPV may prove more favorable than ETI and controlled mechanical ventilation.

There are two types of NIPPV: 1) continuous positive airway pressure (CPAP) and 2) bilevel positive airway pressure (BiPAP). Continuous positive airway pressure applies uniform supportive pressure during both inspiratory and expiratory phases. Bilevel positive airway pressure is similar to CPAP but alternates different levels of inspiratory and expiratory pressure. Both CPAP and BiPAP systems typically provide pressure support of 4–20 cmH<sub>2</sub>O.

## RATIONALE FOR PREHOSPITAL NONINVASIVE POSITIVE PRESSURE VENTILATION

Acute dyspnea is a common prehospital emergency potentially resulting from medical conditions such as acute heart failure (pulmonary edema), asthma, chronic obstructive pulmonary disease, or pneumonia. The severity of respiratory distress may range from mild (minimal symptoms requiring no assistance) to severe (apnea or obtundation). Patients with mild dyspnea may respond to simple measures such as supplemental oxygen. Patients with severe dyspnea often require ETI and mechanical ventilation.

The management of a patient with moderate to severe dyspnea presents clinical challenges. These individuals may require ventilatory assistance, yet ETI may prove difficult and risky because of the presence of intact protective airway reflexes.<sup>3</sup> Neuromuscular-blockade-assisted intubation (rapid-sequence intubation) is a viable option, but few emergency medical services (EMS) personnel are trained in these techniques.<sup>4</sup> Many medical directors also do not support sedation-only facilitated intubation of these patients because of the risks of hypotension as well as incomplete airway relaxation.<sup>3</sup>

Noninvasive positive pressure ventilation is a viable prehospital treatment option for patients with moderate to severe dyspnea and early respiratory failure. By reducing the work of breathing, NIPPV may obviate the need for immediate invasive airway

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management. It may also reverse the underlying physiologic processes causing the dyspnea.

## EVIDENCE SUPPORTING NONINVASIVE POSITIVE PRESSURE VENTILATION

### In-Hospital Noninvasive Positive Pressure Ventilation

Most in-hospital NIPPV studies involve small to moderate sized series and generally describe reduced rates of intubation and mortality.<sup>1,5–22</sup> The benefits of in-hospital NIPPV have been confirmed through meta-analyses. In a systematic review and meta-analysis of NIPPV in acute cardiogenic pulmonary edema, Masip et al. found that NIPPV was associated with reduced need for intubation (relative risk [RR] 0.43; 95% confidence interval [CI], 0.32–0.57) and mortality (RR 0.55; 95% CI 0.40–0.78) compared with conventional therapy.<sup>23</sup> In Peter et al.'s meta-analysis of CPAP and BiPAP vs. standard therapy, CPAP was associated with reduced need for mechanical ventilation (RR 0.44; 95% CI 0.29–0.66) and mortality (RR 0.59; 95% CI 0.38–0.90).<sup>8</sup> While BiPAP was not associated with

reduced mortality (RR 0.63; 95% CI 0.37–1.10), it was associated with the reduced need for mechanical ventilation (RR 0.50; 95% CI 0.27–0.90).

### Prehospital Noninvasive Positive Pressure Ventilation

Descriptions of prehospital NIPPV suggest potential clinical benefits for acute dyspnea (Table 1). While many of these studies occurred in Europe, the findings may be applicable to U.S. EMS settings.

Case series verify the feasibility of prehospital NIPPV and indicate relatively low rates of subsequent prehospital or (ED) intubation. Kosowsky et al. studied prehospital CPAP use in a case series of 19 patients in Cincinnati; two patients subsequently underwent ETI in the ED.<sup>24</sup> Templier et al. evaluated CPAP by a French EMS agency for 57 acute dyspnea patients; four subsequently required intubation on scene, and six received intubation within one hour of ED arrival.<sup>25</sup> In a Finnish series, Kallio et al. describe CPAP use in 121 patients; six required subsequent intubation in the field, and six required intubation in the ED.<sup>26</sup> In a French series, Bruge et al. studied prehospital BiPAP use on

TABLE 1. Studies of Prehospital Noninvasive Positive Pressure Ventilation

Reference*	Country	Study Design, Modality, and Sample Size	Primary Findings (ETI, Survival)
Kosowsky et al., 2001 <sup>24</sup>	USA (Cincinnati, OH)	Case series; CPAP (n = 19)	No field ETI; 2 of 19 (10.5%) required ED ETI.
Templier et al., 2003 <sup>25</sup>	France	Case series; CPAP (Boussignac) (n = 57)	Four of 57 required field ETI (7.0%); 6 of 57 (10.5%) received ETI within 1 hour of ED arrival.
Kallio et al., 2003 <sup>26</sup>	Finland	Case series; CPAP (n = 121 in study; n = 116 received CPAP)	Six of 116 (5.2%) required field ETI; 6 of 116 (5.2%) required ED ETI.
Bruge et al., 2008 <sup>27</sup>	Finland	Case series; BiPAP (n = 138)	Eleven of 138 (7%) required field ETI; 24 of 138 (17.4%) required hospital ETI.
Craven et al., 2000 <sup>28</sup>	USA (Norfolk, VA)	Quasi-experimental; 5 EMS units with BiPAP (n = 37), 5 with conventional therapy (n = 25)	Four of 37 (11%) BiPAP vs. 7 of 25 (28%) conventional required field or ED ETI (p = 0.10). No difference in survival (p = 0.37).
Hubble et al., 2006 <sup>29</sup>	USA (North Carolina)	Quasi-experimental; 2 EMS agencies, CPAP (n = 120) vs. conventional therapy (n = 95)	Ten of 120 (8.9%) BiPAP vs. 24 of 95 (25.2%) conventional required field or ED ETI (p = 0.003). Conventional therapy associated with higher mortality (OR: 7.7; 95% CI: 2.0–28.5).
Warner, 2010 <sup>30</sup>	USA (Alabama)	Before–after; conventional therapy (n = 89) vs. CPAP (n = 106; 20 received CPAP)	Seven of 89 (7.9%) required field or ED ETI in “before” period. No field or ED ETI in “after” period. (Survival not reported.)
Plaisance et al., 2007 <sup>31</sup>	France	Randomized controlled trial; early BiPAP only (n = 63) vs. conventional therapy + later BiPAP (n = 61)	Six of 63 (9.5%) early BiPAP vs. 16 of 61 (26.2%) conventional + later BiPAP required field or ED ETI (OR 0.3; 95% CI: 0.09–0.89). Early BiPAP associated with lower mortality (OR: 0.22; 95% CI: 0.03–0.10).
Weitz et al., 2007 <sup>32</sup>	Germany	Randomized controlled trial; BiPAP (n = 10) vs. conventional therapy (n = 13)	ETI rates not reported. No difference in survival (p = 0.9).
Thompson et al., 2008 <sup>34</sup>	Canada (Nova Scotia)	Randomized controlled trial; CPAP (n = 35) vs. conventional therapy (n = 34)	Seven of 35 (20.0%) CPAP vs. 17 of 34 (50.0%) conventional therapy required field or ED ETI (OR 0.3; 95% CI: 0.09–0.89). CPAP associated with lower mortality (OR 0.3; 95% CI: 0.09–0.99).
Schmidbauer et al., 2010 <sup>33</sup>	Germany	Randomized controlled trial; noninvasive ventilation (type not specified; n = 18) vs. conventional therapy (n = 18)	Three of 18 noninvasive ventilation vs. 7 of 18 conventional therapy required field or ED ETI (p = 0.13). All patients survived.

\*For complete reference citations, see the reference list.

BiPAP = bilevel positive airway pressure; CI = confidence interval; CPAP = continuous positive airway pressure; ED = emergency department; EMS = emergency medical services; ETI = endotracheal intubation; OR = odds ratio; USA = United States of America.

138 dyspnea patients; treatment failure, defined as ETI in or out of hospital, occurred in 35 patients.<sup>27</sup>

Comparisons of NIPPV with conventional therapy employ a range of different study designs but generally suggest improved oxygenation and reduced need for prehospital or ED intubation. Craven et al. conducted a nonrandomized study of prehospital BiPAP in Norfolk, Virginia, matching five BiPAP-equipped EMS units with five non-BiPAP units.<sup>28</sup> While the authors observed improvements in oxygen saturation, the intubation rates, lengths of hospital stay, and mortality rates were similar between the groups.

Hubble et al. performed a nonrandomized comparison of acute pulmonary edema management in two North Carolina EMS systems, one equipped with CPAP and the other with conventional therapy.<sup>29</sup> The odds of intubation and mortality were higher for the conventional therapy than with CPAP. There were also appreciable differences in respiratory rate, heart rate, and dyspnea score improvement.

Warner conducted a before–after evaluation of prehospital CPAP for acute dyspnea at a single EMS agency in Alabama.<sup>30</sup> While intubation within 48 hours occurred in four of 89 patients in the before-CPAP period, none required intubation in the after-CPAP period. Hospital and intensive care unit (ICU) length of stay were also lower with CPAP.

Several prospective controlled trials support prehospital NIPPV use. In a controlled trial in France, Plaisance et al. randomized 176 prehospital patients to either early BiPAP only or conventional medical therapy with later BiPAP (after 15 minutes of medical therapy).<sup>31</sup> Prehospital or ED intubation were less frequent in the early-BiPAP group than in the medical-therapy+later-BiPAP group. Mortality rates were similar between the groups.

In a German trial, Weitz et al. compared 10 patients receiving prehospital BiPAP with 13 receiving conventional therapy; oxygenation saturation improved faster with BiPAP.<sup>32</sup> Intubation rates were not reported. In another German trial, Schmidbauer et al. describe successful NIPPV use in 36 prehospital patients, finding improved respiratory rate, level of dyspnea, and length of ICU stay.<sup>33</sup>

In a controlled trial in Nova Scotia, Canada, Thompson et al. randomized 71 acute respiratory failure patients to prehospital CPAP or usual care.<sup>34</sup> Compared with standard therapy, the use of CPAP reduced intubation and mortality. While the authors found no difference in hospital or ICU length of stay, the study was not powered to determine these associations.

Hubble et al. evaluated the cost-effectiveness of prehospital CPAP in acute pulmonary edema.<sup>35</sup> Using data from their 2006 publication, they predicted that four of every 1,000 EMS patients would require CPAP for acute pulmonary edema, resulting in 0.75 lives saved. Accounting for the cost of CPAP equipment,

including the cost of the CPAP-generating system, disposable mask, and tubing for each patient, training of personnel, and oxygen usage, the authors estimated that the cost-benefit of prehospital CPAP was \$490 per life saved. They also predicted that CPAP would reduce hospitalization costs by \$4,075 per year per application.

## RECOMMENDATIONS FOR PREHOSPITAL NONINVASIVE POSITIVE PRESSURE VENTILATION APPLICATION

### Availability

Noninvasive positive pressure ventilation is appropriate for use by advanced-level EMS providers. It may be appropriate for both urban and rural EMS settings.

### Types of Prehospital Noninvasive Positive Pressure Ventilation Systems

Commercially available systems provide portable NIPPV through either a conventional external pressure regulator or a turbulent flow “virtual” valve. Both designs contain key features that may influence system selection and implementation.

Regulator-based portable NIPPV systems generate continuous pressure from oxygen flow, directly controlling inspiratory and expiratory pressure. Regulator-based NIPPV systems allow different inhaled oxygen fractions, reducing oxygen consumption. At 10 cmH<sub>2</sub>O pressure and 100% inspired oxygen (flow rate of 15 L/min), a size D oxygen cylinder will last between 20 and 30 minutes.<sup>36</sup> At 65% inspired oxygen, a size D oxygen cylinder may last approximately 35 minutes. Regulator-based systems are often compatible with end-tidal capnometry and in-line medication nebulizers.

A disadvantage of regulator-based systems is their size; portable NIPPV regulators weigh approximately 3 pounds. Regulator-based systems are also expensive; the regulator costs \$1,000–\$1,500, and each disposable hose circuit costs \$25–\$50. Portable NIPPV systems may not be compatible with hospital wall oxygen outlets. During transition of care to the ED, EMS personnel may need to rely on portable oxygen tanks to maintain NIPPV operation until the availability of hospital NIPPV equipment.

The Boussignac CPAP system uses a different NIPPV approach, accelerating oxygen flow through a series of channels to create turbulence.<sup>37</sup> The turbulence acts as a virtual valve, generating positive airway pressure. The system is lightweight and disposable (single use) and uses a conventional oxygen source and flow regulator. Each disposable circuit costs approximately \$70. On arrival at the ED, EMS personnel may transfer the system to hospital “wall” oxygen, thus minimizing

care transfer delays. A disadvantage of the Boussignac system is its limited maximum positive pressure of 10 cmH<sub>2</sub>O with an oxygen flow of 25 L/min. Consequently, the system requires large quantities of oxygen. For a CPAP pressure of 5.0 cmH<sub>2</sub>O, a size D oxygen cylinder will last approximately 23 minutes. To generate a CPAP pressure of 10 cmH<sub>2</sub>O, a size D cylinder will last 14 minutes.<sup>37</sup>

Select transport ventilators may be designed to provide BiPAP or CPAP. While dependent on the individual brand and model, the process involves placing the ventilator in pressure support mode, setting a desired inspiratory pressure support value, and setting a desired positive end-expiratory pressure (PEEP) value.

## Indications and Contraindications

The general indication for NIPPV is dyspnea accompanied by early respiratory failure in patients with intact protective airway reflexes and mental status. The majority of NIPPV studies have focused on patients with acute pulmonary edema.<sup>6–9, 11, 13–26, 29, 31, 32, 35, 38–41</sup> However, NIPPV may prove useful with other reversible disease processes such as chronic obstructive pulmonary disease or asthma exacerbations.<sup>33, 42, 43</sup> While utilized in in-hospital practice, the role of NIPPV for pneumonia-associated respiratory failure is less clear.<sup>44–49</sup> While some clinicians advocate the use of NIPPV to augment oxygenation prior to ETI in the in-hospital setting, there are no studies evaluating this strategy in the prehospital setting.<sup>50</sup>

Patients with severe respiratory distress may not tolerate NIPPV. Noninvasive positive pressure ventilation may also not be suitable for patients with an absence of a gag reflex or altered mental status. These latter patients may not be able to cooperate with NIPPV and may have increased risks of vomiting and aspiration with ventilatory support. Emergency medical services practitioners may consider ETI for these patients.

The utility of NIPPV in the setting of major trauma is unclear and merits formal evaluation. Invasive airway management of major trauma is difficult, and NIPPV may provide transient ventilatory support in these patients.<sup>51–55</sup> However, potential NIPPV pitfalls in the setting of trauma include the risk of pneumocephalus, subcutaneous emphysema or bacterial meningitis in patients with midface fractures, pneumothorax in thoracic trauma, and increased intrathoracic pressure causing hypotension.<sup>56–58</sup>

## Clinical Application of Prehospital Noninvasive Positive Pressure Ventilation

The technique of NIPPV application may vary with the employed system. Application of the face mask must ensure a tight seal. Facial hair may require trimming to achieve a tight seal. An adequate mask seal may not be

possible with edentulous patients or individuals with facial abnormalities.

Continuous positive airway pressure systems have a single pressure setting for both inspiration and expiration. A typical initial setting is 5 cmH<sub>2</sub>O, with pressure adjustments every few minutes in response to the patient's subjective and objective work of breathing, respiratory rate, and oxygen saturation. The typical range of pressure settings is 5–20 cmH<sub>2</sub>O. Bilevel positive airway pressure is similar to CPAP, but alternates a higher inspiratory pressure with a lower expiratory pressure. Typical initial settings include an inspiratory pressure of 10 cmH<sub>2</sub>O and an expiratory pressure of 5 cmH<sub>2</sub>O, with subsequent adjustments according to patient response.

Hospital clinicians commonly administer rescue medications during BiPAP therapy. When appropriate and available, EMS personnel may complement NIPPV with concurrent drug therapies specified by local protocols, for example, furosemide, nitroglycerin, and albuterol nebulizer treatments.

If a patient cannot tolerate or does not respond to NIPPV, EMS personnel should apply a non-rebreather mask with 100% oxygen or perform ETI.

## Monitoring Response to Noninvasive Positive Pressure Ventilation

There are currently no validated guidelines for titrating NIPPV therapy in response to specific signs or symptoms. Emergency medical services personnel may use physiologic (vital signs) and subjective measures to monitor clinical response to NIPPV. Potential measures for monitoring NIPPV response include the following:

- **Respiratory rate:** A reduction in respiratory rate (and effort) may indicate clinical response to NIPPV.
- **Heart rate:** Improvement in ventilation and perfusion with NIPPV may reduce the heart rate. However, the heart rate may also increase in response to increased intrathoracic pressure and decreased venous return.
- **Systolic blood pressure:** The increase in intrathoracic pressure from NIPPV may decrease venous return to the heart, leading to a decrease in blood pressure. The development of hypotension (systolic blood pressure <100 mmHg) or hypoperfusion (cyanosis, decreased capillary refill) may indicate the need for reduced NIPPV support.
- **Oxygen saturation:** Oxygen saturation may improve with application of NIPPV.
- **End-tidal capnography:** Some practitioners use end-tidal carbon dioxide (ETCO<sub>2</sub>) monitoring to gauge NIPPV response.<sup>59</sup> Upon initial application of NIPPV, ETCO<sub>2</sub> may increase from improvement in ventilation-perfusion mismatch. Decreasing

ETCO<sub>2</sub> may reflect respiratory improvement from NIPPV.

- **Subjective dyspnea:** Subjective dyspnea scores such as the Borg score or visual analog scale score may prove helpful for gauging NIPPV response.<sup>60</sup> In a hospital evaluation of CPAP for pulmonary edema, Plaisance et al. described the use of a dyspnea clinical score, incorporating ratings of patient subjective dyspnea, auscultation intensity, cyanosis, and accessory respiratory muscle use.<sup>31</sup> These measures have not been quantitatively or logistically validated in the prehospital setting.

Emergency medical services personnel should monitor for NIPPV adverse events, such as pneumothorax, gastric distention, vomiting, worsening of respiratory distress, and patient intolerance. These events may indicate the need for alternate dyspnea management strategies.

### Coordination of Noninvasive Positive Pressure Ventilation Care with the Receiving Emergency Department

A patient initiated on prehospital NIPPV will likely require continuation of the therapy on ED arrival. Providers should provide advanced notification to receiving EDs to facilitate early ED NIPPV preparation. As described previously, prehospital NIPPV systems may not be compatible with ED oxygen delivery systems. The EMS providers may need to continue NIPPV use with portable oxygen cylinders until the ED NIPPV system is ready for application.

### TRAINING IN NONINVASIVE POSITIVE PRESSURE VENTILATION APPLICATION

The application of NIPPV requires appropriate training in the technique and concurrent patient management. Key elements of training should cover:

- Pathophysiology of acute dyspnea
- Physiology of NIPPV systems
- Description of CPAP and BiPAP mechanics, with focus on the systems available to the individual EMS agency
- Indications and contraindications for NIPPV
- Initiation and titration of NIPPV therapy
- Titration of concurrent pharmacologic therapy
- Management of adverse events
- Transition of care at the receiving hospital
- Alternate care strategies

### QUALITY ASSURANCE AND IMPROVEMENT

Emergency medical services agencies should collect clinical data to verify the safety and appropriate use

of NIPPV. Basic data elements may include patient age, past medical history (e.g., renal failure, congestive heart failure, asthma, chronic obstructive pulmonary disease), indications, vital signs, oxygen saturation, and level of respiratory distress. The EMS personnel should measure and document vital signs and respiratory distress on a frequent basis to gauge the patient's clinical response to NIPPV. Practitioners should document adverse events such as vomiting, hypotension, and cardiac arrest. The EMS personnel should report if the patient required prehospital or ED intubation.

The connections between prehospital NIPPV and mortality or hospital length of stay are difficult to establish in small series without risk adjustment. These outcomes may be less useful for quality assurance purposes.

### FUTURE DIRECTIONS

Some systems propose the use of NIPPV by basic life support (BLS) providers. There are currently no formal reports of BLS NIPPV application. This area requires additional study.

While in-hospital evaluations suggest potential NIPPV benefit in children with respiratory distress, there have been few formal evaluations in this population.<sup>61–63</sup>

### CONCLUSION

Noninvasive positive pressure ventilation is a viable prehospital therapeutic option for acute dyspnea. Emergency medical services agencies should select NIPPV systems and develop dyspnea care protocols suited to their patient population, clinical capabilities, and receiving ED resources.

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