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Research Article

Role of initial arterial blood gas variations in predicting the outcome of pneumonia patients with type I/II respiratory failure

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ABSTRACT

Background: A correlation between, the early variations in the individual arterial blood gas (ABG) parameters - pH, PaO_2, $PaCO_2$ and HCO_3-, and the treatment outcome, in pneumonia patients in respiratory failure, has not been well investigated. If a statistically significant variation among the individual ABG parameters would be an early, reliable predictor of the treatment outcome, it would facilitate prompt active management of the patient in respiratory failure from pneumonia before a clinically apparent downward turn culminates.
Methods: This prospective study was conducted on a sample of 42 patients, with clinical evidence of pneumonia and baseline clinical data and 2 arterial blood samples (one, at the baseline and another, within 24 hours from the first) were harvested for ABG analysis. Assessment of the ABG reports classified patients as belonging to group 'A' with type I (hypoxemic) respiratory failure or as group 'B' with type II (hypercapnic) respiratory failure. Binary logistic regression analysis was performed.
Results: In group A, the individual ABG parameters had a significant positive correlation with the treatment outcome: pH (p=0.034), HCO_3- (p=0.034), PaO_2 (p=0.035), $PaCO_2$ (p=0.045), whereas in Group B, a non-significant positive correlation, pH (p=0.284), HCO_3- (p=0.248), PaO_2 (p=0.39), $PaCO_2$ (p=0.240) was observed. In group B, a treatment failure rate of 40.91% was seen, as against 25% in Group A.
Conclusions: Variations among individual ABG parameters can predict treatment outcome in pneumonia patients of type I respiratory failure, and fail to do so in those with type II respiratory failure.

Keywords: Arterial blood gas, Pneumonia, Hypoxemia, Hypercapnia, Chronic obstructive pulmonary disease

INTRODUCTION

Community-acquired pneumonia (CAP) is one of the commonest diseases plaguing the human race, affecting approximately 450 million people a year and occurring in all parts of the world.[1] It is a major cause of mortality among all age groups resulting in 4 million deaths (7% of the world's yearly total).[1]

Most of the all-cause and pneumonia-related deaths among the inpatients can be attributed to the severity of the disease process itself, instigated or complicated by the prevalence of co-morbidities and also to the inability of the clinician to predict the outcome of the treatment within the golden 24 to 48 hours of the patient immediately following admission to the hospital. Treatment (both specific and supportive) is usually started empirically, and as such, a clinically detectable downward turn in the disease course of the patient is warranted before intensive therapy is instituted. Hence, tools to guide the physician to predict and accordingly alter the line of management in patients with an underlying pneumonia, would greatly aid the physician to intervene, and prevent fatality.

Pneumonia leads to consolidation of the lung parenchyma, eventually leading to oxygenation (hypoxemic) failure, i.e. type I respiratory failure. Much literature exists, linking chronic obstructive pulmonary disease (COPD) with pneumonia. Pneumonia, when in conjunction with an acute exacerbation of chronic obstructive pulmonary disease (AECOPD) commonly results in acute ventilatory (hypercapnic) failure i.e. type II respiratory failure. Pneumonia can also end in respiratory failure by triggering acute respiratory distress syndrome (ARDS), which results from a combination of infection and inflammatory response. Diagnosis and treatment of respiratory failure rests on arterial blood gas analysis.

Arterial blood gas (ABG) analysis is done to evaluate the oxygen and carbon dioxide gas exchange and acid-base status. ABG analysis is said to be one of the commonest tests performed in an ICU setting. The exalted growth of ICUs in the mid 20th century coincided with the dawn of the ABG analysis. With the invention of better and more accurate electrodes for the precise estimation of pH, partial pressures of oxygen and carbon dioxide (PaO_2, $PaCO_2$ respectively), and also the calculated bicarbonate (HCO_3-) levels, in the arterial blood sample, the indications for the test are also on the rise.[2,3] Other general indications for ABG analysis in severely ill adults include pathophysiologic abnormalities that can alter gas exchange or acid-base disturbances.[4] Conventionally, however, there have been few studies implicating the use of serial arterial blood sampling to attain a prospective outlook at the patient.[4,5] This study aimed to observe the variations in the ABG parameters (pH, PaO_2, $PaCO_2$ and HCO_3-) of pneumonia patients admitted to the medical intensive care unit (MICU) with type I and type II respiratory failure, in the initial 24 hours following admission. The objective was to assess if any statistically significant variations in the ABG parameters in the initial 24 hours following admission, could predict the outcome, as it would deem useful for the treating physician to make decisions on the change in the line of treatment before the cultures and other investigations prove the etiological agent.

METHODS

This prospective, observational study was conducted at the medical intensive care unit (MICU), of a tertiary teaching hospital in South India, for the 12 months period from June 2012 to June 2013. This study was approved by the Institutional Ethics Committee (IEC) before commencing, and written informed consent was obtained from all patients or their proxy (bystanders) before enrollment into the study.

Patient baseline assessment

For all the study patients, the baseline clinical data at the time of presentation was assessed by patient interview and also the medical records. The clinical data collected included the presence of symptoms and physical examination findings at presentation, baseline vital signs, respiratory rate, pulse rate, blood pressure and temperature, primary diagnosis, mode of oxygen delivery and co-morbid illnesses.

The patients with clinical evidence of any of the following symptoms- fever, dyspnoea, cough with expectoration, pleuritic chest pain or haemoptysis with or without radiographic infiltrates, were included and categorized into two groups: group A; 20 patients with type I or hypoxemic respiratory failure, considered as and group B; 22 patients with type II or hypercapnic respiratory failure.

The patients who succumbed to mechanical ventilatory support within 24 hours of admission and those with a history of admission/discharge from a health-care centre within 10 days prior to presentation were considered ineligible to be included into this study. Patients with a previous history of co-morbidities like congestive cardiac failure, cerebro-vascular disease, and renal and liver failure or malignancy were also excluded. Arterial blood gas analysis was done twice, once at the baseline (at the time of presentation/ ICU admission) and the other, within 24 hours from the first.

The arterial blood sample for ABG analysis was obtained either by arterial puncture with a thin bore needle 6 or directly from an indwelling intra-arterial catheter 7 with clean, sterile, 2 ml sodium heparin-coated (1000µ/ml) close-fitting syringes to minimise contamination of the arterial blood sample with room air.[8] To reduce the dilution effects, heparin was expelled from the syringe and a 1 ml sample of blood withdrawn into the syringe and discarded prior to drawing the 2 ml test sample. Air bubbles were expressed and the syringe was capped and iced immediately.[9] The samples were analysed with blood gas analysers, which were calibrated according to the manufacturer's specifications and regular quality control measures were taken up, so as to minimise the measurement errors.

Criterion of grouping patients

Analysis of the parameters of pH, PaO_2, $PaCO_2$ and HCO_3- of the baseline ABG report is used to group patients as type I or type II respiratory failure.

All patients with PaO_2 level of ≤70mm of mercury were grouped under type I respiratory failure (group A), provided that the $PaCO_2$ was either below or within the normal limits. All patients with $PaCO_2$ levels ≥50 mm of mercury were classified as type II respiratory failure and were included under group B.

Patient follow up and criteria for determination of outcome

Each patient was followed up until the final outcome of the individual could be assessed. The total duration of

ICU stay and hospital stay in days was recorded and the outcome was considered to be success if the total duration of stay was ≤21days and the patient was discharged satisfactorily on clinico-radiological grounds. The outcome was considered 'failure' if the patient had a long hospital stay of >21 days or died during treatment or if he/she required invasive endotracheal intubation and mechanical ventilatory support during the course of the illness.

Statistical analysis

Analysis was done with the IBM SPSS 10 software package, to carry out binary logistic regression analysis of the data obtained. The p value of significance was set at 0.05.

RESULTS

Of the 42 patients enrolled in this study, 20 patients with type I or acute hypoxemic respiratory failure were grouped into group A and 22 patients with type II or hypercapnic respiratory failure were labelled as group B.

Among the 20 patients in the group A, at the end of the treatment, outcome of 15 (75%) patients, who got discharged satisfactorily, within 21 days of admission, was considered success, while that of 5 (25%) patients who succumbed to death during the course of treatment was regarded as failure. Half of the patients belonging to the success group were treated in room air, with no artificial or mechanical ventilation during the course of their stay, 4 patients required oxygen therapy with nasal mask, while 1 patient was put on nasal prongs. Patients who required oxygen therapy were put either on nasal mask or nasal prongs empirically with the aim of keeping the oxygen saturation above 90% in the initial hours of inpatient care.[10,11] Among the 5 patients of the failure group, in the initial hours of treatment, 1 patient was treated with room air, 3 others were given oxygen therapy using nasal prongs, while 1 patient was put on nasal mask. All these patients succumbed to death during the course of treatment.

Although the mean duration of MICU stay, in group A, was shorter for patients belonging to the success group (1.47 days), while that of the failure group was longer (4.2 days), the duration of total hospital stay appears to be higher in the success group (10.2 days) in comparison to that of the failure group (5.6 days) (Table 1).

Among the 22 patients of group B, the outcome of 13 patients who were discharged satisfactorily, within 21 days of admission, was considered success, while that of 4 patients who died during the treatment (of which, 2 patients required mechanical ventilatory support for 4 and 6 days respectively) and 5 patients with prolonged hospital stay was considered failure. The success group had shorter mean ICU stay (1.85 days) and total hospital stay (8.77 days) in comparison to those of the failure group (4.34 days and 15.56 days respectively). While 7 of the 13 patients belonging to the success group required oxygen therapy in the initial hours of treatment, the figure in the failure group was 8 of the 9 patients (Table 2).

Table 1: Group A-type I respiratory failure.

	Success group	Failure group	Total
Total no. of patients	15 (75%) §	5 (25%) §	20
Relieved	15 (100%) #	0 (0%) #	15
Death	0 (0%) #	5 (100%) #	5
Mechanical Ventilation	0 (0%)	0 (0%)	0
Room air	10 (50%) §	1 (5%) §	11
Nasal Mask	4 (20%) §	1 (5%) §	5
Nasal Prongs	1 (5%) §	3 (15%) §	4
Total ICU stay (days):			
Range	1-8	1-10	
Average	1.47	4.2	
Total hospital stay (days):			
Range	5-18	2-10	
Average	10.2	5.6	
Age (years)			
Range	29 -98	59 -83	
Average	59.74	71.2	
Gender			
Male	9	5	14
Female	6	0	6

§: Among the total of 20 patients in group A; #: Among the total of 15 and 5 patients constituting success and failure groups.

Table 2: Group B: type II respiratory failure.

	Success group	Failure group	Total
Total no. of patients	13 (59.09%)§	9 (40.91%)§	22
Relieved	13 (72.23%)#	5 (27.78%)#	18
Death	0 (0%)	4 (18.18%)	4
Mechanical Ventilation	0 (0%)	2 (9.09%)	2
Room Air	6 (27.27%)§	1 (4.54%)§	7
Nasal Mask	3 (13.63%)§	7 (31.82%)§	10
Nasal Prongs	4 (18.18%)§	1 (4.54%)§	5
Total ICU Stay (days)			
Range	1-6	1-15	
Mean	1.85	4.34	
Total hospital Stay (days)			
Range	2-21	1-33	
Mean	8.77	15.56	
Age (years)			
Range	40-76	60 -74	
Mean	64	68.78	
Gender			
Male	8	8	16
Female	5	1	6

§: Among the total of 22 patients in group B. **#:** Among the total of 13 and 9 patients constituting success and failure groups.

There was a higher failure rate among the patients of group B (40.91%) in comparison to that of group A (25%).We found a significant association with changes among the pH (p=0.034), PaO_2 (p=0.03), $PaCO_2$ (p=0.045) and HCO_3- (p=0.034) among the patients of group A. Among the patients of group B, however, we found no significant association between either of PaO_2, $PaCO_2$, HCO_3- or pH individually with the final outcome of the patient.

In group A, we found a significant association with the outcome, when the change in pH and PaO_2 (p=0.036), pH and $PaCO_2$ (p=0.043), pH and HCO_3- (p=0.041), $PaCO_2$ and HCO_3- (p=0.0432) and PaO_2 and HCO_3- (p=0.035) were considered in pairs. We found a non-significant positive co-relation between the variations among $PaCO_2$ values and treatment outcome in patients of group B.

DISCUSSION

In the present study it was found that, in type I respiratory failure, significant variations among any of the 4 parameters of arterial blood, i.e. pH, PaO2, PaCO2 and HCO3- within the first 24 hours following admission could reliably predict the outcome of the treatment. However, in patients with type II respiratory failure, the early changes of these ABG parameters fail to predict the outcome reliably.

Whereas no previous study, to our knowledge, was designed to predict outcome in pneumonia patients going into respiratory failure, through estimation of the early variations among the ABG parameters, our findings in the type II respiratory failure patients contradict that obtained in the retrospective survey conducted by Jeffrey et al 12 in 1992 where, they concluded that arterial (H^+) is a reliable predictor of outcome in these patients. This contradiction could be owed to the fact that the current study aims at predicting the outcome of treatment in patients from the 2 samples of arterial blood analysed in the first 24 hours following admission, while, the published literature goes beyond the initial 24 hours, to analysis of ABG samples obtained during the entire course of treatment, to predict the outcome.[12]

Among the patients of group A, i.e., type I respiratory failure, 30% of the patients had a positive history of chronic obstructive pulmonary disease, and 20% of the patients had other co-morbid illnesses, excluding congestive cardiac failure, cerebro-vascular disease chronic kidney disease, liver disease or active malignancy. 25% of the patients had diabetes mellitus and another 25% were on treatment for hypertension, 15% of these patients had both diabetes mellitus and hypertension.

Although we find that variations in the individual ABG parameters themselves can reliably predict the outcome of treatment, our data also reveals that the significance of using variations in any single parameter to predict treatment outcome is nearly just as dependable as using variations among 2 such parameters. Inclusion of variations among 3 ABG parameters together is significantly less dependable, than the former.

The most reliable predictor of treatment outcome in type I respiratory failure appears to be the variations in the values of pH and HCO3- (p=0.034), independently, followed by that of PaO_2 (p=0.035) and lastly by $PaCO_2$ (p=0.045).

In the group B patients, a non-significant positive correlation was obtained between the patient outcome and the variations in the ABG parameters. This can be attributed to the positive history of COPD in 16 (72.72%) of the patients and the presence of other co-morbidities in 27.27% of which cardiac, in 22.73%. 36.36% of the patients were either hypertensive or diabetic and 9% were both hypertensive and diabetic. Many articles have shown a link between chronic obstructive pulmonary disease and community-acquired pneumonia in that episodes of AECOPD could be associated with an episode of CAP[13-18], and also CAP as a complication of the long term use of potent inhalational steroids used for the control of COPD.[22, 23] COPD is considered as a risk factor for CAP, and previous studies of CAP including inpatient, outpatient, and ICU cohorts have shown that COPD is frequently reported as a co-morbid condition.[24, 25] Hence, the early changes in the ABG parameters could not reliably predict the outcome, because the interplay of the other co-morbid conditions with the disease state of the patient becomes very prominent in the case of the type II respiratory failure patients we included.

Our results are supported by a recent study, conducted by Christensen et al aimed to examine the influence of arterial blood gas derangement and burden of co-morbidities on 90-day and 1-year mortality of chronic obstructive pulmonary disease patients treated with invasive mechanical ventilation and they concluded that chronic obstructive pulmonary disease patients treated with invasive mechanical ventilation have substantial long-term mortality.[26] Neither the levels of arterial blood gas values measured immediately before invasive mechanical ventilation was initiated nor the burden of co-morbidity were strong determinants of long-term mortality among these patients.

The current study has many limitations that are important to acknowledge. Firstly, the sample size we considered was small. Secondly, we did not consider radiographic evidence of pneumonia to be strictly incorporated into the inclusion criteria. Among most of the patients with radiographic lung infiltrates, the baseline ABG was assessed prior to obtaining the chest X ray film, although, eventually, the diagnosis of pneumonia was confirmed. Finally, we also considered known cases of COPD, who, during the study period, required admission owing to episodes of acute exacerbation of the disease. A significant correlation between AECOPD and CAP is well established, and treatment with antimicrobials for pneumonia was started empirically in these patients,

owing to the published literature of better outcome with this tactic. However, it is also known, that patients of COPD suffer from various other co-morbidities and the outcome of treatment in a patient with co-existing pneumonia and COPD is grim, in comparison to a non-COPD patient presenting with pneumonia.[24,25]

The neglect of research in the field of pneumonia over the past decade has left many important clinical and epidemiological questions unanswered.[27] Further studies implicating a larger sample size and more stringent inclusion and exclusion criteria are warranted, to decisively predict the outcome of conservative inpatient care in pneumonia patients presenting with respiratory failure; through indicators and indices that are easily accessible to the clinician, early in the treatment, such as arterial blood gas analysis; as these would turn out to be very useful to prevent treatment failure and mortality in these patients. The clinician would then be able to alter the line of management of the patient and institute intensive therapy, if required, to protect the patient before damage caused by the disease triggers a downward spiral.

CONCLUSION

Variations among individual ABG parameters can predict treatment outcome in pneumonia patients of type I respiratory failure, and fail to do so in those with type II respiratory failure.

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