Original Research Article

A study of non-invasive ventilation in acute respiratory failure

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Abstract

Introduction: Noninvasive positive-pressure ventilation is a safe and effective means of improving gas exchange in patients with many types of acute respiratory failure. This study focuses on use of NPPV in the intensive care unit and in the care of patients with acute respiratory failure due to various diagnoses.

Materials and methods: We included 50 consecutive patients admitted to medical intensive care unit satisfying our inclusion/exclusion criteria from April 1, 2014 till March 31, 2015. Various clinical and physical parameters were monitored during the period of the stay. All the complications experienced by the patients were also noted. Data was analyzed by applying appropriate statistical tests. Statistical analysis was applied $P < 0.05$ was considered as significant.

Results: Average age of the patients was 42 years and the most common diagnosis was Acute Respiratory Distress Syndrome (ARDS) followed by pneumonia. Our analysis we did find a statistically significant association between the type of diagnosis and non-invasive ventilation failing (chi-square = 22.22; p-value = 0.004). This was however not true for patients' clinical outcome in terms of mortality (chi-square = 13.51; p-value = 0.09). In our patients air leak was the most common complication and hemodynamic instability was the least common. We also observed that death occurred in patients who failed to recover on NIV.

Conclusions: Our study showed that non-invasive failure has no statistically significant relation to age of the patient. The diagnosis of patient is a good predictor for NIV success or failure. We recommend the use of full face mask with proper exhalation device for preventing air leak.

Key words

Acute respiratory failure, Ventilation, mortality, Non-invasive.

Introduction

Non-invasive positive pressure ventilation (NPPV) refers to positive pressure ventilation delivered through a non-invasive interface (nasal mask, facemask, or nasal plugs), rather than an invasive interface (endotracheal tube, tracheostomy) [1]. Its use has become more common as its benefits are increasingly recognized. Interest in NPPV has grown since 1987, when several reports [1–3] found that it relieved symptoms and improved gas exchange in patients with chronic respiratory failure. Since then, it has been successfully used in many patients with acute respiratory failure as well, and its use has increased dramatically in the last 5 years. Because NPPV avoids some of the complications of intubation (pneumonia, sinusitis, and trauma to the airway), NPPV patients incur shorter hospital stays, lower mortality rates, and lower healthcare costs [1]. Another advantage is that it is more comfortable for the patient, who retains the ability to speak, swallow, and protect the upper airway.

Non-invasive positive-pressure ventilation is a safe and effective means of improving gas exchange in patients with many types of acute respiratory failure. For example, in patients with acute exacerbations of chronic obstructive pulmonary disease and hypercapnic respiratory failure, adding non-invasive ventilation to standard therapy decreased the need for endotracheal intubation and reduced mortality. Similarly, non-invasive continuous positive airway pressure was effective in patients with cardiogenic pulmonary edema, particularly those with hypercapnia. In patients with various forms of acute hypoxemic respiratory failure (pneumonia, congestive heart failure, chest-wall impairment, and so forth), this therapy slightly decreased the rate of intubation and improved survival, but the effect was not statistically significant. The efficacy of positive-pressure ventilation in patients with hypoxemic respiratory failure is not known.

NPPV appears to be most valuable in patients with exacerbations of COPD, although some success has been achieved in patients with cardiogenic pulmonary edema [1]. Results in patients with acute hypoxemic non-hypercapnic respiratory failure have not been as encouraging. NPPV can avoid being intubated. Furthermore, the reduction in the need for intubation results in a reduction in the mortality rate [1]. In addition, NPPV translates into shorter hospital stays and decreased costs of care [4].

This study focused on use of NPPV in the intensive care unit and in the care of patients with acute respiratory failure due to severe exacerbations of chronic obstructive pulmonary disease (COPD), cardiogenic pulmonary edema, and acute hypoxemic non-hypercapnic respiratory failure, including severe pneumonia or acute respiratory distress syndrome (ARDS).

Materials and methods

Study design and patient population

The study was conducted on 50 consecutive patients admitted to medical intensive care unit having the following criteria. Duration of study was from April 1, 2014 till March 31, 2015. We included patients aged 13 years and above who had signs and symptoms of acute respiratory distress, moderate to severe dyspnea, had respiratory rate greater than 24 breaths per minute. Alert and cooperative patients with pCO_2 more than 45 mmHg, pH less than 7.35 and pO_2 to fiO_2 ratio less than 200 were included in the study. We excluded patients who suffered a respiratory arrest, had excessive secretions, hemodynamic instability of life threatening arrhythmia and had high risk of aspiration. We also excluded patients who were uncooperative or agitated patient, had life – threatening refractory hypoxemia with pH less than 7.1 and pCO2 more than 92 mm Hg and those patients were excluded who were deemed to be 'DNR' (do not resuscitate), could not protect airway or cough to clear secretions adequately, were in septic shock, or could not cooperate with NPPV.

Study setting

Mumbai is the most populous city in India, with an estimated metropolitan area population of 20.7 million according 2011 census [5]. Greater Mumbai has a literacy rate of 94.7%, which is higher than the national average of 86.7%. Apart from Marathi, which is the native language, Hindi, Gujarati and English are spoken and understood well in this region.

Technique used for NPPV

- Head of the bed elevated at 45 degree angle
- Dressing to forehead, nasal bridge and face around nose
- Clear, full-face mask
- Straps are adjusted so that two fingers can slide underneath the straps
- Optional nasogastric tube
- FiO2 to keep O2 saturation > 90%
- Adjust ventilator settings on the basis of pulse oximetry and arterial blood gases
- Do not sedate patients

Patients were put on non-invasive ventilation with a tight fitting comfortable facemask using Bilevel Positive Airway Pressure Ventilators (BiPAP) starting with inspiratory pressures of 8-12 cm of water and expiratory pressures of 2-5cm of water till the following endpopints were achieved.

- Relief of symptoms of respiratory failure / fatigue.
- Reduce work of breathing in chronic obstructive pulmonary diseases to decrease PaCO2 and improve pH.
- Improve gas exchange and alveolar oxygenation in acute settings.
- Achieve patient ventilator synchrony.
- Comfort the patient.
- Avoid intubation.
- Improve sleep duration and quality of life in the chronic setting.
- FiO2 = 0.6 or less or PaO2/FiO2 > 200

During the first 24 hours, continuous ventilation was maintained until oxygenation and clinical status improved. Then each day, the patient was evaluated without ventilatory support for 15 minutes. Ventilatory support was discontinued if the patient maintained a respiratory rate lower than 30 and a PaO2 > 75 mm Hg on an FiO2 of < 0.5 without ventilatory support. As much as possible, peak mask pressure was kept < 30 cm H2O to reduce the likelihood of gastric distension.

Patient monitoring

All the included patients were monitored for physical symptoms like oximetry, arterial blood gases, respiratory rate, blood pressure, heart rate, subjective response, dyspnea rating, patient comfort, sternocleidomastoid muscle activity and patient ventilator synchrony. Patients were also monitored for any complications like mental alertness, secretions and risk of aspiration, mask discomfort and local damage, mask air leak, gastric distension, anxiety, barotrauma, risk of rebreathing leading to hypercarbia, hemodynamic instability, nasal congestion, eye irritation and inability to sleep.

Data collection and analysis

The data was collected during the period 1st April 2014 to 31st March 2015. Data was tabulated and analyzed by applying Pearson’s Chi square test, Unpaired t test, correlation coefficient (Spearman’s ratio), likelihood ratio non parametric tests for analysis of variance with the help of a statistician and using SPSS software.

Statistical analysis was applied P < 0.05 was considered as significant.

Results

A total of 50 patients were included in the study, with an average age of 42 years (**Table - 1**). The most common diagnosis was Acute Respiratory Distress Syndrome (ARDS) followed by pneumonia. On our analysis we did find a statistically significant association between the type of diagnosis and non-invasive ventilation failing (chi-square = 22.22; p-value = 0.004) (**Table - 2**). This was however not true for patients' clinical outcome in terms of mortality (chi-square = 13.51; p-value = 0.09) (**Table - 3**). Comparing the Acute Physiology and Chronic Health Evaluation II (APACHE 2 score) of our patients at presentation with the outcome and occurrence of NIV failure we can see that a high APACHE 2 score has yielded a poor outcome in the form of death (unpaired t-test = 2.067; p-value = 0.044). Moreover, our studied showed that the change in pH on NIV does not show any significant variation over subsequent days, which is usually seen on starting NIV.

Table - 1: Description of patient population.

Variable	***n* = 50**
Age	42 years (SD = 3.48)
Male patients	22
Diagnosis	
Acute Respiratory Distress Syndrome	21
Chronic Obstructive Pulmonary Disease (COPD)	6
COPD + Bronchiectasis	2
COPD + Pneumonia	6
COPD + Pneumonia + Bronchiectasis	1
COPD + Pneumonia + Interstitial Lung Disease	1
Pneumonia	7
Pneumonia + Pulmonary Edema	1
Pulmonary Edema	5

Table - 2: Association between disease diagnosis and noninvasive ventilation (NIV) failure.

Diagnosis	**NIV failure**		**Total**
	Yes	No	
Acute Respiratory Distress Syndrome	7	14	21
Chronic Obstructive Pulmonary Disease (COPD)	0	6	6
COPD + Bronchiectasis	1	1	2
COPD + Pneumonia	3	3	6
COPD + Pneumonia + Bronchiectasis	1	0	1
COPD + Pneumonia + Interstitial Lung Disease	1	0	1
Pneumonia	7	0	7
Pneumonia + Pulmonary Edema	0	1	1
Pulmonary Edema	0	5	5
Total	20	30	50

Chi-square Tests	**Value**	**df**	**p-value**	**Association**
Pearson Chi-Square	22.222	8	0.00452	Significant
Likelihood Ratio	29.477	8	0.000261	Significant

Table - 3: Association of disease diagnosis with patient clinical outcome.

Diagnosis	Outcome		Total
	Death	Survival	
Acute Respiratory Distress Syndrome	5	16	21
Chronic Obstructive Pulmonary Disease (COPD)	0	6	6
COPD + Bronchiectasis	1	1	2
COPD + Pneumonia	2	4	6
COPD + Pneumonia + Bronchiectasis	1	0	1
COPD + Pneumonia + Interstitial Lung Disease	1	0	1
Pneumonia	4	3	7
Pneumonia + Pulmonary Edema	0	1	1
Pulmonary Edema	0	5	5
Total	14	36	50

Chi-square Tests	Value	df	p-value	Association
Pearson Chi-Square	13.506	8	0.096	Not significant
Likelihood Ratio	16.271	8	0.039	Significant

NIV has proven to favorably affect the pCO2 values most and hence considered a good therapeutic modality in cases of COPD with acute exacerbation i.e. in hypercapnic respiratory failure. Our study included more number of patients with infective COPD exacerbation, which could be the reason for not getting a statistically significant change in pCO2 levels. In our patients air leak was the most common complication and hemodynamic instability was the least common (**Table - 4**). The maximum expiratory pressures required in our patients had a significant relation with gastric distension. We also observed that death occurred in patients who failed to recover on NIV. The reasons for a high mortality in these intubated patients could be; higher initial APACHE score, delay in intubation (prolonged NIV in spite of non improving ABG parameters).

Table - 4: Association of various complications with NIV failure.

Complication	NIV failure		Chi-square	p-value
	Yes	No		
Gastric distension				
Yes	4	9	0.624	0.43
No	16	21		
Air leak				
Yes	6	18	4.32	0.038
No	14	12		
Impaired mental status				
Yes	7	2	6.52	0.011
No	13	28		
Hemodynamic instability				
Yes	6	1	7.08	0.008
No	14	29		

Discussion

NIV is being practiced in our MICU since many years with the use of NIV as well as conventional ventilators using nasal or face masks. We have seen many patients improve with NIV while a few deaths also occurred. Though at first sight NIV looks to be beneficial in many patients with various diagnoses, this study may help us to statistically analyze our use of NIV and help us to decide on the criteria to be considered in deciding whether NIV should be applied to a particular patient in future and help in forming guidelines for use of NIV in our setting. In our study we have used NIV ventilators – pressure limited (Bi-Level), spontaneous + timed mode, with flow cycling. The ventilator patient interface was a full face mask. Nasal mask was tried in some patients but it lead to increased rate of mouth breathing especially in patients with COPD ultimately being replaced by the full face mask. Of the face masks used those with silicone cushions and proper non return valves and advanced exhalation devices showed a better patient comfort. These findings in our study could not be analyzed statistically due to a smaller sample size for each type of mask. Total no. of NIV failures were 20 (20 patients needed endotracheal intubation). Out of these 12 patients expired in spite of providing timely invasive ventilation while 2 patients died of sudden cardiac arrest while on NIV and were resuscitated with intubation but could not be revived from that sudden event. We found a significant association between the various diseases in our patients and incidence of NIV failure and outcome. This shows a high incidence of NIV failure and death in patients with ARDS and still higher in patients with pneumonia. This study gives clear evidence as to pneumonia leading to increased NIV failure. Many other trials give similar evidence. Philippe Jolliet, et al. in their study of Non-invasive pressure support ventilation in severe community-acquired pneumonia found an intubation rate of 66%, mortality of 33% and median ICU stay of 16 days [6].

This study showed a poor result for patients of COPD contrary to other trials. In our study out of 16 COPD patients 10 had advanced respiratory failure in the form of lower pH at presentation i.e. below 7.2 or had 2 high pCO2 above 60mmHg 3 patients required intubation. NIV seems to have failed in patients with COPD overall. This could be attributed to presence of infection in the form of pneumonia in many of our patients. Also those patients who had a plain acute exacerbation of COPD were analyzed separately showed a favorable outcome. The number of such patients was only 6 and none of them required intubation. There could also be a role of rebreathing through the old type of interface used for some patients in the earlier days before new masks with proper exhalation devices were available [6, 7]. This could be the reason also for a prolonged duration of NIV in these patients. Soo-kyung Strambi, et al. in their study of effectiveness of Non invasive mechanical ventilation in COPD and non COPD patients found NIV to be unsuccessful in 13 out of 62 non COPD patients (20.7%), (6 death, 7 EI) and in 9 out of 65 COPD patients [8].

Ambrosino N, et al. [9] concluded that success with non-invasive mechanical ventilation was associated with less severely abnormal baseline clinical and functional parameters, and with less severe levels of acidosis assessed during an initial trial of non-invasive mechanical ventilation [6]. Our patients had complications as stated earlier. Commonest being air leak. Gastric distension also appears frequently. The average duration of NIV for patients with gastric distension and air leak are 5.538 and 4.635 respectively. There is no relation of gastric distension to increased incidence of NIV failure. Also other minor complications like headache, eye irritation and local damage have no effect on continuation of NIV and its tolerability. No lethal complication like cardiac arrhythmias occurred though some patients had complications like impaired mental status and hemodynamic instability. In published studies of NIV, data on oxygen saturation or transcutaneous CO_2 have seldom been reported. However, several studies have shown that oxygen levels improve early with NIV and, on this basis, SpO_2 monitoring is likely to be helpful, although does not replace the need for frequent measurements of arterial blood gas tensions in the early stages of treatment [6]. Ideally, there should be continuous monitoring of SpO_2 for the first 24 hours of treatment, aiming to keep saturation above 85%, with supplemental oxygen if necessary. Transcutaneous CO_2 monitoring may also be used where it is available [7, 10, 11].

Conclusion

Our study showed that non-invasive failure has no statistically significant relation to age of the patient. The diagnosis of patient is a good predictor for NIV success or failure. COPD with acute exacerbation pulmonary edema are associated with good predictors for NIV success whereas pneumonia and COPD with pneumonia lead to a poor NIV outcome. Moreover mortality rate is high in patients of NIV failure. Air leak and gastric distension are common complications seen in patients receiving NIV and it was observed that air leak leads to increased incidence of NIV failure.

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