Use of a Ventilatory Support System (BiPAP) for Acute Respiratory Failure in the Emergency Department

Janet M. Poponick, Jeffrey P. Renston, Richard P. Bennett and Charles L. Emerman

_Chest_ 1999;116;166-171
DOI 10.1378/chest.116.1.166

The online version of this article, along with updated information and services can be found online on the World Wide Web at: http://chestjournal.chestpubs.org/content/116/1/166.full.html
Study objectives: Bilevel pressure ventilation has had proven success in the treatment of acute respiratory failure (ARF). The purpose of this study was to identify patient characteristics early in the course of acute illness that can predict the successful use of bilevel pressure ventilation.

Methods: Ventilatory assistance using a ventilatory support system (BiPAP model ST-D; Respironics; Murrysville, PA) was considered a treatment option for stable patients with ARF. The system was titrated to patient comfort. Once stable settings had been achieved for 30 min, a posttrial arterial blood gas (ABG) measurement was obtained. Patient charts were reviewed for pretrial and posttrial ABG levels, along with demographics, APACHE (acute physiology and chronic health evaluation) II score, Glasgow Coma Scale (GCS), and length of stay (LOS) data.

Results: Bilevel pressure ventilation trials were performed on 58 patients. In 43 patients (74.1%), the trials were successful. Of the 15 patients (25.9%) in whom the trials were not successful, 13 patients required intubation. The pretrial ABG levels did not predict success, as there were no significant differences between the success and failure groups for pH and Paco2, respectively: 7.26 vs 7.26 mm Hg and 75.3 vs 72.8 mm Hg. After 30 min, posttrial ABG levels for pH and Paco2 predicted successful avoidance of intubation: 7.34 vs 7.27 mm Hg (p < 0.002) and 61.9 vs 73.0 mm Hg (p < 0.04), respectively. There were no significant differences between the success and failure groups in age, gender, GCS, or APACHE II. There were differences between the success and failure groups for LOS data (ventilator days, ICU days, and hospital days): 1.8 vs 10.4 days (p < 0.01), 4.2 vs 12.3 days (p < 0.02), and 7.5 vs 15.6 days (p < 0.02), respectively.

Conclusion: Successful treatment with bilevel pressure ventilation could not be predicted by pretrial data (including pH and Paco2) obtained in the emergency department; however, a successful outcome could be determined quickly with a 30-min trial. Successful treatment with bilevel pressure ventilation significantly reduced LOS data.

Clinical implications: Our inability to predict success based on initial data supports the use of bilevel pressure ventilation trials for all stable patients with ARF. If the patient’s condition fails to improve within 30 min, intubation and mechanical ventilation is indicated.

Key words: acute respiratory failure; bilevel pressure ventilation; BiPAP; noninvasive positive pressure ventilation

Abbreviations: ABG = arterial blood gas; APACHE = acute physiology and chronic health evaluation; ARF = acute respiratory failure; CHF = congestive heart failure; CPAP = continuous positive airway pressure; ED = emergency department; EMG di = diaphragm electromyogram; IPAP = inspiratory positive airway pressure; EPAP = expiratory positive airway pressure; GCS = Glasgow Coma Scale; LOS = length of stay; PEEP = positive end-expiratory pressure; PSV = pressure support ventilation; Vt = tidal volume

Patients presenting with acute respiratory failure (ARF) frequently require some form of assisted ventilation. In the past, intubation and mechanical ventilation were the treatments of choice. However, complications such as nosocomial pneumonia and barotrauma have been noted in patients requiring traditional intervention.1,2 Noninvasive methods of ventilatory assistance have become a popular alternative to intubation and mechanical ventilation in selected patients with ARF.3 Noninvasive ventilation
can provide adequate ventilatory support while conventional medical therapy (bronchodilators, diuretics, and oxygen) is being instituted.\textsuperscript{3–5}

Noninvasive ventilation using bilevel pressure ventilation via nasal mask or full face mask has been shown to improve arterial blood gas (ABG) data, decrease hospital length of stay (LOS) and complication rates, and improve patient survival.\textsuperscript{3–5} A number of studies support the use of bilevel pressure ventilation in patients with ARF.\textsuperscript{6–8}

Recently, with the intent of decreasing hospital LOS and improving patient outcome,\textsuperscript{8,9} we implemented a bilevel pressure ventilation protocol for use in emergency department (ED) patients with impending respiratory failure. However, little data existed to aid us in selecting the patients who would benefit from noninvasive mechanical ventilation, or in determining the duration of this treatment prior to intubation. The purpose of this study was to identify patient characteristics that could predict a successful outcome following a trial of bilevel pressure ventilation.

**Materials and Methods**

This study was conducted in the ED of MetroHealth Medical Center, a large, urban, county-owned institution. All patients who presented with dyspnea were given standard medical therapy, including aerosolized 8-agonist medications every 20 min and IV steroids for patients with obstructive lung disease. The patients with pulmonary edema received diuretics and afterload reduction. An ABG measurement was obtained on all patients following the initial medical therapy. Bilevel pressure ventilation was offered to patients in ARF who were unresponsive to the initial medical therapy (Table 1). Patients were excluded from the trials if they were obtunded, uncooperative, or combative; lacked a gag reflex; or were in hemodynamically unstable condition. The hospital charts were reviewed retrospectively for patient demographics, pretrial and posttrial ABG data, APACHE (acute physiology and chronic health evaluation) II score, Glasgow Coma Scale (GCS), diagnosis, and LOS data. The inclusion criteria and protocol were agreed on by the emergency physicians, ICU physicians, and respiratory therapists.

A ventilatory support system with monitor (BiPAP model S/T-D; Respirronics; Murrysville, PA) was the preferred instrument for our trials. This system measures the following patient parameters on a per-breath basis: actual inspiratory positive airway pressure (IPAP) delivered, actual expiratory positive airway pressure (EPAP) delivered, estimated tidal volume (Vt), and estimated leak. Prior to implementing our protocol in the ED, the resident physicians and attending staff were given instruction on the procedure by using lectures, current literature, and bedside teaching. In each trial, a respiratory therapist was present for the initial instrument set-up, the titration of IPAP and EPAP, and the monitoring of oxygenation via pulse oximetry. The respiratory therapist remained in the ED throughout the trial course to monitor the patient’s respiratory status and to provide reassurance. Depending on the patient’s status, a nasal mask or full face mask was chosen. Most patients were initially given a nasal mask (a chin strap was optional). The patients who complained of sinus pressure or congestion were switched to a full face mask. Other reasons for using a full face mask included mouth breathing or the inability to tolerate the chin strap. The initial trial parameters (in spontaneous mode) were 8 cm H2O of IPAP and 4 cm H2O of EPAP, with an oxygen flow rate of 6 L/min. The IPAP and EPAP parameters were titrated by the respiratory therapist to optimize Vt by pressure support. Each patient was continuously monitored for level of cooperation, mental status, physical appearance, oxygen saturation, signs of air leakage around the mask, and vital signs. Once stable settings were achieved for at least 30 min, a posttrial ABG level was obtained in all patients to assess adequacy of ventilation.

The Student’s t-test was performed for the comparison of groups, and \( \chi^2 \) analysis was performed for categorical variables. Significance was defined as \( p < 0.05 \). Because this study was a nonrandomized assessment of bilevel pressure ventilation as part of routine clinical practice, it was exempt from review by the Institution Review Board for Human Studies. Interdepartmental quality assurance reviews were performed to assess the adherence to inclusion criteria.

**Results**

From November 1994 to February 1997, our study protocol was instituted in 66 trials. From these trials, 60 charts were available for review. Two patients refused or could not tolerate the oxygen mask because of claustrophobia. Forty-three of the trials (74.1%) were successful, and 15 of the trials (25.9%) were unsuccessful. Of the 15 unsuccessful trials, 13 patients required intubation and 2 patients had advanced directives and were not intubated.

Most of the patients in our study were treated for an exacerbation of COPD or congestive heart failure (CHF; Table 2). Although the CHF patients were more likely to have successful treatments with bilevel positive airway pressure, a CHF diagnosis did not predict outcome. Many of the COPD patients were treated successfully with bilevel pressure ventilation; however, one third of these patients failed the trial and required intubation. The age range of the study patients was 25 to 88 years old. There was no significant difference in the mean (± SD) age between the success group and the failure group: 64 ± 12 vs 60 ± 18 years old, respectively. There were no significant differences between the success

<table>
<thead>
<tr>
<th>Table 1—Inclusion Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemodynamically stable*</td>
</tr>
<tr>
<td>Alert and cooperative</td>
</tr>
<tr>
<td>Capable of protecting airway</td>
</tr>
<tr>
<td>Evidence of fatigue†</td>
</tr>
<tr>
<td>ABG data consistent with ARF</td>
</tr>
<tr>
<td>( \text{PaCO}_2 &gt; 50 \text{ mm Hg with pH} &lt; 7.30 )</td>
</tr>
<tr>
<td>( \text{PaO}_2 &lt; 60 \text{ mm Hg with FIO}_2 &gt; 50% )</td>
</tr>
</tbody>
</table>

*Patient does not require vasopressors.
†Fatigue is defined as increased respiratory rate, use of accessory muscles, paradoxical breathing, or a subjective complaint of feeling tired. FIO\(_2\) = fraction of inspired oxygen.
group and the failure group in GCS, APACHE II, or predicted mortality rates (Table 3).

The mean (± SD) pretrial and posttrial ABG data from the success group and the failure group were compared, and the data are shown in Table 4. Ultimately, successful treatment with bilevel pressure ventilation was predicted by an improvement in pH and PaCO₂ during the 30-min trial. The mean (± SD) IPAP in the success group was higher than that in the failure group: 12 ± 2 cm H₂O vs 10 ± 4 cm H₂O (p < 0.02), respectively. There was no significant difference in EPAP between the success group and the failure group: 5 ± 1 cm H₂O vs 4 ± 1 cm H₂O, respectively.

The data for hospital LOS, ICU LOS, and ventilator days (BiPAP system or traditional mechanical ventilation) are shown in Figure 1. The hospital LOS was significantly shorter in the success group than in the failure group: 7.5 ± 5.0 days vs 15.6 ± 11.7 days (p < 0.02), respectively. The ICU LOS was significantly shorter in the success group than in the failure group: 4.2 ± 3.1 days vs 12.3 ± 11.6 days (p < 0.02), respectively. The number of days receiving artificial ventilation was significantly reduced in the success group when compared to the failure group: 1.8 ± 1.4 days vs 10.4 ± 11.6 days (p < 0.01), respectively.

Overall, bilevel positive airway pressure therapy was successful in the majority of ED patients with ARF. During the trials, patient vital signs stabilized with decreases in heart rate and respiratory rate. Use of accessory muscles decreased, and subjective improvement (less dyspnea) was reported by the patients. In the ICU, medical treatment continued with aerosolized β-agonists or diuretics. Bilevel pressure ventilation was used continuously for the first 16 to 24 h, with increased time off the system once the medical situation stabilized. The mean time spent on bilevel pressure ventilation was 1.8 ± 1.4 days. Complications were rare (1 in 58 trials), including a spontaneous pneumothorax in a COPD patient. Interestingly, two patients with a final diagnosis of subendocardial myocardial infarction were successfully treated with bilevel pressure ventilation. Both of these patients had severe coronary artery disease and known CHF (left ventricular ejection fraction = 25%) and initially presented to the ED with signs and symptoms of pulmonary edema; however, their initial ECG and enzyme analysis were not suggestive of myocardial injury. Both patients tolerated bilevel pressure ventilation without chest pain or other complications. No complications occurred during the trials with bilevel pressure ventilation in the ED. However, a variety of complications occurred in the patients who required intubation and mechanical ventilation, including a right mainstem intubation in one patient, cardiac arrhythmias in three patients, pneumonia progressing to sepsis in two patients, and a tracheostomy in one patient.

The patients who failed the trial of bilevel pressure ventilation were intubated based on their posttrial ABG levels and clinical appearances. Three patients initially did well with bilevel pressure ventilation but required intubation 3 h later because of refractory hypoxia and a change in mental status. Only two patients required intubation after 24 h of successful treatment with bilevel pressure ventilation. The remainder of the patients were promptly intubated in the ED after the posttrial ABG demonstrated continued hypoxia or worsening acidosis associated with a change in mental status. There were two deaths, both in the failure group, occurring in the two patients with advanced directives.
Several published studies support the use of bilevel pressure ventilation as a treatment for a variety of causes of ARF. These randomized, controlled trials have shown an improvement in gas exchange, a decrease in hospital stay, and a lower in-hospital mortality rate. Ambrosino et al retrospectively reviewed their experience with bilevel pressure ventilation in patients with COPD. After an analysis of multiple variables, the baseline pH remained the best predictor of success (sensitivity, 97%; specificity, 71%). The patients who failed bilevel pressure ventilation in this study had severe clinical abnormalities, a poorer neurologic status, and a diagnosis of pneumonia. However, predicting which patients will be successfully treated with bilevel pressure ventilation in an acute setting remains difficult. Our study demonstrates that a short trial of bilevel pressure ventilation in cooperative patients can aid the physician in deciding whether or not to continue bilevel pressure ventilation as a treatment.

The present study is a retrospective review of our experience with bilevel pressure ventilation in the ED setting. We evaluated clinical data in an attempt to predict which patients could be successfully ventilated with bilevel pressure ventilation. As in other studies, demographic and initial clinical data such as age, APACHE II, and ABG data could not predict success. The improvements in pH and PaCO₂ after a short trial of bilevel pressure ventilation were the best indicators that intubation was not necessary in patients with ARF.

Although it is difficult to predict which patients will be successfully treated with bilevel pressure ventilation upon arrival in the ED, patients with preserved neurologic status who are cooperative and capable of protecting their airway should be offered a trial. In multiple studies, bilevel pressure ventilation has been shown to decrease the complications associated with ARF, primarily by avoiding intubation and mechanical ventilation. Much of the work with bilevel pressure ventilation has been done with COPD. Pressure support ventilation (PSV) with external positive end-expiratory pressure (PEEP), delivered by face mask or nasal mask to patients with severe stable or acute exacerbations of COPD, has been shown to reduce the inspiratory workload of...
breathing and the magnitude of inspiratory efforts, leading to improvement in gas exchange.\textsuperscript{12,13} Since the ventilatory support system utilizes PSV (IPAP phase) and applies external PEEP (EPAP phase), similar clinical effects would be expected in patients with COPD exacerbations. In addition, Appendini et al\textsuperscript{12} have postulated that the application of PEEP or continuous positive airway pressure (CPAP) may foster the relaxation of expiratory muscles in COPD patients with hyperinflation. By counteracting intrinsic or dynamic PEEP, the application of external PEEP (EPAP) via bilevel pressure ventilation may act to reduce lung hyperinflation and to passively “assist” lung emptying during expiration.

The inspiratory pressures utilized in the success group were significantly higher than those in the failure group: 12 ± 2 cm H\textsubscript{2}O vs 10 ± 4 cm H\textsubscript{2}O, respectively. The pressures used were similar to those used in other studies;\textsuperscript{7–9} however, the significance of the higher pressure in our success group is unclear. The application of PSV and PEEP (via bilevel pressure ventilation) results in an unloading effect on the inspiratory muscles, as reflected by a reduction in diaphragm electromyogram (EMG di) activity. The application of higher levels of IPAP results in greater reductions in inspiratory muscle activation.\textsuperscript{13} Although we did not measure EMG di, it is possible that the patients in the success group, who received 12 cm H\textsubscript{2}O IPAP, had greater reductions in EMG di (and, hence, more effective “resting” of the respiratory muscles), compared to the patients in the failure group, who were given 10 cm H\textsubscript{2}O IPAP. Diaz et al\textsuperscript{14} have shown that PSV applied via face mask improves alveolar ventilation by optimizing breathing patterns in patients with hypercapnic exacerbations of COPD. Our patients who received higher IPAP levels may have shown more “success” because of the achievement of large VTs and lower respiratory rates, leading to better gas exchange and reduced anxiety compared to the patients who received lower IPAP levels.

In our study, the patients with CHF or pulmonary edema were more likely to have successful treatment with bilevel pressure ventilation. Positive pressure ventilation has been shown to decrease preload and afterload, leading to improved ventilation in patients with pulmonary edema, and especially in patients with central sleep apnea.\textsuperscript{15} In patients with pulmonary edema, bilevel pressure ventilation may improve lung volumes and, thereby, stabilize gas exchange. Bilevel pressure ventilation may also recruit atelectatic lung units, resulting in improved ventilation-perfusion matching in the setting of pulmonary edema.

However, in a recent study by Mehta et al\textsuperscript{16} in a small group of patients with CHF treated with bilevel pressure ventilation, the incidence of myocardial infarction was significantly increased. The reason for this was unclear. Subendocardial infarction may have been the cause of pulmonary edema, leading to randomization of these patients to the bilevel pressure ventilation group. However, there is concern that bilevel pressure ventilation may have altered intrathoracic pressure and reduced cardiac venous return, resulting in decreased myocardial blood flow. If this is the case, bilevel pressure ventilation should be utilized conservatively in patients with pulmonary edema, perhaps by using lower inspiratory and expiratory pressures. It may be reasonable to avoid bilevel pressure ventilation in all patients, except for those with significant CO\textsubscript{2} retention. Alternatively, CPAP has been shown to be effective in resting respiratory muscles without significantly changing cardiac output.\textsuperscript{17} CPAP, therefore, is a reasonable noninvasive alternative for patients with CHF.

The major limitations of our study are its retrospective design and relatively small sample size. Every effort was made to review the charts of all patients who were given a trial of bilevel pressure ventilation. In addition, our bilevel pressure ventilation protocol has not been rigorously validated. Nevertheless, we believe our data reflect our overall successful experience with bilevel pressure ventilation in ARF.

Although we were unable to determine predictors of success at the time of presentation, our study supports an interventional trial of bilevel pressure ventilation in patients with ARF in the ED, because the patients who were successfully treated with bilevel pressure ventilation had lower complication rates, decreased hospital and ICU stays, and reduced ventilator times (Fig 1). This study demonstrates that a 30-min trial can predict success with bilevel pressure ventilation, as shown by an improvement in pH and PaCO\textsubscript{2} and overall clinical appearance. Therefore, any patient with ARF who is capable of cooperating with the respiratory therapist should be offered a trial of bilevel pressure ventilation. The failure to improve after 30 min on stable bilevel pressure ventilation settings should be an indication for the discontinuation of bilevel pressure ventilation and the initiation of conventional mechanical ventilation.

REFERENCES
3 Abou- Shala N, Meduri GU. Noninvasive mechanical ventila-
5 Jasmer RM, Luce JM, Matthay MA. Noninvasive positive pressure ventilation for acute respiratory failure: underutilized or overrated? Chest 1997; 111:1672–1678

Need a reason to attend CHEST 1999 in Chicago?

We have 65.

CHEST 1999 • October 31 - November 4 • Chicago, Illinois
For more information call 800-343-2227 or visit ChestNet at www.chestnet.org/CHEST/1999/announce.html
Use of a Ventilatory Support System (BiPAP) for Acute Respiratory Failure in the Emergency Department
Janet M. Poponick, Jeffrey P. Renston, Richard P. Bennett and Charles L. Emerman

_Chest_ 1999;116; 166-171
DOI 10.1378/chest.116.1.166

This information is current as of August 1, 2011

Updated Information & Services
Updated Information and services can be found at:
http://chestjournal.chestpubs.org/content/116/1/166.full.html

References
This article cites 17 articles, 7 of which can be accessed free at:
http://chestjournal.chestpubs.org/content/116/1/166.full.html#ref-list-1

Cited Bys
This article has been cited by 22 HighWire-hosted articles:
http://chestjournal.chestpubs.org/content/116/1/166.full.html#related-urls

Permissions & Licensing
Information about reproducing this article in parts (figures, tables) or in its entirety can be found online at:
http://www.chestpubs.org/site/misc/reprints.xhtml

Reprints
Information about ordering reprints can be found online:
http://www.chestpubs.org/site/misc/reprints.xhtml

Citation Alerts
Receive free e-mail alerts when new articles cite this article. To sign up, select the "Services" link to the right of the online article.

Images in PowerPoint format
Figures that appear in CHEST articles can be downloaded for teaching purposes in PowerPoint slide format. See any online figure for directions.