Original Article

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Predicting Efficacy and Failure Risk of Non-Invasive Positive Pressure Ventilation in Chronic Obstructive Pulmonary Disease Exacerbation through Arterial Blood Gas Analysis

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Abstract

Background: The purpose of this prospective study was to assess the efficacy and likelihood of failure of non-invasive positive pressure ventilation (NPPV) by means of arterial blood gas analysis (ABG) in patients with exacerbation of chronic obstructive pulmonary disease (COPD) which could predict the need for endotracheal intubation to be instituted at the earliest.

Methods: Risk stratification of NPPV failure was assessed in 50 patients admitted at Chest Disease Hospital in Goa Medical College Hospital units, including intensive care units, NPPV was used in all patients with pH between 7.20 and 7.35 at admission. ABG was done on patients come with COPD exacerbation (at admission, after 1 h, and after 6 h of NPPV). The outcome variable was defined as failure of NPPV due to invasive ventilation or death. The aim was to predict the risk of failure using ABG at the earliest to decide whether or not to intubate.

Results: Clear differences were found between the patients who succeeded and those who failed, with respect to the predictor variables observed at admission and after 1 h of NPPV. After 1 h and 6 h of NPPV, the main factor influencing the outcome was the pH value: If pH <7.25, the odds ratio (OR) for failure is 21.02 ($P < 0.0001$), whereas if pH after 1 h is between 7.25 and 7.30, the OR is 2.92 ($P < 0.005$). Chi-square test value for our study population is $\chi^2 = 5.43$ and the $P < 0.05$ and the response obtained with non-invasive ventilation is not by chance.

Conclusions: pH seems to be a very important variable in predicting failure of NPPV, the current authors evaluated that pH <7.25 after 1 h and 6 h of NPPV in a patient admitted with COPD exacerbation predict the failure risk with 100% specificity.

Key words: Intubation, Non-invasive, Pulmonary disease, Respiratory failure, Ventilation

INTRODUCTION

Non-invasive positive pressure ventilation (NPPV), in patients with exacerbations of chronic obstructive pulmonary disease (COPD) and respiratory acidosis, reduces the intubation rate and mortality.[1-9] Operated by well-trained teams, NPPV is effective and safe in both intensive care settings[10] and general respiratory wards.[8] A randomized, clinical trial showed that NPPV also reduces mortality in COPD patients in the intensive care unit (ICU) within the inclusion criteria for intubation.[6] Nevertheless, two recent consensus guidelines on NPPV in acute respiratory failure (ARF) recommend that NPPV should not be used as a substitute for endotracheal intubation and invasive ventilation when the latter is clearly more appropriate.[11,12] The likelihood of failure of NPPV is crucial in deciding if and when to apply this ventilator technique.

The purpose of the current study was to assess the risk of NPPV failure at the earliest with the help of arterial blood gas (ABG) alone and to build a risk chart of failure of NPPV to be used in hospitals.

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METHODS

The study was conducted from period of September 2008 to September 2011. The data were collected from 50 patients affected by COPD exacerbation and respiratory acidosis with pH between 7.20 and 7.35 that were treated by NPPV in addition to standard medical therapy (oxygen supplementation, systemic corticosteroids, inhaled bronchodilators, antibiotics, and diuretics if needed). These patients were admitted to general wards and ICUs where NPPV is the first-line intervention for such patients. The admission criteria for different units were based on the need for an appropriate level of care, but the personnel in each unit were well-trained in the use of NPPV. ABG was done on patients come with COPD exacerbation (at admission, after 1 h, and after 6 h of NPPV). The outcome variable was defined as both success group where patients improved and discharged after NPPV and failure group where patients end up invasive ventilation or death.

The units used NPPV Respironics bi-level positive airway pressure (BiPAP®)|pro 2 via face and/or nasal mask. Every patient who satisfied the criteria with hypercapnic respiratory failure and respiratory acidosis due to exacerbation of COPD was included in the current observational study received NPPV at admission. The definition of COPD exacerbation was in accordance with that of the American Thoracic Society. NPPV failure was defined as the need for endotracheal intubation.

The study used strict inclusion and exclusion criteria to reduce the influence of external factors (Table 1).

Pre-determined Criteria for Endotracheal Intubation Included

1. Worsening of pH and carbon dioxide tension in arterial blood ($PaCO_2$) in spite of correct NPPV administration (e.g. pH ↓0.04 and $PaCO_2$ ↑0.8 kPa, 6 mmHg)
2. The need to protect the airways (coma or seizure disorders) or to manage copious secretions
3. Hemodynamic instability (heart rate, 50 beats/min with loss of alertness, and/or systolic blood pressure, 70 mmHg)
4. Agitation and inability to tolerate the mask.

The following Data were Collected for Every Patient

1. General demographic information (age, sex, weight, and height) and clinical data
2. Data relative to the institution of NPPV, including cause of exacerbation, ABGs (before beginning NPPV, after 1 h, at 6 h, and at discharge), respiratory rate (RR), cardiac frequency, length of stay in hospital, and total hours of ventilation.

Table 1: Inclusion and exclusion criteria

Inclusion criteria
Known case of COPD with supportive or high probability of disease (based on clinical history, smoking history, physical examination, and chest radiography) with Type II respiratory failure
RR >25 breaths/min
Respiratory acidosis with
pH between 7.20 and 7.35
PCO_2 >45 mmHg but <75 mmHg
Use of accessory muscles or abdominal paradox
Hemodynamically stable, functional GIT, normal bulbar, and having spontaneous respiratory drive
Exclusion criteria
Patient with PCO_2 of >74 mmHg and severe acidosis of pH <7.20
Recent upper airway or GIT surgery
Fixed upper airway obstruction
Facial trauma
Severe cardiac disease New York Heart Association IV. (Unstable angina, severe cardiac arrhythmias)
Disorders of basal brain nerves/derangement in swallowing or persistent vomiting
Local derangement of face/skin/tongue/upper airway/larynx
Impaired consciousness (GCS <8)
Pneumothorax without ICT
Hemodynamic instability with BP<90 mmHg
HR <60 beats/min
Bronchorrhea (copious secretions)
Pneumonia and other illness which will influence the invasive ventilator requirement

HR: Heart rate, BP: Blood pressure, GCS: Glasgow coma scale, ICT: Insertion of a chest tube, GIT: Gastrointestinal tract, COPD: Chronic obstructive pulmonary disease

Variable Definition and Statistical Analysis

The outcome variable was defined as failure of NPPV due to invasive ventilation or death. Three charts of failure risk were built from the final predictive models obtained using logistic regression; they refer to the proportion predicted to fail with NPPV treatment at admission, 1 h and after 6 h of NPPV. The aim was to predict the risk of failure using ABG at the earliest to decide whether or not to intubate.

RESULTS

A total of 50 patients were recruited and were treated with NPPV for the management of ARF due to COPD exacerbation (Table 2).

NPPV was performed successfully in 46 patients (92%) until the normalization of ABGs. Among the 4 (8%) patients who failed, 2 (4%) patients were intubated and 2 (2%) died without intubation due to a previous "do-not-intubate" order. Among the 2 intubated patients, 1 patient successfully completed the treatment and 1 patient died.

Successful patients had better values of $PaCO_2$, pH, RR, and oxygen arterial tension after 1 h of NPPV compared with patients who failed to improve.

Comparison of ABG Analysis between Success and Failure Group

Comparison of ABG analysis for pH, PCO_2, and SaO_2 were done at baseline, after 1 h and 6 h of BIPAP between success and failure group (Table 3 and Graph 1).

The variables measured that were found to significantly increase the probability of NPPV failure were pH, 7.25 (odds ratio [OR] 51.97, $P = 0.05$), PCO_2 ($P = 0.05$) SaO_2, and RR. After 1 h and 6 h of NPPV, the main factor influencing the outcome was the pH value: If pH <7.25 the OR for failure is 21.02 ($P = 0.0001$), whereas if pH after 1 h is between 7.25 and 7.30, the OR is 2.92 ($P = 0.005$).

Chi-square test value for our study population is $\chi^2 = 5.43$ and the $P < 0.05$ and the response obtained with non-invasive ventilation (NIV) is not by chance. There is a significant association between use of NIV and improvement of the patient with COPD in exacerbation with Type II respiratory failure.

Repeated measures ANOVA test by Greenhouse-Geisser method was used to analyze the data. $P < 0.05$ was taken as statistically significant. Changes occurred in pH, PCO_2, and SaO_2 at 1 h and 6 h after starting the BIPAP had been compared with the same parameters before initiation of BIPAP. The change in pH and PCO_2 after 1 h of starting the NPPV determines the failure risk of NPPV treatment and guides the further course of management.

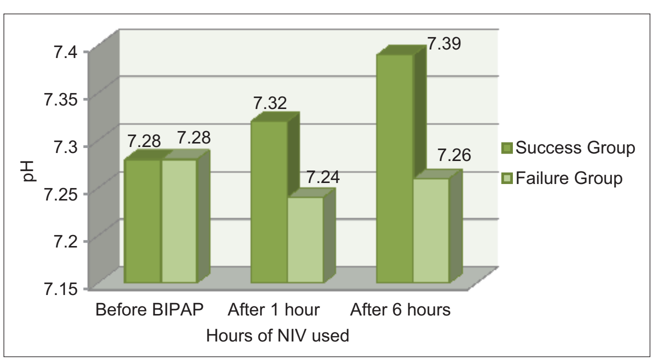
Table 2: Main demographic characteristics at the start of NPPV

Age	Total number	Percentage
51-60	24	48
61-70	21	42
>70	5	10

Table 3: ABG data

Variable	Success group	Failure group	Significance
Before BIPAP			
pH	7.28	7.28	NS
PCO_2	55	57	NS
SaO_2	84	82	NS
After 1 h			
pH	7.32	7.24	S
PCO_2	48	58	S
SaO_2	88	78	S
After 6 h			
pH	7.39	7.26	S
PCO_2	40	58	S
SaO_2	91	80	S

BIPAP: Bi-level positive airway pressure, ABG: Arterial blood gas



Graph 1: pH comparison

DISCUSSION

The author used the data to assess the risk of NPPV failure using at admission, 1 h and after 6 h of ventilation. These values could be used to determine the possibility of failure or success of NPPV in patients with acute decompensate COPD and to help the clinical decision-making process. In particular, given that the Gold Initiative for Chronic Obstructive Lung Disease guidelines suggested an initial trial of NPPV for most patients anyway, the decision to continue or not continue with NPPV can be greatly helped by ABG values obtained after 1 h and 6 h of NIV.[13-20]

The mortality rate in the current study is better than observed in the most quoted controlled trials on NPPV in carefully selected patients with acute exacerbation of COPD.[1-3,5] Data from a multicenter study performed in British respiratory general wards showed that if pH and/or $PaCO_2$ improved after 1-4 h, successful NPPV was probable.

Clear differences were found between the patients who succeeded and those who failed, with respect to the predictor variables observed at admission and after 1 h of treatment.[21-24] In particular, after 1 h of NPPV, the main factor influencing the outcome was the pH value. Since pH seems to be a very important variable in predicting failure of NPPV and there is much discussion about which is the correct cut off to choose, the current authors evaluated that pH <7.25 after 1 h and 6 h predict the failure risk with 100% specificity.[25-27]

CONCLUSION

The efficacy of NPPV in acute exacerbation of COPD is well-documented that international guidelines[28] recommends it as the first choice treatment of ARF with respiratory acidosis. Nevertheless, given that NPPV is used in a variety of care settings, it may be important to know the likelihood of failure of NPPV by means of readily available simple investigation like ABG in patients with exacerbation of COPD could predict the need for endotracheal intubation to be instituted at the earliest.

Thus, the authors think they could greatly help the decision on clinical management of the patient. Using the ABG alone, it is possible to predict "a priori" the probability of NPPV failure and reduce the useless and prolonged use of NPPV in patients with respiratory acidosis due to COPD exacerbation.

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