To Assess the Usefulness of Noninvasive Ventilation (NIV) in the Treatment of Acute Respiratory Failure (ARF) in Patients with Bronchiectasis Caused by Cystic Fibrosis (CF)

Ranjeet Kumar[1], Shashi kant[2]

[1]Assistant Professor, Department of Anaesthesia, Netaji Subhas Medical College and Hospital, Bihta, Patna, India

[2]Assistant Professor, Department of Anaesthesia, Netaji Subhas Medical College and Hospital, Bihta, Patna, India

Abstract

Aim: To evaluate the role of noninvasive ventilation (NIV) for treatment of acute respiratory failure (ARF) among patients with noncystic fibrosis (CF) bronchiectasis. **Methods:** This was a retrospective study conducted in the Department of Anaesthesia, Netaji Subhas Medical College and Hospital, Bihta, Patna, India for 1 year. We included 130 patients with bronchiectasis and ARF who required either NIV or invasive mechanical ventilation (IMV). **Results:** Out of 250,130 patients who required either NIV or IMV. The most common etiology of bronchiectasis was post-tuberculosis (52%) followed by idiopathic (22%), ABPA (16%), and immunodeficiency (6%). NIV was initiated as first line of ventilator support for 100 patients. Among these, 65(65%) were managed successfully with NIV. 35 (35%) patients failed NIV and required endotracheal intubation during the hospital stay. Reasons for NIV failure were worsening or non-improvement of ventilatory or oxygenation parameters (n=15), hypotension (n = 7), worsening of sensorium (n = 5), and intolerance (n = 6). NIV failure occurred after a median duration of 2.69(95% confidence interval [CI]-1.47–4.32) days after the initiation. There was total 15 deaths in the study group. Among patients who failed NIV, total days (median [range]) spent on ventilator (6.8 [2–63] vs. 6.2 [3–17] days; P = 0.31), duration (median [range]) of hospital stay (7.5 [4–63] vs. 12 [5–16] days; P = 0.29), and mortality (11 [11%] vs. 4 [13.33%]; P = 0.21) were comparable to the IMV group. The causes of death among patients who failed NIV were septic shock (n=7) and ventilator-associated pneumonia (n = 4). Predictors of noninvasive ventilation failure: For identification of the early predictors of NIV failure univariate and multivariate regression analysis was performed using various baseline clinical and laboratory parameters of patients managed successfully with NIV and who failed NIV. **Conclusion:** NIV is feasible for management of ARF with non-CF bronchiectasis. High APACHE may predict NIV failure among these patients.

Keywords: Acute respiratory failure, mechanical ventilation, noncystic fibrosis bronchiectasis, noninvasive ventilation

Introduction

Non-invasive ventilation (NIV) is the application of ventilatory support via a non-invasive interface instead of an endotracheal tube or tracheostomy. Following early mechanical ventilation applications as negative pressure ventilation in the 1930s, the use of NIV in children has increased exponentially around the world in recent years[1]. Bronchiectasis is a condition wherein the bronchial tubes of the lungs are enlarged and permanently damaged, giving way for excess mucus and bacteria to build up in the lungs, causing infections. Bronchiectasis is a chronic condition in which the walls of the bronchial tubes are enlarged and permanently damaged. The thickened and damaged air passage due to inflammation allows mucus & bacteria to develop in the lungs. Eventually, the air passage gets infected & blocked. People who suffer from bronchiectasis will have periodic episodes of bad health characterised by temporary exacerbations; the period when breathing becomes difficult and lung health deteriorates. The disease is generally not curable. However, it can be treated and controlled so that the oxygen supply to the body is not cut off during an acute attack[2].

Non-cystic fibrosis bronchiectasis is a progressive condition generally associated with chronic bacterial infections and characterized by irreversible destruction and dilation of the airways[3]. The clinical course of individuals with non-cystic fibrosis bronchiectasis is variable, with a significant proportion of patients developing transient exacerbation leading to severe acute respiratory failure (ARF) and requiring ventilatory support[4]. Although the use of NIV in bronchiectasis exacerbations may appear attractive as it can reduce ICU stay, its failure rate exceeds 25%[5]. At the same time, subsequent application of invasive mechanical ventilation, which is associated with a mortality rate of 19 –35% and prolonged ICU stay, appears problematic[6]. According to the National

Institute for Health and Care Excellence guidance document issued in June 2012[7], extracorporeal CO_2 removal should be used to remove CO_2 from the blood of patients receiving mechanical ventilation who are unable to achieve adequate gas exchange at maximal tolerable ventilation pressures. Sporadic case reports and short case series concerning the use of an extracorporeal CO_2 removal system in patients who develop severe acute hypercapnic respiratory failure of various etiologies but do not respond adequately to NIV have been published in recent years. Extracorporeal CO_2 removal has, in fact, been successfully employed, and intubation has been avoided in some cases of exacerbation of COPD[8-11], cystic fibrosis, pulmonary fibrosis, severe asthma[8] and bronchiolitis obliterans[12]. Despite increasing interest in the use of extracorporeal CO_2 removal systems in patients who develop refractory hypercapnic ARF, its utility in the event of exacerbations in non-cystic fibrosis bronchiectasis has not been assessed. This report describes the management of a patient with exacerbated bilateral bronchiectasis, fibrothorax, and hypercapnic respiratory failure who was successfully treated by extracorporeal CO_2 removal following ineffective NIV support.

Material and methods

This was a prospective, randomized and double blinded clinical comparative study conducted in the Department of Anaesthesia, Netaji Subhas Medical College and Hospital, Bihta, Patna, India for 1 year.

Inclusion criteria

- Patients with bronchiectasis
- Patients who were admitted with ARF and required either NIV or invasive mechanical ventilation (IMV)

Exclusion criteria

- Patients with bronchiectasis who required admission for reasons other than ARF were excluded.
- patients who had ARF but managed with oxygen

The diagnosis of bronchiectasis was based on computed tomographic scan of the thorax showing typical findings[13] or etiology of bronchiectasis, all patients admitted under pulmonary medicine are routinely evaluated for ABPA, CF, connective tissue disease, mycobacterial infection, and immune deficiency. If the clinical and laboratory workup is negative than it is labeled as idiopathic. For this study, the final diagnoses at the time of discharge were used to classify the etiology of bronchiectasis. ARF was diagnosed based on the history of acute worsening of cough, breathlessness, respiratory distress or cyanosis and arterial blood gas (ABG) analysis showing either PaO_2 <60 mmHg or $PaCO_2$ >45 mmHg.

NIV start with inspiratory positive airway pressure (IPAP) of 8–10 cm of H_2O and expiratory positive airway pressure of 4–6 cm of H_2O. The patient is closely monitored for clinical stability/improvement and IPAP is adjusted accordingly. The IPAP is increased by 2–4 cm of H_2O every 5–10 min while observing the use of accessory muscles, respiratory rate, and comfort of the patient. Oxygen is given to keep oxygen saturation between 88% and 92%. If the patient does not improve even with IPAP of 20 cm of H_2O or develop intolerance at any IPAP, we switch to endotracheal intubation and mechanical ventilation. Furthermore, if the patient develops any signs of failure or contraindication of NIV such as hemodynamic instability, decreased mental status, and worsening respiratory acidosis at any time during NIV treatment, we will intubate and start mechanical ventilation. Those patients who stabilized with NIV were treated with NIV for the maximum duration on day 1, allowing breaks for meals and nebulization. Once patient recovered from the acute illness, weaning from NIV is accomplished by gradually increasing the off NIV periods as recommended by the British Thoracic Society[14].

Statistical analysis

To find the early predictor of NIV failure, univariate and multivariate analyses were performed to compare various clinical and ABG parameters between patients who were successfully managed with NIV as compared to who failed NIV. One way analysis of variance analysis was done for more than two groups with Bonferroni correction. $P < 0.05$ was considered to represent statistical significance for the study.

Results

There was a total of 250 patients with bronchiectasis who were admitted during the above specified period. Among these, 130 patients were admitted with ARF. Totally 130 patients who required either NIV or IMV. The most common etiology of bronchiectasis was post-tuberculosis (52%) followed by idiopathic (22%), ABPA (16%), and immunodeficiency (6%). The baseline characteristics of these patients are shown in Table 1.

NIV was initiated as first line of ventilator support for 100 patients. Among these, 65(65%) were managed successfully with NIV 35 (35%) patients failed NIV and required endotracheal intubation during the hospital stay. Reasons for NIV failure were worsening or non-improvement of ventilatory or oxygenation parameters (n=15), hypotension (n = 7), worsening of sensorium (n = 5), and intolerance (n = 6). NIV failure occurred after a median duration of 2.69(95% confidence interval [CI]-1.47–4.32) days after the initiation. The comparison of total duration of stay in hospital, number of days spent on ventilator support and mortality rate

between NIV and IMV are shown in Table 2. There was total 15 deaths in the study group. Among patients who failed NIV, total days (median [range]) spent on ventilator (6.8 [2–63] vs. 6.2 [3–17] days; P = 0.31), duration (median [range]) of hospital stay (7.5 [4–63] vs. 12 [5–16] days; P = 0.29), and mortality (11 [11%] vs. 4 [13.33%]; P = 0.21) were comparable to the IMV group. The causes of death among patients who failed NIV were septic shock (n=7) and ventilator-associated pneumonia (n = 4). Predictors of noninvasive ventilation failure: For identification of the early predictors of NIV failure univariate and multivariate regression analysis was performed using various baseline clinical and laboratory parameters of patients managed successfully with NIV and who failed NIV. The results are summarized in Table 3

Table 1 Demographic profile of the patients

Parameters	NIV (n=100)	IMV (n=30)
Age (years), mean±SD	48.01±20.13	51.75±16.12
Gender male, n (%)	65 (65)	20(66.67)
APACHE, mean±SD	14.03±4.21	16.65±6.78
Associated COPD, n (%)	13 (13)	7(23.33)
Reason for exacerbation, n (%)		
Infective	87 (87)	25 (83.33)
Noninfective	16 (16)	7(23.33)
Etiology, n (%)		
Post tuberculosis	52 (52)	23 (76.67)
Idiopathic	22 (22)	4 (13.33)
ABPA	16(16)	2 (6.67)
Immunodeficiency	6 (6)	0
Arterial blood gases at the time of admission (mean±SD)		
pH	7.65±0.087	7.21±0.14
$PaCO_2$ (mmHg)	76.26±20.33	83.31±21.07
PaO_2 (mmHg)	72.27±32.16	69.36±19.47
Bicarbonate (mmHg)	32.23±6.78	29.23±8.64
Oxygen saturation (%)	88.11±7.03	88.78±8.36

Table 2: Comparison of important clinical outcome

Outcome parameters	Mode of ventilation		P value
	NIV	IMV	
Days on ventilatory support, median (IQR	0 (0-4)	6 (2-11)	<0.001
Hospital length of stay (days), median (IQR	8 (6-12)	13 (6-13)	0.91
Mortality, n (%)	11 (11)	4 (13.33)	0.21

IQR: Interquartile range; NIV: Noninvasive ventilation; IMV: Mechanical ventilation

Table 3: Univariate and multivariate analysis for predictors of noninvasive ventilation failure

Parameter	OR (95% CI)	P value	OR (95% CI)	P value
Age (years)	1.21(0.97-1.15)	0.87	-	-
Gender	0.66 (0.18-1.42)	0.24	-	-
APACHE score	1.15 (1.14-1.43)	0.002	1.19(1.14-1.45)	0.001
Blood gases at admission				
pH	0.023 (0.005-4.75)	0.21	-	-
$PaCO_2$ (mmHg)	1.11(0.95-1.12)	0.44	-	

PaO$_2$ (mmHg)	1.11(1.07-1.12)	0.02	1.12(1.08-1.041)	0.05
Bicarbonate (mmHg)	0.97(0.93-1.12)	0.92	-	-
Oxygen saturation (%)	1.05(0.92-1.09)	0.53	-	-

CI: Confidence interval; OR: Odds ratio; APACHE: Acute physiology and chronic health evaluation

Discussion

Bronchiectasis may result from a number of infective and acquired causes, including pneumonia, tuberculosis, immune system problems, and cystic fibrosis. Cystic fibrosis eventually results in severe bronchiectasis in nearly all cases. The cause in 10–50% of those without cystic fibrosis is unknown. The mechanism of disease is breakdown of the airways due to an excessive inflammatory response. Involved airways (bronchi) become enlarged and thus less able to clear secretions. These secretions increase the amount of bacteria in the lungs, result in airway blockage and further breakdown of the airways[15].

Our study results have shown that NIV as the "primary modality" of ventilatory support is feasible for treatment of ARF among patients with non-CF bronchiectasis. Its use was associated with success rate of 65%. The correction of various ABG parameters using NIV at various time intervals was comparable to that of IMV. There was total 15 deaths, 11 in NIV and 4 in IMV group. The duration of hospital stay for NIV was comparable with IMV. Selection of mode of ventilatory support during ARF among patients with structural lung disease is crucial for optimum outcome. For COPD, NIV remains the mode of the first choice[16]. Patients with bronchiectasis have similar clinical features as COPD, such as cough, breathlessness, and obstructive pattern on spirometry. Many of these patients develop hypoventilation and hypercapnic respiratory failure[6]. However, for management of ARF among patients with bronchiectasis NIV is not used routinely. In our study, more than 76.92% (100/130) patients with bronchiectasis and ARF were given NIV as the first mode of ventilatory support. High rate of NIV use in our study was to be probably due to two reasons. First, our hospital is a tertiary care center and we have very good experience of NIV and Intensive Care Unit (ICU) backup, if required. Second, these patients had hypercapnic respiratory failure and there is enough evidence to support NIV use for correction of hypercapnia and respiratory acidosis[16-18]. This might have led to use of NIV for bronchiectasis and respiratory failure. Studies have shown that insertion of endotracheal tube in patients with structural lung diseases such as bronchiectasis would result in complications[19]. The successful use of NIV as shown in this study highlights that in almost two-third of the patients with bronchiectasis and ARF the endotracheal intubation may be avoided. Phua et al. reported their experience with NIV for management of 31 patients of non-CF bronchiectasis with ARF[6]. Their success rate of NIV was comparable to our study (65% vs. 68%). One of the reasons for not using NIV in patients with bronchiectasis may be the presence of copious amount of sputum. Inability to handle respiratory secretions is one of the contraindications for NIV use[16,17]. However, it should be noted that in this study none of the patients failed NIV due to excessive secretions. These results were consistent with the previous study in which also no patient failed NIV due to inability to handle respiratory secretions[6]. Normalization of the physiological parameters such as blood gas values is also one of the goals of ventilatory support[20]. Longer stay in hospital and ICU has been associated with increased chances of nosocomial infections, increased the cost of care and

mortality[21,22]. Faster the normalization of these parameters and early weaning may avoid all these. IMV, due to better control on set variables, is expected to correct both ventilatory and oxygen parameters faster than NIV. However, our study has shown that the various ABG parameters at different time intervals were comparable between patients on NIV and IMV. These results indicate that the rate of correction of ABG parameters similar to IMV may be achieved with NIV without potential complications associated with endotracheal intubation. One observation in this study which needs to be discussed is the NIV failure. Failure rate of NIV described in patient with COPD and ARF was approximately 20%[23]. The failure rate of NIV in our study was approximately 35% which is higher than described in patients with COPD[23]. However, this rate was comparable (34% vs. 35%) to those reported by Phua et al., in patients with bronchiectasis[6]. Both these studies were limited by retrospective study design therefore true association with the outcome is still not known. Overall mortality in NIV group (11%) was lower than IMV (13.33%). In NIV Group, 11 patients died and all these had failed NIV and subsequently put on IMV. These results highlight the importance of early identification of the patients who would likely to fail NIV to avoid worse outcome. We tried to find the predictors of early NIV failure. In our study, univariate analysis showed that high APACHE score and worse PaO_2 at the time of admission were associated with failed NIV, however the association was weak. When multiple regression model was applied only high APACHE score was associated with NIV failure (odd's ratio [95% CI]: 1.19 (1.14-1.45)]). These results indicate that APACHE score may be used as a predictor of NIV failure for these patients. Other studies also reported the predictors of NIV failure which included APACHE score, worse hypercapnia, and hypoxemia[16,6,24]. In our study, $PaCO_2$ and PaO_2 at baseline and at 2 h were

similar in both groups. Our study also showed that the duration of hospital stays and time spent on ventilator by patients who failed NIV were comparable with the patients who received IMV as first-line management strategy. This implies that the failure of initial trial of NIV among these patients did not impart additional risk of adverse outcome in these patients. This is one of the largest studies describing the outcome of NIV use in patients with non-CF bronchiectasis and ARF.

Conclusion

The present investigation revealed that NIV is feasible for management of ARF with non-CF bronchiectasis. High APACHE may predict NIV failure among these patients.

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