ISSN:0975 -3583,0976-2833 VOL14, ISSUE 07, 2023

Original research article

A study on acid-base balance, serum electrolytes, and need for noninvasive ventilation in patients with hypercapnic acute exacerbation of chronic obstructive pulmonary disease

[1]Dr. Parveen Shaik, [2]Dr. Akkem Vijaya Jyothi, [3]Dr. P Sukumar, [4]Dr. Devagudi Rama Devi

[1]Assistant Professor, Department of Physiology, Government Medical College, Kadapa, Andhra Pradesh, India

[2]Assistant Professor, Department of Pathology, Government Medical College, Kadapa, Andhra Pradesh, India

[3]Assistant Professor, Department of General Surgery, Government Medical College, Kadapa, Andhra Pradesh, India

[4]Assistant Professor, Department of Paediatrics, Government Medical College, Kadapa, Andhra Pradesh, India

Corresponding Author:
Dr. Devagudi Rama Devi

Abstract

Background: Hypoventilation produces or worsens respiratory acidosis in patients with hypercapnia due to acute exacerbations of chronic obstructive pulmonary disease (AECOPD). In these patients acid–base and hydroelectrolite balance are closely related. Aim of the present study was to evaluate acid–base and hydroelectrolite alterations in these subjects and the effect of non-invasive ventilation and pharmacological treatment.

Materials and Methods: We analyzed 110 patients admitted to the Pulmonology Department at Government General Hospital, Kadapa, from January 2022 to December 2022, for hypercapnic AECOPD. On admission, all patients underwent history taking, full examination, and arterial blood gas analysis and received oxygen with nasal cannula or a venturi mask to preserve normal oxygen saturation, as well as received pharmacological treatment. NIV was started when patients had severe dyspnea, increased work of breathing, and respiratory acidosis despite optimum management.

Result: The mean potassium of the patients who needed medical treatment only was 5.74±0.44 m E q/l and mean Sodium was 139.31±5.99 m E q/l, whereas the mean potassium for the other group was 6.34±0.59 m E q/l and mean Sodium was 137.23±6.22 m E q/l. The mean serum Bicarbonate of the group the need medical treatment only was 25.71±3.39 m E q/l. The mean serum Bicarbonate of the other group was 31.03±3.15 m E q/l. In table: 5, the Sodium and Potassium levels before treatment were 137.22±6.22 and 6.33±0.59 m Eq/l, respectively, and mean Sodium and Potassium levels after treatment were 135.38±5.79 and 5.48±0.58 m Eq/l, respectively.

Conclusion: Higher smoking index and frequency, more frequent COPD exacerbations, higher heart rate and respiratory rate,lower serum electrolytes (Na & K),lower PH and PaO2/FiO2 can significantly indicate a more severe AECOPD and higher smoking index (SI), PaCO2, frequent AECOPD, or lower PaO2 and Pao2/FiO2 can be used as independent predictors for the need for NIV.

Keywords: COPD, AECOPD, NIV, ABGs, electrolytes, Na, K

Introduction

Hypercapnic respiratory failure is a complex clinical and functional condition, characterized by an alteration of the acid/base (AB) balance, associated with multi-organ impaired function [1]. Several physiological systems are involved in the control of the AB balance, namely the respiratory system, the kidney, as well as red blood cells and blood proteins, and the bicarbonate buffering system [2]. The AB balance and hydro-electrolytic (HE) balance are closely related, as for any increase in CO2 (Respiratory Acidaemia), a counterbalancing metabolic alkalosis occurs as main compensatory mechanism achieved by a complex ion urinary excretion mechanism [3].

Therefore, in order to manage the AB disorders it is necessary to understand its fine regulatory mechanisms. For the interpretation of AB disorders two approaches can be used: a physical-chemical approach (which relies on the theory of the Strong Ion Difference [SID]) or a pathophysiologic approach (which relies on the compensation laws) [3]. Many authors consider the physicochemical approach a complex and unfeasible approach, and poorly matching with the clinical reality. Moreover, it requires many factors to calculate the SID [4]. On the other hand, the physio-pathological approach is easier and much more reliable, because it provides a quantitative measurement of the AB compensatory responses. Many trials, performed in different clinical disorders, have supported its use in humans [5].

In this study we used the pathophysiologic approach, according to the compensation laws, to evaluate the Chronic Obstructive Pulmonary Disease (COPD) acute exacerbations [6].

In hypercapnic AECOPD the hypoventilation produces or worsens respiratory acidosis. Since most of these patients, especially if elderly and critical, are multi-drugs recipients for comorbidities, the AB and HE disorders are very common, producing a potential bias in the interpretation of the final values [7].

Materials and Methods

This study was carried out on 110 patients who were admitted with COPD exacerbation to the Pulmonology Department at Government General Hospital, Kadapa, from January 2022 to December 2022.

Through clinical examination including: general examination, including vital signs (blood pressure, pulse, and respiratory rate) and level of consciousness according to Glasgow Coma Scale and local examination.

Laboratory investigations were performed at the laboratory of the Menoufia University Hospitals. They include the following:

1. Complete blood count.
2. Arterial blood gases (ABG).
3. Electrolyte levels [potassium (K) and sodium (Na)].
4. Random blood sugar.
5. Kidney function test (serum urea and creatinine).

Radiological investigations

Chest radiography can be reported as suggestive of COPD but is not diagnostic. Radiographs was used for the diagnosis of pneumonia, and exclusion of other causes of dyspnea in patients with COPD such as ruptured emphysematous bullae. On admission, all patients received oxygen through nasal cannula or venturi mask to preserve a normal arterial oxygen saturation (≥90%) and received bronchodilators, corticosteroids, and antibiotics [8]. Follow-up was done for patients with clinical examination and laboratory investigations, which showed that some of them improved and others deteriorated, so received NIV. None of our patients refused the treatment or interrupted ventilation for discomfort. NIV was removed when clinical steady-state was reached: respiratory rate<24/min, heart rate<110 beats/min, pH>7.35, and SaO_2>90% with FiO_2<40% [9]. Patients were transferred to ICU after NIV failure for invasive mechanical ventilation if the following conditions occurred: (a) worsening of arterial pH and $PaCO_2$; (b) clinical signs of disturbed conscious level; and (c) hemodynamic instability [10].

Results

In the table 1, the mean age of the NIV positive was 62.64±7.91 years and NIV negative were 65.19±7.95 years, who were admitted to the Department of pulmonary medicine, with hypercapnic COPD exacerbation. They were classified according to the type of management into two groups: the first group received medical treatment and the second received non- invasive positive pressure ventilation (NIPPV). The total number of patients were 90, where 60 of them were males and 30 females.

Table 1: Distribution of sex and age

Gender	Need for non-invasive ventilation		p-value
	NIV Positive (N=45)	NIV Negative (N=45)	
Male	37 (82.2)	35 (77.8)	0.07
Female	8 (17.8)	10 (22.2)	
Age	62.64±7.91	65.19±7.95	0.38

Table 2: Arterial blood gases finding of the studied group

Acid–base disturbance	Need for non-invasive ventilation		p-value
	NIV Positive (N=45)	NIV Negative (N=45)	
Compensated respiratory acidosis	9 (20)	40 (88.9)	<0.0001
Mixed respiratory acidosis and metabolic alkalosis	20 (44.4)	4 (8.9)	
Combined respiratory and metabolic acidosis	16(35.6)	1 (2.2)	
PO2	57.15±6.77	66.25±6.44	<0.05
PCO2	62.29±6.24	52.35±8.8	<0.05

In table: 2, according to ABG finding, patients were classified into three groups: the first group comprised 49(54.4%) patients who had compensated respiratory acidosis, and the majority of them (40 Patients) received medical treatment only. The second group comprised 24 (26.7%) patients, who had mixed respiratory acidosis and metabolic alkalosis. Overall, 20 patients needed non-invasive mechanical

ISSN:0975 -3583,0976-2833 VOL14, ISSUE 07, 2023

ventilation with the medical treatment. The third group comprised 17 (18.9%) who had combined respiratory and metabolic acidosis. Of them, 16 patients needed non-invasive mechanical ventilation with the medical treatment and mean PO2 was 57.15±6.77 mmHg whereas mean PCO2 was 62.29±6.24 mmHg.

Table 3: Electrolytes finding of the studied group

Electrolytes	**Need for non-invasive ventilation (Mean ± SD)**		**p-value**
	NIV Positive	NIV Negative	
Sodium (mEq/l)	137.23±6.22	139.31±5.99	0.41
Potassium (mEq/l)	6.34±0.59	5.74±0.44	<0.05
Bicarbonate (mEq/l)	31.03±3.15	25.71±3.39	<0.05

In table 3, the mean potassium of the patients who need medical treatment only was 5.74±0.44 m E q/l and mean Sodium was 139.31±5.99 m E q/l, whereas the mean potassium for the other group was 6.34±0.59 m E q/l and mean Sodium was 137.23±6.22 m E q/l. The mean serum Bicarbonate of the group the need medical treatment only was 25.71±3.39 m E q/l. The mean serum Bicarbonate of the other group was 31.03±3.15 m E q/l.

Table 4: Outcome and characteristic of the group that needed NIPPV from the start

Acid–base disturbance	**Studies groups non-invasive ventilation (N=45)**		**p-value**
	Improved (N=40)	**Failed (N=5)**	
Compensated respiratory acidosis	12 (30)	0 (0)	<0.0001
Mixed respiratory acidosis and metabolic alkalosis	16(40)	2 (40)	
Combined respiratory and metabolic acidosis	12 (30)	3 (60)	
PO2	57.03±5.71	44.20±6.89	<0.0001
PCO2	62.07±5.69	59.18±5.22	0.25

Table 5: Effect of COPD treatment on the patient electrolytes

	Before treatment	**After treatment**	**P**
Sodium (mEq/l)	137.22±6.22	135.38±5.79	>0.05
Potassium (mEq/l)	6.33±0.59	5.48±0.58	<0.05

In table: 5, the Sodium and Potassium levels before treatment were 137.22±6.22 and 6.33±0.59 m Eq/l, respectively, and mean Sodium and Potassium levels after treatment were 135.38±5.79 and 5.48±0.58 m Eq/l, respectively.

Discussion

Comparing the demographic data of both groups, group II patients showed an older age but to a non-significant value (p 0.61). This is in concordance with Schiavo, 2016 as they found that patients group who required NIV was insignificantly older than the other group (p 0.94) [11]. This agrees with Ramesh 2016 as they found that the ventilated group has an older age (70.18±12.31) versus (61±8.90) in the nonventilated group [12].

Insignificant difference was found between both groups regarding gender predilection with more male presentation in both groups (p 0.08). This agrees with Schiavo 2016 as they also found insignificant difference between both groups regarding gender [11].

The present study revealed statistically higher smoking frequency and smoking index in group II whose exacerbations were more severe and required NIV (p 0.05). Moreover, univariate regression analysis elucidated that higher SI is an independent predictor for the need for NIV. This agrees with Franciosi 2006 as they proved in their meta-analysis that the number of smoking related pack-years increased with the severity of exacerbation and their results showed a clear difference between in- and out- patients settings regarding smoking. Poor nutritional status can adversely affect pulmonary function through impairment of respiratory muscle strength and exercise tolerance and moreover, through decreasing ventilatory drive and altering lung defense mechanisms [13].

The present study showed a significant statistical difference between both groups regarding frequency of AECOPD per year (p 0.024) with more frequent exacerbation in group II patients and that the increased frequency of AECOPD per year is an independent predictor for the need for NIV. Near to these results, Miravitlles 2011 found more frequent exacerbation in patients in need for invasive MV (2.6±1.7) than those not requiring it (2.5±2) but to an insignificant degree. This may be explained that they studied frequency of exacerbations in the last year only [14].

The current study revealed a statistically significant difference between both groups regarding heart rate which was higher in the ventilated group (94.24±15.16) versus (83.1±10.9) beats per minute in the non-ventilated group (p 0.000). This is in accordance with Schiavo 2016 who found significantly higher HR in the NIV group ($p < 0.001$). This also agrees with Franciosi 2006 as they found little variation in heart rate between levels of exacerbations with clear differences in heart rate between in- and out- patients and they explained that it may be due to the associated anxiety and dyspnea due to the exacerbation or may be due to an underlying cardiovascular disease that is more prominent in the severe COPD patients [13]. Moreover, respiratory rate was also significantly ventilated group (26.6±5.4 and 21.8±3.8 breaths per minute respectively) (p 0.000). Gravil 1998 stated that respiratory rate of > 25 breaths per minute and heart rate of 110 beats per minute or more were arbitrary cut off points indicating a severe exacerbation [15].

Length of hospital stay (LOS) was significantly longer in group II patients (p 0.000). This agrees with the study of Wang 2014 who proved that higher arterial PaCO2 was associated with a prolonged LOS [16]. This also agrees with Chandra 2007 who reported that duration of hospital stay was longer for patients who needed ICU care [17].

The current study compared both groups regarding Na and K levels. The study showed a significantly lower Na and K levels in group II patients and both groups had lower than normal values. This can be attributed to the more use of Beta-2 agonists in the more severe cases, as these medications cause electrolytes disturbances [18]. Moreover, Goli 2016 found significantly lower PH in patients with electrolyte disturbance which is also present in the current study [19]. They also found a significantly low level of serum sodium (132±5.65Meq/lit) and potassium (3.29±0.96 Meq/lit)) in subjects with acute exacerbation of COPD than their healthy controls (Na+ =140±2.28 Meq/lit and K+ = 4.51±0.02 Meq/lit ($p<0.05$).

Pulmonary spirometry showed lower levels of FEV1 and FVC in group II than group I with insignificant statistical difference ($p<0.05$). Franciosi 2006 also reported that FEV1 and FVC decreased from exacerbation level I to level II [13]. Moreover, Vitacca 1996 proved that FVC (% predicted) provided a significant distinction between the 2 studied groups (Those requiring MV and those not requiring it) [20].

Conclusion

Higher smoking index and frequency, more frequent COPD exacerbations, higher heart rate and respiratory rate, lower PH and PaO2/FiO2 can significantly indicate a more severe AECOPD and higher smoking index (SI), PaCO2, frequent AECOPD, or lower PaO2 and Pao2/FiO2 can be used as independent predictors for the need for NIV.

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