Role of Noninvasive Ventilation in the Management of Acutely Decompensated Heart Failure

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Over the past decade, there have been a number of studies of the use of noninvasive ventilation (NIV) in patients with respiratory failure, including that associated with acute congestive heart failure (CHF). Many of these studies have focused on using NIV in an effort to avoid endotracheal intubation, with its associated complications and costs. Most studies have been small, retrospective, and not well focused on the CHF population. As a result, clinical use of NIV in a setting of severe CHF has been controversial and recommendations mixed; however, most studies support a beneficial role for NIV in patients with acute cardiogenic pulmonary edema. Its use is associated with lower endotracheal intubation rates and possibly lower mortality. This article describes two NIV modalities, continuous positive airway pressure (CPAP) and bi-level positive airway pressure (BLPAP), and compares their efficacy. Though BLPAP has theoretical advantages over CPAP, there are questions regarding its safety in a setting of CHF. The key to success in using NIV to treat severe CHF is proper patient selection, close patient monitoring, proper application of the technology, and objective therapeutic goals. When used appropriately, NIV can be a useful adjunct in the treatment of a subset of patients with acute CHF at risk for endotracheal intubation.

[Rev Cardiovasc Med. *2002;3(suppl 4):S35–S40*]

Key words: Pulmonary edema • Congestive heart failure • Noninvasive ventilation • Continuous positive airway pressure • Bi-level positive airway pressure • Endotracheal intubation

The earliest efforts to employ noninvasive ventilation (NIV) or pressure support in acute-care medicine utilized intermittent positive pressure breathing (IPPB) via facemask or mouth piece.[1] With IPPB, a pressure-cycled ventilator would deliver positive pressure flow, triggered by patient inspiratory efforts. It was typically used to deliver bronchodilator treatments to patients with acute exacerbations of asthma or chronic obstructive pulmonary disease (COPD).[2] It was suggested that IPPB pressure drove the aerosol particles deeper into the distal airways, that IPPB decreased the work of breathing, and that it had an overall beneficial effect on respiratory mechanics.[3] There were also, however, occasional reports of IPPB treatment causing decreased cardiac output and barotraumas.[3] Most importantly, there was a lack of proven efficacy.[4]

More recently, the use of continuous positive airway pressure (CPAP) in asthma and other respiratory disorders has been reported. CPAP provides a constant "background" of positive pressure, beyond which the pressure in the patient's upper airway is not allowed to drop. It applies the same pressure during inspiration and expiration. Theoretically, CPAP improves oxygenation by increasing the functional residual capacity and lung compliance.[5] CPAP can be applied noninvasively via specially fitted nasal or facial masks. As with IPPB, concerns have been raised that CPAP could decrease venous return and thereby decrease cardiac output[5]; however, there also is some evidence that CPAP supplies some of the inflating pressure needed during inspiration, potentially "off-loading" the inspiratory muscles and reducing fatigue.[6] Evaluation of a simple, positive expiratory pressure device, which provided no inspiratory flow pressure, showed no benefit in asthma.[7] This further suggested that CPAP assisted inspiratory muscles and lessened fatigue.

A recently developed NIV modality is that of bi-level positive airway pressure (BLPAP), which is essentially a combination of CPAP and IPPB.[8] It provides two different levels of noninvasive positive airway pressure. Higher airway pressures are applied during inspiration and lower during expiration, but BLPAP always applies some positive pressure. In addition, the higher positive inspiratory support is generally applied for a longer duration than was true with IPPB. (Note that the term "BiPAP," which is commonly used for this modality, is actually a proprietary term for the BLPAP device manufactured by one company [Respironics, Inc, Murraysville, PA].) A number of studies have demonstrated beneficial effects of BLPAP in acute asthma.[9–11] Most importantly, these studies have demonstrated a decrease in intubation rates with the use of BLPAP.[10] Similar benefits have been demonstrated in patients with severe pneumonia.[11]

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In the past with CPAP, facial skin necrosis with prolonged use was considered a problem; however, with soft mask cushions and stoma paste, this is no longer a problem. BLPAP can also be applied nasally, with a specially configured, smaller mask. This improves patient comfort and allows greater ease of access for clearing airway secretions. CPAP requires a very cooperative patient and loses much of its effectiveness whenever a significant mask leak is present. BLPAP, however, is more leak tolerant and therefore can be used in less cooperative patients with better results and for longer periods of time. With all NIV modalities, the patient controls the tidal volume and breathing frequency; however, newer BLPAP delivery devices have highly sensitive, flow-triggered inspiratory valves that reduce both the patient effort and the time from breath initiation to the delivery of assistance.[12]

Use of NIV has both advantages and disadvantages, which are summarized in Table 1. The most important

Table 1
Advantages and Disadvantages of Noninvasive Inhalation

Advantages

- Decreases the work of breathing
- Increases functional residual capacity
- Improves gas exchange
- Improves general pulmonary function
- Reduces venous return to the heart (may be a disadvantage in a setting of hypotension)
- Avoids intubation complications and costs
- Decreased mortality in properly selected patients

Disadvantages

- Patient discomfort
- Facial skin necrosis
- Increased aspiration risk
- Reduces venous return to the heart (may be an advantage in volume overload)

clinical question is whether NIV can replace conventional mechanical ventilation and decrease mortality in selected patients with acute respiratory failure from acutely decompensated congestive heart failure (CHF). When endotracheal intubation is clearly indicated, it certainly should not be delayed; however, endotracheal intubation of such patients can be fraught with increased risks—and certainly increased expense—both in the emergency department (ED) and in the intensive care unit.[13] The results of several studies indicated that NIV does indeed decrease the need for endotracheal intubation in patients with acute respiratory failure.[8,14,15] A recent meta-analysis concluded that, compared with standard treatment, NIV was associated with an 8% reduction in mortality, a 19% reduction in the need for mechanical ventilation, and a shorter hospital stay (by 2.74 days).[16] The greatest benefits were seen in patients with COPD exacerbations; however, there was evidence of benefit across the full spectrum of patients with acute respiratory failure, including CHF. This was particularly true of patients in whom hypercapnia was present.[14]

One randomized clinical trial was particularly impressive: in the CPAP-treated group, the intubation rate was only 5%, versus 33% for those on standard therapy.

NIV Use in Cardiogenic Pulmonary Edema

The majority of patients with cardiogenic pulmonary edema can be stabilized and managed in the ED with conventional pharmacologic therapy and supplemental oxygen; however, a minority will have more severe symptoms that require the consideration of assisted ventilation. Many of the studies of NIV included patients with acute pulmonary edema, and some investigations focused specifically on that population.[17–20] Overall, the studies support a useful role for NIV in the management of these patients, but evidence may favor CPAP over BLPAP.

In one randomized trial comparing treatment with CPAP to standard therapy, CPAP was associated with more rapid improvement in oxygenation, more rapid and profound decrease in the $PaCO_2$, and greater improvements in the respiratory rate, heart rate, and blood pressure. Also, the rate of endotracheal intubation was 50% lower in the CPAP group.[17] A second study demonstrated that patients receiving CPAP (compared to controls) had improved alveolar–arterial oxygen gradients and increased stroke volume, as well as an improvement in PaO_2. The intubation rate was also decreased by more than 50%.[18] The sample size was not sufficient to demonstrate a decrease in mortality. A more recent randomized clinical trial was particularly impressive. In the CPAP-treated group, the intubation rate was only 5%, versus 33% for those on standard therapy.[21] When high-quality, randomized clinical trials were pooled in a meta-analysis, treatment with CPAP was associated with a 26% lower intubation rate.[22] Greatest benefits were seen in patients with the most severe respiratory failure.

It also appears that CPAP is safe and effective in patients with pulmonary edema associated with acute myocardial infarction (AMI). A randomized trial of nasal CPAP in 22 patients with CHF and AMI showed improvements in oxygenation and hemodynamics. In addition, patients treated with nasal CPAP, as opposed to standard oxygen masks, had significantly lower in-hospital intubation rates (18% vs 73%) and mortality rates (9% vs 64%).[23]

BLPAP is more leak tolerant and can be used in less cooperative patients with better results and for longer periods of time.

As already described, BLPAP has some theoretical advantages over CPAP; however, nonrandomized comparisons have not demonstrated any such benefit in CHF patients.[24] There is even some evidence of a possible negative effect of BLPAP in acute CHF.[19] In one study, a post hoc subgroup analysis showed that BLPAP was associated with increased mortality in the group of patients with acute CHF.[19] Although this was a small study, not focused on the CHF population, it is supported by observations in other studies. A prospective trial of 40 patients with acute pulmonary edema randomized patients to either standard therapy and high-dose nitrates or standard-dose nitrates and BLPAP. The study had to be prematurely terminated because of evidence of harm in the BLPAP arm.[20] Another relatively small trial randomized patients with acute CHF to either CPAP or BLPAP. Though patients receiving BLPAP showed more improvement in some physiological parameters, the trial was terminated early because of a much higher myocardial infarction rate in patients treated with BLPAP (71% vs

Table 2
Indications and Contraindications for Noninvasive Ventilation

Indications

- Inadequate response to initial standard therapy
- At risk for endotracheal intubation
- Respiratory rate ≥ 30
- 0_2 saturation ≤ 90% on 4 L/min oxygen
- Mild hypercapnia
- Sense of respiratory muscle fatigue

Contraindications

- Apnea
- Hemodynamic instability
- Inability to protect the airway
- Abnormal facial anatomy
- Uncontrollable vomiting
- Altered mental status or uncooperative
- Inability to tolerate the mask

38%).[25] It was speculated that the BLPAP may have been associated with higher intrathoracic pressures and that this may have decreased myocardial perfusion either directly or indirectly. The study had multiple methodological problems, however, which may invalidate the results. Smaller studies and case series have not demonstrated problems with BLPAP in acute CHF; however, because safety has not been definitely demonstrated with BLPAP, CPAP may be a better NIV modality choice in acute pulmonary edema. Larger comparative clinical trials are needed to answer these questions.

There is sufficient evidence to conclude that NIV significantly decreases the need for endotracheal intubation in CHF patients with acute respiratory failure. Avoiding the associated complications and additional costs of endotracheal intubation is a worthy goal; however, not all patients with respiratory failure and acute CHF are appropriate candidates. Patients with mild or moderate CHF exacerbations that can be managed with standard care do not appear to benefit from NIV. In addition, patients with hemodynamic instability or florid cardiogenic shock are generally better managed more aggressively, including with endotracheal intubation. At the very least, the safety of NIV for such critically ill patients has not been demonstrated. The best candidates for NIV are those patients who are able to cooperate, who are at risk for intubation, and in whom clinical circumstances would normally predict a relatively brief period of ventilatory support. Patients who are obtunded, uncooperative, or otherwise unable to protect their airway are better managed by conventional endotracheal intubation. For such patients, NIV may only delay the use of more aggressive management and increase the risk of complications such as aspiration and AMI. Important criteria for the selection of appropriate patients are summarized in Table 2.

How to Use NIV

When considering NIV, thought should be given to the expertise and availability of the support staff, especially during the initial hours when the patient may be less stable. There is evidence that NIV demands more time of the health care professional; it is usually best performed

Table 3
Noninvasive Ventilation Settings

Continuous Positive Airway Pressure

- Start with 5 cm H_20
- Increase in increments of 2 cm H_20, as tolerated and indicated

Bi-Level Positive Airway Pressure

- Initial inspiratory pressure of 8–10 cm H_20
- Initial expiratory pressure of 2–4 cm H_20
- Increase in increments of 2–4 cm H_20
- Maximum inspiratory pressure is 24 cm H_20 and expiratory pressure 20 cm H_20

Noninvasive Pressure Support Ventilation

- Pressure support of 8–10 cm H_20 and positive end expiratory pressure of 2–4 cm H_20
- Adjust as for bi-level positive airway pressure

by a respiratory therapist who is dedicated to the patient until such time as they are stablized.[12]

Recommended pressure settings for NIV have not yet been standardized; however, most studies have used similar approaches. These are summarized in Table 3. The first decision involves the type of machinery (ventilator) that is available and its capabilities. A decision must be made whether to use CPAP, BLPAP, or a conventional ventilator with pressure support ventilation settings. As already mentioned, it has not been proven that BLPAP is less safe than CPAP in patients with acute severe CHF, but concerns have been raised. Therefore, many practioners start with CPAP. However, if the patient is already hypercapnic, BLPAP probably has advantages over CPAP based on experiences in patients with obstructive airways disease.

If CPAP is used, it is usually started with low pressures (such as 5 cm H_20). If needed to achieve therapeutic goals, increases are then generally in increments of 2 cm H_20, as tolerated by the patient. The target goal of therapy is a respiratory rate < 25 and oxygen saturation > 90%, with hemodynamic stability; however, patient comfort or preference may be just as important an outcome measure. In those settings in which the measurement is available, an exhaled tidal volume > 5–7 mL/kg is a desirable target endpoint.[16]

With BLPAP, the inspiratory pressures (IPAP) must be set separately from the expiratory pressures (EPAP). Generally, the IPAP settings start at 8–10 cm H_20, and can range from 4 to 24 cm H_20. The EPAP settings typically start at 2–4 cm H_20, and range from 2 to 20 cm H_20. These initial settings are designed to optimize patient tolerance and provide a stabilization or training period. Whenever using BLPAP, it is important that the IPAP always be maintained higher than the EPAP to ensure a bi-level flow pattern.

Because safety has not been definitely demonstrated with BLPAP, CPAP may be a better NIV modality choice in acute pulmonary edema.

Not all institutions have the ready availability of machines to perform CPAP or BLPAP, but recent-generation ventilators that include the options of positive end expiratory pressure (PEEP) and pressure support ventilation are commonly available. Using these two modalities, connected to a CPAP-type facial mask, it is possible to achieve the same pressure and flow patterns as BLPAP. With such a machine, the initial "pressure support" ventilation is generally set at 8–10 cm H_20, combined with a PEEP setting of 2–4 cm H_20, which mirror settings described above for BLPAP.

Regardless of the NIV ventilatory mode selected, it is critically important to closely monitor these patients during the initial hours of therapy. Because of the nature of the mask that is used in NIV, patients are at greater risk of aspiration than is true for the usual oxygen masks. Also, these are critically ill patients who are at relatively high risk for sudden deterioration requiring intubation or other resuscitative measures.

Discontinuing NIV generally requires a "weaning" period. During this time, close observation of the patient is essential. Indications for weaning the NIV include general patient stability, consistent oxygenation > 90%–92% with 4 L/minute (or less) of supplemental oxygen, and a respiratory rate < 25. The weaning process of decreasing the pressure settings should generally parallel the process by which pressures were increased: if several increments of increase were used, the reverse should hold true for the weaning process. Consider resuming or

Main Points

- Noninvasive ventilation (NIV) has the advantage of avoiding many of the risks and the additional costs associated with conventional intubation.
- Not all NIV is the same. Continuous positive airway pressure (CPAP) provides a constant and consistent positive airway pressure throughout the entire respiratory cycle. Bi-level positive airway pressure (BLPAP) provides a higher inhalation pressure and a lower exhalation pressure.
- NIV should not yet be considered the "standard of care" for the treatment of acute congestive heart failure (CHF); however, CPAP has been shown to be safe and probably effective. BLPAP has not yet been proven to be as safe, and it requires additional study.
- The key to success in using NIV in an acute setting of CHF is proper patient selection and close monitoring of the patient until stabilized.

increasing the NIV if the respiratory rate increases to >30, oxygen saturation drops below 90% (despite 4 L/minute of oxygen), or if the $PaCO_2$ increases by at least 5 mm Hg. Sudden or severe deteriorations warrant consideration of conventional intubation techniques and mechanical ventilation.

In summary, NIV has been shown to be of benefit to some acute CHF patients with pulmonary edema. It decreases the need for endotracheal intubation in those with the most severe symptoms. There may be some advantage to the use of CPAP rather than BLPAP. Close monitoring and proper patient selection are essential. ■

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