

Continuous Positive Airway Pressure Ventilation in Prehospital Settings

Summary

Alba Marin, MD | O-Two Clinical Specialist

Acute respiratory failure is a common life-threatening medical emergency. Non-invasive positive pressure ventilation provides respiratory support through a tight-fitting mask usually applied around the patient's mouth and nose. It is used in the emergency department (ED), but it is more effective if the ventilatory support is initiated by emergency medical services during transport. For more than two decades, prehospital continuous positive airway pressure (CPAP) ventilation has been evaluated around the world, these trials were small and the findings were not consistent. However, in recent years, large controlled randomized trials have shown that the use of CPAP, by appropriately trained EMS, is effective in reducing respiratory symptoms in patients with acute respiratory distress. In general, studies showed that prehospital CPAP is a cost-effective coadjutant treatment that improves physiologic parameters, and reduces endotracheal intubation and mortality rates. Implementing CPAP as a prehospital support requires additional training and equipment for paramedics, but patients' clinical outcomes outweigh training costs, by reducing significantly hospital admissions and shortening times in the ED.

In-hospital acute pulmonary edema

Acute cardiogenic pulmonary edema is a common cause of respiratory distress in patients presenting to the emergency department (ED). Patients with less severe symptoms of acute heart failure may respond to conventional treatment with oxygen, diuretics, and vasodilators^{1,2}. However, patients with severe respiratory compromise may require endotracheal intubation and mechanical ventilation. Invasive ventilatory support has been associated with significant morbidity, such as nosocomial pneumonia, increased need for sedation, and thus longer duration of ventilation^{1,3}.

Since 1998, there have been several studies comparing **noninvasive positive pressure ventilation** (NIPPV) in addition to standard medical therapy versus standard medical therapy alone in an attempt to clarify the role of noninvasive ventilation in cardiogenic pulmonary edema. These trials suggested a decreased rate of intubation with NIPPV compared with standard medical therapy only^{1,2}.

It can be estimated that *early* application of noninvasive ventilation in the ED can decrease the relative risk of mortality by 39% and the necessity of endotracheal intubation by 57%⁴. Collings *et al.* suggest that noninvasive ventilation with standard medical therapy is advantageous over standard medical therapy alone in ED patients with acute cardiogenic pulmonary edema¹.

NIPPV should be the first option for ventilatory support for patients with either a severe exacerbation of chronic obstructive pulmonary disease or cardiogenic pulmonary edema in ED⁵. In-hospital noninvasive ventilation such as **continuous positive airway pressure** (CPAP) safely provides earlier improvement and resolution of dyspnea, respiratory distress, and metabolic abnormalities than does standard oxygen therapy^{1,3,6}. Therefore, CPAP should be considered as adjunctive therapy in patients with acute cardiogenic pulmonary edema who have severe respiratory distress or whose condition does not improve with pharmacologic therapy^{3,6}.

Acute pulmonary edema in prehospital settings

Complaints of respiratory distress place a significant burden on already strained health care systems. Recent estimates place the annual cost of hospitalizations due to acute decompensated heart failure² and exacerbation of chronic obstructive pulmonary disease in excess of \$18 and \$20 billion, respectively. Intensive care unit admission is the basis of the majority of these costs. Within **emergency medical services** (EMS) systems, complaints of respiratory distress account for 13% of total EMS response calls⁷.

In the United States, approximately 1 million patients per year are treated by paramedics for acute congestive heart failure. The associated morbidity and mortality are significant, as is the overall cost on the health care system^{8,9}. The most optimal **prehospital management protocol** of these patients remains a work in progress; historically, EMS would center the acute pulmonary edema treatment on the use of oxygen, nitrates, diuretics, and morphine.

Nevertheless, patients with severe symptoms whose respiratory efforts are failing are in need of some degree of **immediate ventilatory support**⁹. The aim of prehospital care is to stabilize patients as quickly as possible without endangering them through the measures performed in this context. Patients with acute pulmonary edema usually receive positive-pressure ventilation by bag-valve-masks or tracheal intubation in the out-of-hospital setting before their arrival at the ED¹⁰. Out-of-hospital intubation attempts in non-cardiac arrest patients are less successful and have higher rates of serious complications such as aspiration of gastric contents, hypoxia, failed intubation, hypotension, or circulatory arrest^{9,10}, than those performed in the ED. For EMS it is therefore particularly important to have strategies for

circumventing these risks, if possible. In addition, patients arriving at the ED already intubated may be more likely to remain so, thus exposing them to the risk of hospital-acquired pneumonia while being mechanically ventilated in the ICU, potentially doubling their mortality risk¹⁰.

Prehospital CPAP in acute pulmonary edema

In 2001, Kosowsky *et al.*⁶ described initial experiences with the **prehospital use of CPAP** for patients with respiratory failure and presumed pulmonary edema. The authors reported a preliminary case series and explained that although the decision to use CPAP is dependent on a variety of factors, the presumption is that the *earlier* therapy is instituted, the *greater* the likelihood of averting endotracheal intubation. Early NIPPV before arrival at the ED **does improve acute symptoms** in patients with acute cardiogenic pulmonary edema predominantly in regard to decreases in patient-reported dyspnea and improvements in vital signs^{11,12}.

Years later, in 2006, Hubble *et al.*¹³ found substantial differences in outcomes when comparing CPAP and conventional therapy in the management of prehospital acute pulmonary edema. Patients treated with CPAP had reduced mortality and a lower rate of endotracheal intubation^{2,8,9,12-14,16-18}. Furthermore, when compared with patients treated only with standard medical therapy, CPAP patients showed a greater degree of improvement in most physiologic variables, including dyspnea score^{7,11,13,20}. With the use of CPAP, **patients improved more quickly** and allowed less admissions and shorter times in the ED²². Also, prehospital CPAP appears to be a cost-effective treatment; the cost per additional life saved is minimal, while the cost savings realized through reducing the need for intubation and mechanical ventilation are substantial²¹.

A decade after, Brusasco *et al.*²³ showed that NIPPV reduces the need for endotracheal intubation, the occurrence of nosocomial infections, and both morbidity and mortality associated with respiratory failure. The **benefits of NIPPV are greater if started early**, thus constituting the rationale for the increasing use of NIPPV in prehospital and emergency department settings. Moreover, immediate use of CPAP in out-of-hospital treatment of acute pulmonary edema and until the condition resolves after admission significantly improves early outcome compared with medical treatment alone^{7,16,24}. Modern systems for delivering CPAP are compact, affordable and simple to operate, making the prehospital use of CPAP conceivable^{6,11,25}.

For patients with acute respiratory failure and presumed pulmonary edema, the prehospital use of CPAP is feasible, beneficial, and may avert the need for invasive ventilation^{1,6,9,13,22}. Most prehospital CPAP are oxygen-driven and deliver a variable concentration of supplemental inspired oxygen titrated upon patient's SpO₂. With concerns about the use of high oxygen concentration and detrimental effects of hyperoxygenation, Bledsoe *et al.*¹¹ studied the effect of prehospital low-fractional oxygen delivery CPAP. The authors concluded that low-fractional oxygen is highly effective, it improves patients' symptoms, respiratory rate and SpO₂^{6,8}. It is important to highlight that current disposable CPAP open-systems use low flow and access to ambient air to achieve oxygen concentrations lower than 100%, as an example 54% at 10 cmH₂O, as the O-Two Single Use CPAP²⁶.

Even though results may vary depending on the healthcare context, EMS team and specific regional protocols²⁷⁻²⁹, paramedics can be trained to use CPAP for patients in severe respiratory failure⁹. There is an absolute **reduction in tracheal intubation** rate of 30%²⁵

and an absolute reduction in **mortality** of 21% in appropriately selected out-of-hospital patients who receive CPAP instead of usual medical care⁹.

Emergency medical services systems should consider making CPAP available as part of the treatment for out-of-hospital severe respiratory distress patients⁹. The effectiveness of a basic affordable device on a respiratory disorder and its associated outcomes makes the use of prehospital CPAP plausible and beneficial²⁵. All paramedic/EMS should receive appropriate training²⁰, and several studies found no significant difference in the compliant use of prehospital CPAP between paramedics trained to primary care paramedic (PCP) level and those trained to the advanced care paramedic level^{20,30}, these results suggest that CPAP use by PCP-level paramedics may be feasible and safe²⁰.

In 2021, Finn *et al.*³¹ conducted a large prehospital randomized controlled trial which showed that the use of CPAP by EMS paramedics was more effective than usual care in reducing dyspnea and tachypnea in patients with acute respiratory distress, with no increased risk of adverse outcomes. The authors concluded that **CPAP is a safe and effective prehospital intervention** for symptom management in patients with acute respiratory distress. They recommend CPAP to be included as an option for managing dyspnea in selected patients in the clinical practice guidelines of EMS.

In conclusion, implementing prehospital CPAP support ventilation in patients suffering from acute pulmonary edema will improve their clinical condition more quickly, reduce hospital admissions and shorter times in the ED. Most of the studies point towards an absolute reduction of endotracheal intubation and mortality rates as well.

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O-Two Medical Technologies Inc.

45A Armthorpe Road,
Brampton, ON, Canada L6T 5M4
Toll Free: (800) 387 3405
Tel: (905) 792 OTWO (6896)
Fax: (905) 799 1339
Emails: resuscitation@otwo.com
clinical@otwo.com
Website: www.otwo.com