

To study an alteration in biochemical parameters in acute and chronic phase of respiratory acidosis and alkalosis

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Abstract

Introduction: The primary abnormality in respiratory acidosis is retention of CO₂ (increased H₂CO₃) due to impaired alveolar ventilation resulting in a rise in pCO₂ causing acidemia. However, respiratory alkalosis occurs when there is decrease in H₂CO₃ concentration. A fall in pCO₂, reduces the ratio of carbonic acid to bicarbonate resulting in alkalemia.

Aim: To study variations in biochemical parameters in respect to respiratory acidosis and alkalosis.

Material and Methods: The biochemical parameters of respiratory acidosis and alkalosis like blood pH, concentration of CO₂, pO₂, pCO₂, level of HCO₃⁻.

Results: The studied components of respiratory acidosis and alkalosis were found to be highly significant in chronic conditions of respiratory acidosis and alkalosis (p<0.01) than acute condition of respiratory failure when compared with the healthy controls.

Conclusion: In this study, we observed that there is marked increase in product of metabolism in acute and chronic phase of respiratory syndrome when compared with the healthy controls.

Keywords: Respiratory acidosis, respiratory alkalosis, blood pH, pO₂, pCO₂, HCO₃⁻

Access this article online	
Quick Response Code:	Website: www.innovativepublication.com
	DOI: 10.5958/2394-6377.2016.00054.X

Introduction

Respiratory system is very crucial for human life. The primary function of the respiratory system is gas exchange. Oxygen (which we need for our cells to function) from the external environment is transferred into our bloodstream while carbon dioxide (a waste product of cellular function) is expelled into the outside air. Hence any derangement in respiratory system function can lead to acid-base imbalance causing either acidosis or alkalosis. Respiratory acidosis results from an increase in concentration of carbonic acid (H₂CO₃) in plasma. An increase in concentration of H₂CO₃ is due to decrease in alveolar ventilation, and which leads to retention CO₂. Which in turn causes increased concentration of H₂CO₃. It results blood pH to get below 7.35. However opposite of respiratory acidosis, the respiratory alkalosis results from lowered concentration of CO₂ or H₂CO₃, due to hyperventilation. Which results blood pH to go beyond 7.45.^[1,2]

During metabolism human body is more prone for acidosis, for example, CO₂ a waste product of cellular respiration combines with water in presence of carbonic anhydrase to form H₂CO₃. Also, lactic acid is a product

of anaerobic metabolism, protein metabolism produces phosphoric and sulfuric acids, and lipid metabolism produces fatty acids. These acidic substances must continuously be eliminated from the body to maintain pH homeostasis. Rapid elimination of acidic products of metabolism results in alkalosis, and the failure to eliminate acidic products of metabolism results in acidosis.^[3,4]

The major effect of acidosis is depression of the central nervous system. When the pH of the blood falls below 7.35, the central nervous system malfunctions, and the individual becomes disoriented and possibly comatose as the condition worsens.^[5] A major effect of alkalosis is hyperexcitability of the nervous system. Peripheral nerves are affected first, resulting in spontaneous nervous stimulation of muscles. Spasms and tetanic contractions and possibly extreme nervousness or convulsions result. Severe alkalosis can cause death as a result of tetany of the respiratory muscles.^[6] Although buffers in the body fluids help resist changes in the pH of body fluids, the respiratory system and the kidneys regulate the pH of the body fluids. Malfunctions of either the respiratory system or the kidneys can result in acidosis or alkalosis.^[7]

Aims and Objectives of the study

Aim of the present study is to understand the features that define respiratory acidosis and alkalosis, and to interpret critical end stage investigation to explain acidosis and alkalosis conditions in Acute and Chronic phase of respiratory syndrome. So the cases and healthy controls were assessed with different biochemical parameters.

Materials and Methods

Study groups and sample collection

The present study was carried out in the Dept. of Biochemistry and Central Clinical Lab Biochemistry section, in Pad. Dr. Vithalrao Vikhe Patil foundation's Medical College and Hospital, Ahmednagar. The patients selected for the present study were attending indoor/outdoor patient department from the Hospital. The clinical checkup of the patient was done by physicians on the basis of detailed clinical history and clinical examination. The ethical committee of the Hospital and Medical College approved the research project work and all the patients have given written informed consent.

In the present study, 100 subjects were included as healthy controls and 240 subjects for disease groups the distribution of the subjects is as follows.

Sr. No.	Groups	Types	No. of subjects
1	I	Healthy controls	100
2	II A	Acute Respiratory Acidosis	60
	II B	Chronic Respiratory Acidosis	60
3	III A	Acute Respiratory Alkalosis	60
	III B	Chronic Respiratory Alkalosis	60

Inclusion criteria

1. Healthy controls: 100 Subjects the control subjects were selected who were completely healthy non-smokers and showed no abnormality on clinical examination and were completely symptom free.
2. Study group (Group II A, II B and III A, III B): Patient with lung disorders like bronchopneumonia, status asthmaticus, chronic bronchitis, emphysema, lung fibrosis, hyperventilation, hysteria, febrile condition septicemia meningitis chronic cardiac failure etc. were included as 60 subjects in four groups total 240. The patients were diagnosed by physicians on the basis of detailed clinical history, relevant biochemical investigations and clinical examination including spirometry. Patients in the clinically stable phase of disease with FEV₁ / FVC < 70 % were included.

Exclusion criteria

Patients with HIV seropositive, diabetes mellitus, hypertension, malignancy, cardiac failure, recent surgery, endocrine, hepatic or renal diseases were excluded from the present study.

Study procedure

After obtaining informed consents, all subjects were screened for inclusion and exclusion criteria. At base line all the clinical parameters were evaluated and then compared with study groups. 5 ml arterial blood sample was collected under all aseptic precautions with 20 number (gauge) needle from radial or brachial artery, the needle was separated immediately and analysis was carried on blood gas analyzer.

The following biochemical parameters were analyzed in healthy controls, and in patients on Cobas b 121 Blood gas analyzer of Roche Co.

using C1, C2 and C3 reagents of the of blood gas analysis.

1. **Blood pH:** Measures H⁺ ions con. of sample against a known pH in a reference electrode hence potential difference calibration with solution of known pH (6.384-7.384).
2. **Concentration of Total CO₂:** CO₂ reacts with solution to produce H⁺ higher CO₂ → more H⁺ → higher pCO₂ measured.
3. **pO₂:** O₂ Diffuses across membrane producing an electrical current measured as pO₂.
4. **Concentration of HCO₃⁻ and pCO₂:**

$$\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{H}^+ + \text{HCO}_3^-$$
 In Acidosis

$$\text{H} + \text{HCO}_3^- \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$$
 In Alkalosis Alkali + Weak acid = H₂CO₃

$$\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{HCO}_3^- + \text{H}^+$$

Statistical Analysis

All the biochemical parameters were evaluated and were statistically compared. Statistical analysis was carried out using students unpaired 't' test. Probability values < 0.05 were considered as significant. Also data were expressed in mean ± SD form.

Results

Measurement of arterial blood pH in healthy controls and patients: The arterial blood pH is very important biochemical parameter for assessing acid- base imbalance. In healthy controls pH was very well in normal limit i.e. 7.4±0.05, whereas it was significantly low in acute respiratory acidosis i.e. 7.31±0.02 as compared to chronic respiratory acidosis which was 7.33±0.01. When evaluated in other group of patients, pH was significantly high in acute respiratory alkalosis i.e. 7.55±0.02 as

compared to chronic respiratory alkalosis which was 7.48 ± 0.01 . (Fig. 1)

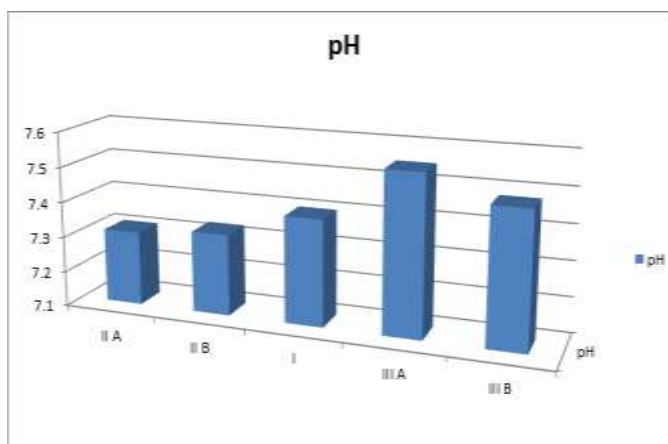


Fig. 1: Variation in the arterial blood pH in respect to different types of respiratory acidosis and alkalosis when compared with the healthy controls. Each bar represents mean pH \pm SD

Measurement of arterial blood total CO₂ in healthy controls and patients: In healthy controls TCO₂ was found to be in normal limit i.e. 27.00 ± 2.79 , whereas its level was comparatively high in chronic respiratory acidosis i.e. 34.12 ± 1.2 as compared to acute respiratory acidosis (30.00 ± 1.6). When compared in other groups of patients, its level was significantly low in chronic respiratory alkalosis i.e. 16.01 ± 1.07 as compared to level found in acute respiratory alkalosis (23.01 ± 0.39). (Table 1)

Measurement of arterial blood pCO₂ in healthy controls and patients: We also correlated pCO₂ levels in healthy controls and patients. We found that pCO₂ levels in healthy controls was in normal limits i.e. 39.00 ± 4.80 , where as its level was significantly high in chronic respiratory acidosis (62.28 ± 2.81) as compared to acute respiratory acidosis group patients which was 50.12 ± 2.19 . When compared in other groups of patients, pCO₂ level was significantly low in chronic respiratory alkalosis (22.53 ± 1.84) as compared to other group of acute respiratory alkalosis which was 25.01 ± 1.76 . (Fig. 2)

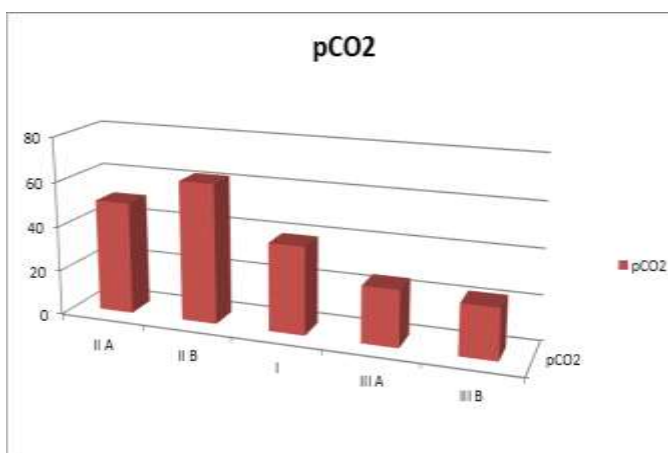


Fig. 2: Variation in the arterial blood pCO₂ in respect to different types of respiratory acidosis and alkalosis when compared with the healthy controls. Each bar represents mean pCO₂ \pm SD

Measurement of arterial blood pO₂ in healthy controls and patients: Another important biochemical marker in acid- base imbalance is pO₂ levels. We studied it in detail, and found that its level is within normal limits in healthy normal i.e. 90.17 ± 10.10 , whereas significantly low in chronic respiratory acidosis (51.27 ± 2.89) and little high to these values in acute respiratory acidosis i.e. 61.93 ± 3.22 . When compared in other groups of patients, its level was found to be nearly in normal levels i.e. 104.61 ± 5.21 and 70.23 ± 4.89 in acute respiratory alkalosis and chronic respiratory alkalosis respectively. (Table 1)

Table 1

Sr. No.	Parameters	Control	Respiratory Acidosis		Respiratory Alkalosis	
			Acute	Chronic	Acute	Chronic
1	pH	7.4±0.05	7.31±0.02	7.33±0.01	7.55±0.02	7.48±0.01
2	TCO ₂ in mEq/L	27.00 ± 2.79	30.01±1.6	34.12±1.2	23.01±0.39	16.01±1.07
3	HCO ₃ ⁻ in mEq/L	25.02± 1.71	26.01±1.02	32.07±1.05	22.08±1.10	16.06±0.71
4	pO ₂ in mmHg	90.17±10.1	61.93±3.22	51.27±2.89	104.61±5.21	70.23±4.89
5	pCO ₂ in mmHg	39±4.80	50.12±2.19	62.28±2.81	25.01±1.76	22.53±1.84

All the values given in the tables represents mean of respective parameter ± SD

Measurement of arterial blood HCO₃⁻ in healthy controls and patients: Arterial blood HCO₃⁻ levels was also evaluated in healthy controls and patients. In healthy controls its level was 25.02±1.71, which was in normal limits. HCO₃⁻ level was significantly high in chronic respiratory acidosis (32.07±1.05) as compared to acute respiratory acidosis, which was 26.01±1.02. When same parameter evaluated in another group of patients, its level was significantly low in chronic respiratory alkalosis (16.06±0.71) as compared to other group of acute respiratory alkalosis (22.08±1.10). (Fig. 3)

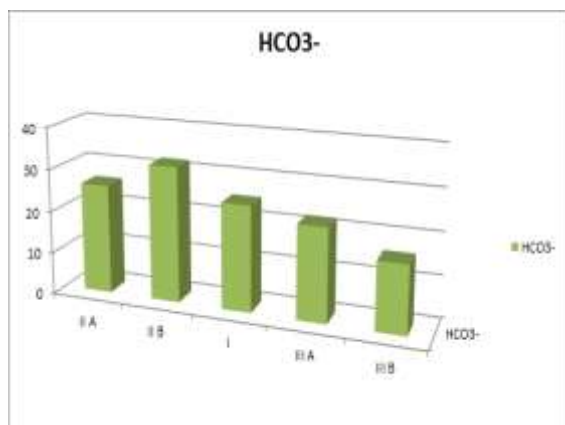


Fig. 3: Variation in the arterial blood HCO₃⁻ in respect to different types of respiratory acidosis and alkalosis when compared with the healthy controls. Each bar represents mean HCO₃⁻ ± SD

Discussion

Inadequate ventilation of the lungs causes respiratory acidosis. The rate at which carbon dioxide is eliminated from the body fluids through the lungs falls. This increases the concentration of carbon dioxide in the body fluids. As carbon dioxide levels increase excess carbon dioxide reacts with water to form carbonic acid. The carbonic acid dissociates to form hydrogen ions and bicarbonate ions. The increase in

hydrogen ion concentration causes the pH of the body fluids to decrease. If the pH of the body fluids falls below 7.35, symptoms of respiratory acidosis becomes apparent.⁽⁸⁾ Acute respiratory acidosis occurs quickly. It is a medical emergency. Left untreated, symptoms will get progressively worse. It can become life-threatening. Chronic respiratory acidosis develops over time. It does not cause symptoms. Instead, the body adapts to the increased acidity. For example, the kidneys produce more bicarbonate to help maintain balance.⁽⁹⁾

Respiratory alkalosis results from hyperventilation of the lungs. This increases the rate at which carbon dioxide is eliminated from the body fluids and results in a decrease in the concentration of carbon dioxide in the body fluids. As carbon dioxide levels decrease, hydrogen ions react with bicarbonate ions to form carbonic acid. The carbonic acid dissociates to form water and carbon dioxide. The resulting decrease in the concentration of hydrogen ions cause the pH of the body fluids to increase. If the pH of body fluids increases above 7.45, symptoms of respiratory alkalosis become apparent.⁽¹⁰⁾ Acute respiratory alkalosis occurs rapidly, have a high pH because the response of the kidneys is slow. Chronic respiratory alkalosis is a more long-standing condition, here one finds the kidneys have time to decrease the bicarbonate level⁽¹¹⁾.

In the present study, there is statistically significant fall in blood pH in acute respiratory acidosis as compared to chronic respiratory acidosis in which body has sufficient time to metabolic compensation. Same type but opposite findings in blood pH level are seen in acute respiratory alkalosis with significantly high pH, as compared to chronic respiratory alkalosis due to metabolic compensatory action. This metabolic compensatory action can very well correlated by HCO₃⁻ in respective groups of patients. In chronic respiratory acidosis, HCO₃⁻ level is significantly high and in chronic respiratory alkalosis, HCO₃⁻ level is found to be significantly low due to metabolic compensation. Acute respiratory acidosis 1-2 mEq/L increase in HCO₃⁻ for every 10 mm Hg increase in PCO₂ is seen, where as in

chronic respiratory acidosis 3-4 mEq/L increase in HCO_3^- for every 10 mm Hg increase in PCO_2 . In other group, acute respiratory alkalosis 1-2 mEq/L decrease in HCO_3^- for every 10 mm Hg decrease in PCO_2 , where as in chronic respiratory alkalosis 4-5 mEq/L decrease in HCO_3^- for every 10 mm Hg decrease in PCO_2 .^(12,13) Equilibrium: $\text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^-$

In respiratory acidosis, the increased carbon dioxide is the primary cause for to increase TCO_2 and pCO_2 which causes the equilibrium to shift right increasing H_2CO_3 , H^+ and HCO_3^- . Increased H^+ ion leads to decreased pH, from normal 7.35 to 7.45. The HCO_3^- is higher than normal.^(14,15) Further significantly low values are reported for pO_2 because in acute respiratory acidosis, the pCO_2 is elevated above the upper limit of the reference range with an accompanying acidemia (i.e., $\text{pH} < 7.35$). In chronic respiratory acidosis, the pCO_2 is elevated above the upper limit of the reference range, with pH secondary to renal compensation and an elevated serum bicarbonate levels.⁽¹⁶⁻¹⁹⁾

Conclusion

Thus, considering result of present study it shows that in respiratory acidosis, there is significant fall in blood pH, whereas significant rise in TCO_2 , pCO_2 along with HCO_3^- (specially in chronic respiratory acidosis). When these biochemical parameters are compared in other group of patient's i.e. respiratory alkalosis, there is significant rise in blood pH and significant fall in TCO_2 , pCO_2 along with HCO_3^- (specially in chronic respiratory alkalosis). Taken together, we can comment that all these biochemical parameters can very well utilized for diagnosing and assessing therapy in respiratory acidosis and alkalosis.

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