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Influence of Hemoglobin Concentration and Serum Electrolyte Levels on Acid-Base Balance in Patients with Chronic Obstructive Pulmonary Disease (COPD): A Clinical Correlation Study

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Abstract:
Background: *Chronic obstructive pulmonary disease (COPD) is a progressive respiratory disease frequently linked to systemic symptoms, such as changes in hemoglobin levels, imbalances in electrolytes, and disturbances in acid-base homeostasis. Optimizing patient management and results requires an understanding of how all of these factors are interconnected.*
Objective: This study aims to assess the correlation between hemoglobin concentration, acid-base balance parameters, and serum electrolyte levels (sodium, potassium, chloride, and bicarbonate) inpatients with COPD.
Methods: A cross-sectional clinical study was conducted on 95 patients diagnosed with moderate to severe COPD at NABL & NABH Accredited Hospital, for 6 months. Heparinized arterial blood samples were analyzed for hemoglobin, serum electrolytes, and arterial blood gases. Statistical correlations using SPSS and Python, were drawn between these variables to assess their influence on acid-base status.
Result: Hemoglobin concentration (THbc), arterial blood gases, and serum electrolytes were found to be significantly correlated in patients with COPD; THbc shown a strong negative correlation with bicarbonate (HCO_3^-; r = -0.620) and calcium (Ca^{2+}; r = -0.674), as well as a moderate positive correlation with carbon dioxide (pCO_2; r = 0.494). The results also revealed a strong inverse relationship between pCO_2 and oxygen (pO_2; r = -0.781), which is consistent with the pathophysiology of COPD. Moreover, sodium (Na^+) showed a positive correlation with bicarbonate (r = 0.702), and calcium with potassium (K^+; r = 0.619), indicating interconnected regulation of acid-base and electrolyte balance. These correlations suggest systemic biochemical adaptations in chronic respiratory conditions.
Conclusion: Hemoglobin concentration, biochemical parameters and electrolyte levels play a vital role in the acid-base regulation in COPD patients .Continuous monitoring or assessing these parameters can help in the early detection of metabolic complications and provide therapeutic strategies to improve clinical outcomes.
Keywords:COPD,Hemoglobin,serumelectrolytes,acid-basebalance,arterialbloodgas,metabolicacidosis

INTRODUCTION

Reduced airflow and an abnormal inflammatory response in the lungs are characteristic features of Chronic Obstructive Pulmonary Disease (COPD), a progressive and impairing respiratory condition[1,2].The World Health Organization states that COPD is a major global cause of morbidity and mortality, especially for smokers and both younger & older adults [3]. The management and prognos is of COPD can be complicated by its systemic effects, which extend beyond its pulmonary manifestations. These effects include changes in oxygen transport, electrolyte abnormalities, and acid-base imbalances [1,2,4].

Respiratory function continues to deteriorate during the prolonged a symptomatic phase of COPD, gradually developing disease. A persistent cough is a typical symptom, especially when mucus is produced. There may also be wheezing, chest tightness, and dyspnea, particularly during activity. Patients frequently arrive at an advanced stage with their first acute exacerbation of COPD. It is typically not until the forced expiratory volume in one second (FEV1) is roughly 50% of the expected normal value that symptoms appear [5].Elastic fibers in normal alveolar septa provide resistance to connective tissue, allowing deformability and passive recoil. They are connected to collage n fibers, regulating lung volume [6]. Emphysema, apheno type contributing to COPD, is characterized by last to lysis, the breakdown of elastic fibers [7,8]. This leads to reduced gas exchange, airspace

enlargement, loss of elastic recoil, hyperinflation, and expiratory flow limitation. The destruction of alveolar walls affects lung tissue stability and diseaseprogression[9,10].During COPD progression, Pulmonary arterial hypertension and diaphragm dysfunction are commonly observed, contributing to exacerbations [11,12]. Acute episodes carried on by bacterial and viral infections are known as exacerbations, and they worsen air way inflammation, reduce lung function and necessitate hospitalization , and raise mortality[13,14]. Exacerbations may increase in frequency and potentially fatal consequences may arise as the disease worsens. Severe airway restriction, significantly reduced performance, and systemic problems are characteristics of end-stage COPD. Patients frequently pass away from lung infections or respiratory insufficiency. Muscle atrophy, dietary problems, and weight loss are extra pulmonary consequences linked to COPD. Several COPD pheno types have been found, each with unique prognostic consequences[15,16]. In some cases, where inflammation is seen frequently, imbalance between proteases and their inhibitors, oxidative stress and infections that generate COPD disease symptoms [17,18,22]. There are patients with increase chemotactic mediators, they displayed increased level of neutron phils , macrophagesand Tcells in lungs[18].Each patient affected should be kept on monitor with their previous medical history like previous cases of asthma, allergies and childhood treated or untreated respiratory diseases. In order to diagnose, stage, and track COPD, pul monary function testing, or PFT, iscrucial. Prior to and following the administration of an inhaled bronchodilator, spirometry is conducted. Short- acting beta2-agonists (SABA), short-acting anticholinergics, or a mix of the two can be inhaled bronchodilators. The diagnosis of COPD is confirmed when the forced expiratory volume in one second(FEV1/FVC)ratio islessthan0.7.Pulse oximetry or arterial blood gas analys is should be used to assess oxygenation in patients who exhibit symptoms of dyspnea and a significantly reduced FEV1 [19,20]. Airflow limitation and decreased gas exchange result from tissue damage, while the inflammatory response and obstruction of the airway decrease the forced expiratory volume (FEV1). Imaging examinations frequently show hyperinflation of the lungs, which is caused by air trapping fromairway collapseduring exhale. Carbon dioxide(CO2) levels riseas a result of the inability to exhale completely. Gas exchange impairment is frequently observed as theconditionworsens.CO2retentionresultsfromeitheradecreaseinventilationor anincreasein physiologic dead space. Hypoxemia-induced diffuse vasoconstriction may occur in pulmonary hypertension [21]. AlthoughPFT's and spirome try remains the cornerstone of COPD diagnosis and staging, but there are various routinely analyzing biochemical correlation such as Hb concentration, bicarbonate levels and electrolyte imbalances which will give a much more clear identification, monitoring and management of COPD complications.In spite of all of this, some previous studies or research has only mentioned the systematically examinedpulmonarypathology,radiographicchangesandsymptomaticmanagement,whichlater needs to be combined with the impacts of serumelectrolytes and hemoglobin levels on the acid- base balance indicate in these COPD patients, but previous studies are giving a need for these broader biomarkers for COPD diagnosis. Therefore, if COPD is detected early, risk factors are modified, pharmacological and non-pharmacological conditions are appropriately managed, and patients are given appropriate treatment, it is a difficult but prevent able disease. Additionally, there is hope for improved therapy in the future because of a number of studies based on the molecular causes of COPD and other medicines.

OBJECTIVE:

The study aims to examine and investigate the correlation between hemoglobin levels, serum electrolytes, and acid-base parameters in patients with COPD, with the goal of providing clinical insight into disease pathophysiology and potential avenues for improved patient care.

MATERIALS AND METHODS:

StudyDesign

A cross-sectional clinical study was conducted on 95 patients diagnosed with moderate to severe COPD at NABL &NABH Accredited Hospital, over a period of 6 months. Heparinized Venous blood samples were analysed for hemoglobin, serum electrolytes, and arterial blood gases. Statistical correlations using SPSS and Python, were drawn between these variables to assess their influence on acid-base status.

Study Populations:The study included 95 patients diagnosed with stable COPD. All these patients were between the age of 40-70 years and had confirmed diagnosis as refered by the doctors.

Inclusive Criteria
Clinically Stable COPD patients
Age40-70years
Informed Written Consent provided
Exclusive Criteria; Patients with known liver, kidney, oranyhemolytic diseases or disorders Patients under any medications or diuretics that affect the serum electrolyte results
Patients with a history of recent blood transfusion or anyacute viral or chronic infections
Data Collection and Laboratory Analysis
All the tests were performed using standard protocols in the NABL & NABHA ccredited Laboratory. Clinical data including age, sex, smoking history, dietary allowances, and disease severity were noted. Heparinized arterial blood samples were drawn under aseptic conditions to assess: HemoglobinConcentration(g/dl)
Serum Electrolytes: Sodium(Na^+),Potassium(K^+),Chlorine(Cl^-)andBicarbonate(HCO^-_3)
Arterial Blood Gase(ABG)analysis:pH,$PaCO_2$,HCO^-_3,andOxygen Saturation
Statistical Analysis
Data were analyzed using Python3.11.8.Continuous variables were presented as mean± Standard deviation (SD), and categorized variables as percentages. Spearman correlation coefficient heatmaps were used to examine correlations between hemoglobin, serum electrolytes level, and acid-base balancing parameters. Multivariate regression analysis was performed to identify independent predictors of acid-base imbalance, with hemoglobin accounting. A p-value of <0.05 was considered statistically significant.

RESULTS

Base line Characteristics

A total of 95 COPD Patients in which 49% Female patients and 51% male patients with in the age limit of 40-70 years.

Parameter	**Mean**	**Median**	**Standard Deviation**
Age	45.5	45	3
Gender	45.5	45.5	0.71
THbc	12.59	10.9	3.75
SerumNa+	118.76	116	11.62
SerumK+	3.11	2.6	0.75
HCO3-	19.69	19.7	4.84
pH	7.29	7.4	0.16
PaO2	94.68	46	76.91
PaCO2	40.12	41	8.04

Table:1Representingthebaseline data

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Correlation Analysis

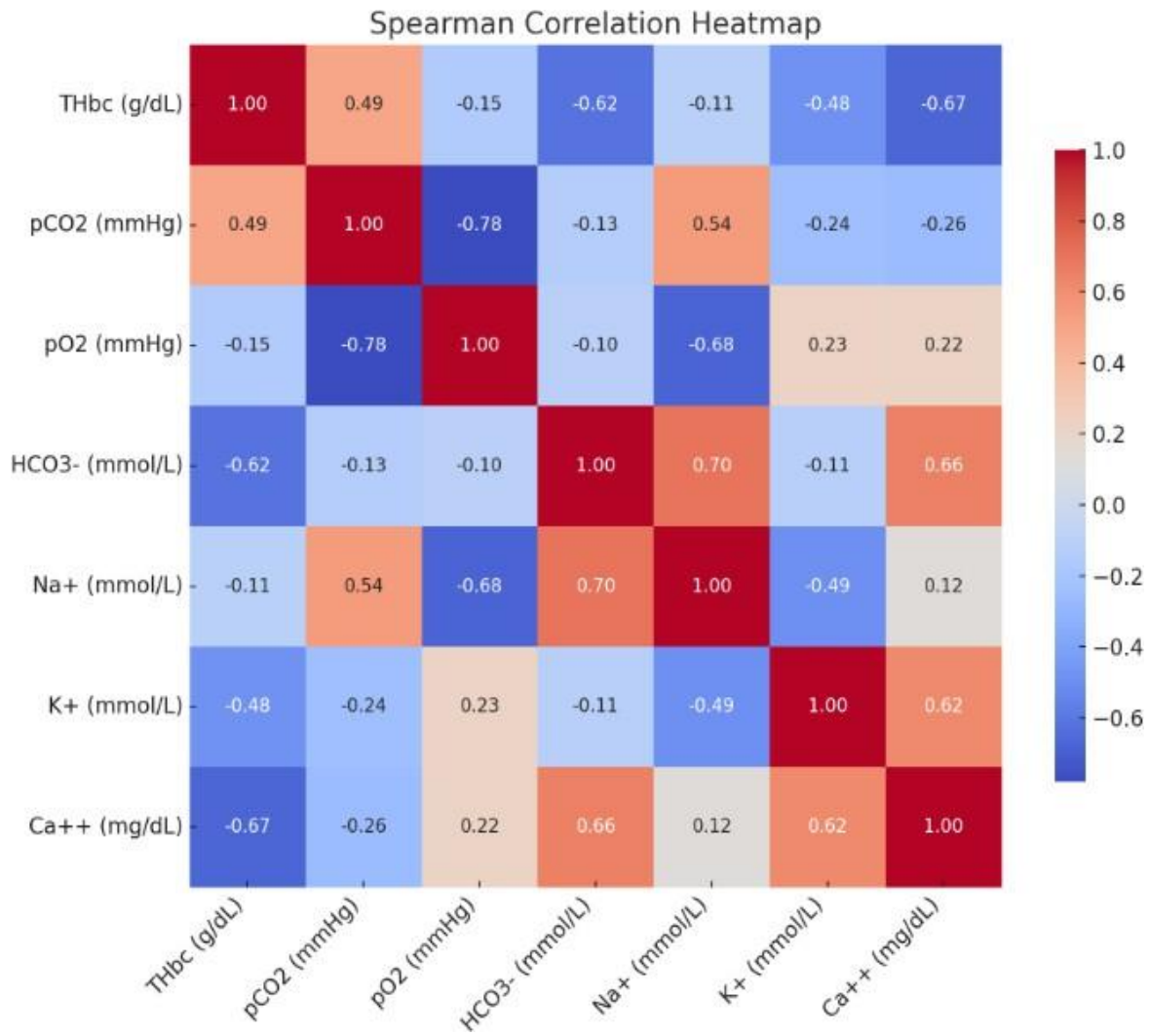

Figure1:Correlative Matrix Heat map demon strating the Pearson Correlation Coefficients

TheFigure1interpretsthecorrelationanalysisofbiochemicalparametersinCOPDpatients.Total hemoglobin concentration (THbc) demonstrates a strong inverse corelation with HCO^{-} and calcium (Ca+) indicating that elevated THbc levels associated with reduced buffering capapcity and calcium concentration. A moderate positive association with pCO_2, suggest Hb role in CO_2 transport. But, a strong negative correlation between pCO_2 and pO_2 which reflects respiratory problems.Hence,astrongpositivecorrelationbetweenNa^{+}andHCO_3^{-},andbetweenCa+andK+, gives a valuable insight in their involvement in maintaining acid-base and electrolytes balance.

Multivariate Analysis

In this regression, hemoglobin and serum bicarbonate emerged as independent predict or so facid- base imbalance ($p<0.05$).

Predictor Variable	Coefficient	Std. Error	t-value	p-value	95%CI (Lower)	95%CI (Upper)
Intercept (const)	0.879	0.272	3.23	0.0017	0.338	1.42
pCO2	0.31	0.073	4.24	<0.0001	0.165	0.455
pO2	-0.068	0.07	-0.97	0.334	-0.207	0.071
HCO3-	0.054	0.071	-8.68	<0.0001	-0.754	-0.47
Na+	0.054	0.071	0.76	0.449	-0.087	0.195
K+	-0.162	0.076	-2.14	0.035	-0.312	-0.01
Ca2+	-0.478	0.057	-8.37	<0.0001	-0.591	-0.36

Table2:Multivariate Linear regression: Predictors of Total Hemoglobin (THbc)

TheTable2representstheHCO3-,Ca+andpCO2arestatistically independentpredictorsofThbc levels ($p<0.05$). Whereas K+ also shows significant but weaker inverse but pO2 and Na+ are not significant predictors in this model. Hence, the overall model supports the hypothesis that acid base balance and serum electrolytes level influence the hemoglobin concentration.

Together, these findings show that hemoglobin actively contributes to regulating the body's reactiontochangesinacid-baseandgasexchangestatusratherthanjustactingasapassiveoxygen or carbon dioxide carrier. In addition to bicarbonate, THbc shows potential as a biomarker for assessinglong-termrespiratorydisordersbyemergingasanindependentandclinicallysignificant predictor of acid-base problems.

DISCUSSION

There is a significant correlation between hemoglobin levels, arterial blood gases, and serum electrolytes in individuals with COPD are highlighted by this particular investigation. A possible compensatory role for hemoglobin in chronic pulmonary acidosis is suggested by the negative correlationsofTHbcwithHCO_3^-andCa^{2+}.Thisissupportedbythesomewhatpositiveconnection between THbc and pCO_2, suggesting that higher hemoglobin levels could help buffer higher carbon dioxide levels. Moreover, the patho physiology of gas exchange deficiencies brough ton by COPD is consistent with the strong negative association between pCO_2 and pO_2. The systemic character of respiratory disorders impacting acid-base and electrolytic homeostasis is apparent in the observed electrolyte correlations, especially Na^+ with HCO_3^- and K^+ with Ca^{2+}.

CONCLUSION

This study demonstrates an important association between acid-base balance parameters in individuals with COPD and hemoglobin concentration and blood electrolytes.The slightly positive correlation with pCO_2 and the substantial negative correlations with bicarbonate and calcium indicate hemoglobin's critical function in the body's compensatory mechanisms for impaired respiration.Disrupted acid-base regulation is likely the cause or consequence of electrolyteimbalances,whichareparticularlylinked.Theseresultspromoteamoreindividualized and comprehensive clinical strategy by high lighting the significance of integrated biochemical monitoringinmanagingCOPDtoevaluatediseaseseverity,directtherapeuticmeasures,and anticipate future metabolic consequences.

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