Original article

Noninvasive ventilation in patients with acute cardiogenic pulmonary oedema: A prospective study to quantify adequate PEEP

Meeti Sivadas*, Anitha Shenoy
Email: meeti_2003@yahoo.com

Abstract

Introduction: Patients with heart failure developing acute pulmonary oedema benefit from immediate administration of noninvasive respiratory support such as continuous positive airway pressure (CPAP) or Biphasic positive airway pressure (BIPAP). **Objective:** To quantify the most advantageous positive end-expiratory pressure (PEEP) required to improve patient's oxygenation and to evaluate outcome of noninvasive respiratory support in patients with cardiogenic pulmonary oedema. **Methods:** This was a nonrandomised interventional study. Patients admitted with acute cardiogenic pulmonary oedema to the cardiac intensive care unit were initiated on CPAP/BIPAP mode of ventilation noninvasively. They were evaluated for the most advantageous PEEP that improved their symptoms. **Results:** A total of thirty two patients were studied. Twenty four patients were included in the CPAP group [mean (± SD) age of (63.66 ± 11.18) years)] and eight in BIPAP group [mean (± SD) age of (67.25 ± 12.6) years]. Most advantageous PEEP (mean (± SD) in CPAP group was 5.62 ± 1.24 cm H_2O and in BIPAP group was 7.125 ± 1.8 cm H_2O (P = 0.0125). Lower serum bicarbonate levels were found at baseline in the BIPAP group (14.4 ± 6.3 mmol/L) compared to CPAP group (19.4 ± 5.59 mmol/L, $P < 0.041$). Patients in BIPAP group needed a longer hospital stay (19.62 ± 14.9 days) compared to CPAP group of 8.12 ± 6.58 days (P 0.0047). **Conclusions:** Most patients of cardiogenic pulmonary oedema can be managed noninvasively with CPAP but patients with metabolic acidosis are likely to require BIPAP and a longer duration of hospital stay.

Keywords: Cardiogenic pulmonary oedema, continuous positive airway pressure, biphasic positive airway pressure.

Introduction

Patients with heart failure can rapidly develop acute pulmonary oedema. It usually presents with sudden onset of acute hypoxaemic respiratory failure that requires rapid diagnosis and treatment.[1] Typically, patients are hypoxaemic with increased work of breathing and acidaemic because of both respiratory and metabolic factors.[2]

Respiratory failure often results in these patients despite use of supplemental oxygen and administration of drugs to reduce lung water and improve myocardial performance. With intubation and mechanical ventilation, improvement in oxygenation and relief of respiratory muscle fatigue occurs in most of the cases but the complications of tracheal intubation outweigh the benefits giving rise to newer methods of administering mechanical ventilation such as noninvasive ventilation.[3]

Meeti Sivadas, MSc RT
Assistant Professor of Respiratory therapy, Manipal College of Allied Health Sciences, Manipal

Anitha Shenoy, MD, FRCA
Professor of Anaesthesiology,
Kasturba Medical College, Manipal

How to cite this article: Sivadas M, Shenoy A. Noninvasive ventilation in patients with acute cardiogenic pulmonary oedema: A prospective study to quantify adequate PEEP. Ind J Resp Care 2012;1:37-41.

Several studies employing noninvasive positive pressure ventilation in cardiogenic pulmonary oedema have been performed in the intensive care units.[4] During the past decade, continuous positive airway pressure (CPAP) has been shown to improve gas exchange and decrease the need for endotracheal intubation in these patients. Apart from improvement in oxygenation, other benefits offered by CPAP include augmentation of cardiac output and oxygen delivery, improved functional residual capacity, improvement of respiratory mechanics, reduction in breathing efforts and decreased left ventricular afterload.[5]

BIPAP in contrast to CPAP delivers two different pressures, inspiratory positive airway pressure (IPAP) and expiratory positive airway pressure (EPAP). It decreases inspiratory work of breathing and can improve diaphragmatic function better than CPAP alone. BIPAP offers similar cardiac and haemodynamic benefits as CPAP in patients with cardiogenic pulmonary oedema.[6,7] In addition, BIPAP unloads the respiratory muscles, reduces respiratory effort and increases tidal volume before any changes in pulmonary mechanics. This is in contrast to CPAP which requires the pulmonary mechanics to change before any benefits of respiratory muscle unloading can be seen.[8] The objective of this study was to quantify the most advantageous positive end-expiratory pressure (PEEP) required to improve patient's oxygenation and to evaluate outcome of noninvasive respiratory support in patients with cardiogenic pulmonary oedema.

Patients and methods

The patients admitted to cardiac intensive care unit with cardiogenic pulmonary oedema suitable for noninvasive ventilation in the period between 1st April 2010 and 31st January 2011 were included in this nonrandomised interventional study. Inclusion criteria were the following: Patients above 18 years of age, all patients with cardiogenic pulmonary oedema fulfilling criteria for noninvasive ventilation. Exclusion criteria were pulmonary oedema of noncardiogenic origin, patients on invasive ventilation, those who require immediate endotracheal intubation, severe sensorial impairment, shock and ventricular arrhythmias.

Noninvasive respiratory support was initiated in all patients with a well-fitting face mask and CPAP mode delivered from (Dräger Savina™ - Dräger Medical Inc., Lübeck, Germany) critical care ventilator. The initial settings were fractional inspired oxygen concentration (FiO_2) of 1.0 and positive end-expiratory pressure of 5 cm H_2O. An increment of 1 cm H_2O of PEEP was made at every 15 min intervals until there was a brisk increase in SpO_2 to a target of at least 95%. If the patients did not show adequate response such as persisting tachypnoea (>35/min), persistent symptoms of respiratory distress and no increase in oxygenation, the patients were changed over to Bilevel mode. The inspiratory pressure (IPAP) was set at 15 cm H_2O and then adjustments (increments or decrements by 2 cm H_2O) were made to achieve tidal volumes of 6-8 ml/kg.

A baseline arterial blood gas (ABG) analysis was obtained before intervention. Vital signs were recorded with every change in parameter. The aim was to maintain a SpO_2 of 95-100% and a PaO_2 > 60 mm Hg. Another ABG was obtained once acceptable SpO_2 was achieved. Once the pulmonary oedema resolved and the patient improved, he/she was weaned off the ventilator. In the CPAP mode decrements of 1 cm H_2O PEEP was made at a time till 5 cm H_2O was achieved. If the patient was on BIPAP mode, the IPAP was reduced by 2 cm H_2O at a time till 5 cm H_2O IPAP was reached and the patient was changed over to CPAP. They were then weaned as in the CPAP group. If the condition worsened with drop in oxygen saturation, decrease in PaO_2, dyspnoea or reduction in consciousness, NIV was discontinued and endotracheal intubation and invasive ventilation was considered. All quantitative data were analysed with Student's t test and qualitative data with Chi-square test, using statistics software SPSS 11, SPSS, Chicago, Illinois.

Results

A total of thirty two patients admitted to the cardiac intensive care with acute cardiogenic pulmonary

oedema suitable for noninvasive ventilation in the period between 1st April 2010 and 31st January 2011 were included in the study. Twenty four patients could be managed with CPAP whereas 8 patients required BIPAP. Comorbidities were distributed similarly in both groups. Demographic data and condition at intervention were similar in both groups except that the serum bicarbonate was lower in the BIPAP group (14.4 ± 6.3 mmol/L) as compared to CPAP group (19.4 ± 5.59 mmol/L) *(Tables 1 and 2)*.

Table 1: Demographic data

		Group CPAP (n = 24)	Group BIPAP (n= 8)	p Value
Age (y) (mean ± SD)		63.66 ± 11.18	67.25 ± 12.6	0.4515
Gender (M/F) (n)		18/6	6/2	1
Comorbidities (n)	Diabetes mellitus	7	6	
	Hypertension	7	2	
	Renal dysfunction	7	1	
	COPD	4	2	
	Pneumonia	2	2	

Table 2: Condition at admission

		Group CPAP (n = 24)	Group BIPAP (n = 8)	p Value
RR (bpm) (mean ± SD)		34 ±7	35 ± 5	0.6195
SpO_2 (%)(mean ± SD)		81.41 ± 13.14	85.125 ± 7.6	0.4570
HR (beats/min) (mean ± SD)		100.17 ± 16.62	104 ± 24	0.618
BP (mm Hg) Systolic (mean ± SD) Diastolic		135 ± 29.2 79.21 ± 18.9	142 ± 24.9 82.25 ± 11.2	0.548, 0.672
CXR Quadrants with infiltrates (1/2/3/4) (n)		0/7/0/11	0/2/0/5	
ABG	pH (mean ± SD)	7.29 ± 0.15	7.20 ± 0.12	0.1351
	PO_2/FiO_2 (mean ± SD)	157.9 ± 57.93	133.8 ± 82.03	0.3664
	PCO_2(mm Hg) (mean ± SD)	39.34 ± 15.35	34.73 ± 16.49	0.475
	HCO_3(mmol/L) (mean ± SD)	19.4 ± 5.59	14.4 ± 6.3	0.041
Need for invasive mechanical ventilation (Yes/No) (n)		5/19	2/6	

The baseline respiratory rate, oxygen saturation, heart rate, systolic and diastolic blood pressures were also similar in the two groups *(Table 2)*. Preoperative chest X-ray showed 64% of all patients had infiltrates in four lung quadrants and the rest in two quadrants. There was no significant difference between the two groups.

A comparison of arterial blood gases prior to intervention showed the patients in BIPAP group had a lower PaO_2/FiO_2 ratio as compared to those in the CPAP group but this did not reach statistical significance. The PCO_2 and the pH were higher in the CPAP group. Patients who required BIPAP were more acidotic (metabolic) as compared to patients who required CPAP alone *(Table 2)*. The improvement in patients' condition with intervention was compared using PaO_2/FiO_2 ratio taken one hour after initiation of NIV. Oxygenation had improved to a PaO_2/FiO_2 ratio of 263.78 ± 119.9 in CPAP group whereas it was 204.8 ± 141.5 in BIPAP group. The patients in CPAP group required a PEEP of 5.62 ± 1.24 cm H_2O and those in BIPAP group required 7.125 ± 1.8 cm H_2O. The PEEP requirement was significantly higher in the BIPAP group *(Table 3)*.

Table 3: Condition with intervention

	Group CPAP (n= 24)	Group BIPAP (n= 8)	p Value
Duration of NIV (days) (mean ± SD)	1.10 ± 0.93	1.75 ± 0.65	0.0781
PaO_2/FiO_2 (mean ± SD)	263.78 ± 119.90	204.8 ± 141.5	0.2579
PEEP (cm H_2O) (mean ± SD)	5.62 ± 1.24	7.125 ± 1.8	0.0125

The number of days of noninvasive ventilation and ICU stay did not differ but patients who required BIPAP also had a significantly longer duration of hospital stay. 79% of the patients in the CPAP group and 75% in the BIPAP group survived *(Table 4)*.

Table 4: Outcome

	Group CPAP	Group BIPAP	P Value
ICU stay (days)	3.95 ± 5.90	6.12 ± 2.99	0.3295
Hospital stay (days)	8.12 ± 6.58	19.62 ± 14.9	0.0047
Survival [n (%)]	79.1	75	

Discussion

Cardiogenic pulmonary oedema occurs due to an imbalance in the forces governing fluid movement in the pulmonary circulation. Hydrostatic pressure in the pulmonary capillaries increases tilting the net outward pressure of the fluid to become positive. This may happen due to acute increases in pulmonary capillary pressures due to reduced contractility of left ventricle, increased back pressure or simply fluid overload. In cardiogenic pulmonary oedema, treatment of increased pulmonary capillary pressures involves the use of oxygen, diuretics, inotropes and analgesics or even revascularisation. Those patients who do not respond to this treatment will need respiratory support till medical treatment takes effect. This may be either invasive or noninvasive respiratory support.

The fact that invasive ventilation can be harmful was mentioned by Sinuff *et al*.[9] Since the basic pathology is reasonably well treated medically and the intention is to support the patient's respiration till it takes effect, it is prudent to attempt noninvasive respiratory support in all eligible patients. This means that the patients should be conscious with intact reflexes and tolerate the noninvasive respiratory support interface (Mirage™ NV Full Face, RedMed).

The aim of this study was to evaluate whether noninvasive support is useful in patients with cardiogenic pulmonary oedema, to determine the most advantageous PEEP and to compare CPAP and BIPAP. Most patients could be managed with CPAP alone. The pretreatment condition of all the patients was similar in that they were all tachypnoeic and hypoxic at admission. Arterial blood gases obtained before any intervention showed that oxygenation was lower in the BIPAP group but this did not reach statistical significance. Those patients who required BIPAP had significantly lower serum bicarbonate level. The lower arterial carbon dioxide levels observed in these patients must have been an attempt by the patient to normalise the pH. Since the respiratory rate was similar in both the groups, the respiratory alkalosis may have been due to increased tidal volume as an attempt to increase alveolar ventilation to compensate for metabolic acidosis.

The cause of this metabolic acidosis is most likely to be due to reduced cardiac output in these patients. The heart rate and blood pressure before any intervention were not different between the groups but no objective measurement of cardiac output was made in any of these patients. It is quite likely that the metabolic acidosis was due to reduced stroke volume and cardiac output. This is in agreement with the study by Anthonisen *et al*[2] describing development of metabolic acidosis in patients with cardiogenic pulmonary oedema. If BIPAP had not been instituted early, these patients quite likely would have eventually developed hypercarbia along with respiratory muscle fatigue.

The improvement in PaO_2/FiO_2 ratio one hour after initiation of NIV was more in the CPAP group (263.78 ± 119.9 in CPAP group vs 204.8 ± 141.5 in BIPAP group). The patients in CPAP group required a PEEP of 5.62 ± 1.24 cm H_2O and those in BIPAP group required 7.125 ± 1.8 cm H_2O. Patients in BIPAP group required NIV for almost a day longer than those in the CPAP group (mean of 1.1 vs 1.75 days respectively). Although the PaO_2/FiO_2 ratio and duration of NIV in each group did not reach statistical significance, the PEEP requirement was certainly higher in the BIPAP group. This again showed that the patients in BIPAP group probably had more severe pulmonary oedema and thus, patients who require BIPAP required higher PEEP setting.

The duration of ICU stay was longer by 2 days although not statistically significant. The duration of hospital stay was however, significantly longer in BIPAP group than the CPAP group (mean of 19.62 *vs* 8.12 days respectively). This again reinforces the possibility that patients who required BIPAP were more sick.

Several studies have shown that the mortality rate does not increase with BIPAP as against CPAP.[10-13] There was no increase in myocardial infarction rates in patients treated with either group unlike Mehta *et al*[11] who found increased myocardial infarction rates with BIPAP.

The patients in CPAP group seemed to have a slightly higher survival rate (79.1%) as compared to BIPAP group (75%) but this difference does not seem significant. Two patients in BIPAP group did not survive. One of them had atrial fibrillation. The other patient was taken home after withdrawing further treatment. Of the six patients in the CPAP group who died, all of them had a cardiac cause such as bradycardia or heart block preceding cardiac arrest.

Winck *et al* [14] concluded from their study that CPAP should be considered as first line intervention as noninvasive positive pressure ventilation did not show a better efficacy, even in patients with more severe conditions, and CPAP is cheaper and easier to implement in clinical practice. BIPAP should be offered to patients who are sicker as evidenced by metabolic acidosis. These patients will also require higher PEEP setting and are likely to stay longer in the hospital. The main drawback of this study was that the sample size was small and all our findings need to be validated in a larger study.

Conclusions

In patients presenting with cardiogenic pulmonary oedema, noninvasive respiratory support is found to be useful. Most patients can be managed with CPAP and patients with metabolic acidosis are likely to require BIPAP mode of ventilation. The most advantageous positive end-expiratory pressure in patients needing CPAP was found to be lesser in CPAP mode. The hospital stay is likely to be longer in patients requiring BIPAP. Mortality is comparable in both modes of ventilation.

References

1. Bersten AD, Holt AW, Vedig AE, Skowronski GA, Baggoley CJ. Treatment of severe cardiogenic pulmonary edema with continuous positive airway pressure delivered by face mask. *N Engl J Med* 1991; **325**:1825–30.
2. Anthonisen NR, Smith HJ. Respiratory acidosis as a consequence of pulmonary edema. *Ann Intern Med* 1965; **62**:991–9.
3. Pingleton SK. Complications of acute respiratory failure. *Am Rev Respir Dis* 1988;**137**:1463–93.
4. Park M, Sangean MC, Volpe Mde S, Feltrim MI, Nozawa E, Leite PF, *et al.* Randomized, prospective trial of oxygen, continuous positive airway pressure, and bilevel positive airway pressure by face mask in acute cardiogenic pulmonary oedema. *Crit Care Med* 2004; **32**:2407–15.
5. Katz J, Kraemer R, Gjerde G. Inspiratory work and airway pressure with continuous positive airway pressure delivery systems. *Chest* 1985; **88**:519–26.
6. Peter JV, Moran JL, Phillips-Hughes J, Graham P, Bersten AD. Effect of noninvasive positive pressure ventilation (NIPPV) on mortality in patients with acute cardiogenic pulmonary oedema: a meta-analysis. *Lancet* 2006; **367**:1155–63.
7. Pang D, Keenan SP, Cook DJ, Sibbald WJ. The effect of positive pressure airway support on mortality and the need for intubation in cardiogenic pulmonary edema: A systematic review. *Chest* 1998; **114**:1185–92.
8. Seals DR, Suwarno NO, Dempsey JA. Influence of lung volume on sympathetic nerve discharge in normal humans. *Circ Res* 1990; **67**: 130–41.
9. Sinuff T, Cook DJ, Randall J, Allen CJ. Evaluation of a practice guideline for noninvasive positive-pressure ventilation for acute respiratory failure. *Chest* 2003; **123**:2062–73.
10. Masip J, Betbesé AJ, Páez J, Vecilla F, Cañizares R, Padró J, *et al*: Noninvasive pressure support ventilation versus conventional oxygen therapy in acute cardiogenic pulmonary oedema: a randomised trial. *Lancet* 2000; **356**: 2126–32.
11. Mehta S, Jay GD, Woolard RH, Hipona RA, Connolly EM, Cimini DM, *et al.* Randomised, prospective trial of bilevel versus continuous positive airway pressure in acute pulmonary oedema. *Crit Care Med* 1997; **25**:620–8.
12. Park M, Sangean MC, Volpe Mde S, Feltrim MI, Nozawa E, Leite PF, *et al.* Randomized, prospective trial of oxygen, continuous positive airway pressure, and bilevel positive airway pressure by face mask in acute cardiogenic pulmonary oedema. *Crit Care Med* 2004; **32**:2407–15.
13. Bellone A, Monari A, Cortellaro F, Vettorello M, Arlati S, Coen D. Myocardial infarction rate in acute pulmonary oedema: Noninvasive pressure support ventilation versus continuous positive airway pressure. *Crit Care Med* 2004; **32**:1860–5.
14. Winck JC, Azevedo LF, Costa-Pereira A, Antonelli M, Wyatt JC. Efficacy and safety of noninvasive ventilation in the treatment of acute cardiogenic pulmonary oedema – a systematic review and meta-analysis. *Crit Care* 2006, **10:**R69.