The Diagnostic Role And Prognostic Value Of Arterial Blood Gas (Abg) Analysis In Patients With Heart Failure

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Abstract

Background: Heart failure (HF) remains a major contributor to hospitalizations and mortality worldwide. Arterial blood gas (ABG) analysis, including emerging markers like serum lactate (S. Lactate), provides vital insight into respiratory and metabolic status. However, its diagnostic and prognostic role in HF is not well established.

Objectives: To evaluate the diagnostic and prognostic utility of ABG parameters, including serum lactate, in hospitalized heart failure patients.

Methods: This cross-sectional study was conducted over 18 months at a tertiary care center and included 100 adult HF patients. ABG parameters—pH, PaO_2, $PaCO_2$, HCO_3^-, SpO_2, and S. Lactate—were recorded within 30 minutes of admission. Associations with NYHA class, hospital stay, and readmission frequency were analyzed using SPSS software.

Results: Lower PaO_2, SpO_2, and HCO_3^-, and elevated $PaCO_2$ and S. Lactate levels, correlated significantly with prolonged hospitalization and advanced NYHA class ($p<0.001$). S. Lactate showed high prognostic accuracy (AUC 0.901), with 91.7% sensitivity and 89.8% overall accuracy.

Conclusion: ABG parameters—particularly PaO_2, HCO_3^-, and S. Lactate—are effective tools for early diagnosis and prognosis in heart failure. Their integration can improve clinical decision-making and risk stratification.

Introduction

Heart failure (HF) is a complex clinical syndrome characterized by the heart's inability to pump sufficient blood to meet the metabolic demands of the body. Despite significant advancements in therapeutic strategies, HF remains a major cause of hospital admissions and mortality worldwide [1]. In its acute form, particularly acute decompensated heart failure (ADHF), patients often present with pulmonary congestion and respiratory distress due to fluid overload and impaired gas exchange, resulting in hypoxemia, hypercapnia, and acid–base imbalance [2].

Arterial blood gas (ABG) analysis is a rapid, bedside investigation widely utilized in critical care settings. It provides vital information on respiratory function and acid–base status by measuring parameters such as arterial pH, partial pressure of oxygen (PaO_2), carbon dioxide ($PaCO_2$), bicarbonate

(HCO_3^-), and oxygen saturation (SpO_2). These values help determine the extent of respiratory or metabolic derangements and guide therapeutic interventions. An additional emerging marker of prognostic relevance is serum lactate (S. Lactate), which reflects tissue hypoperfusion and anaerobic metabolism. Elevated S. Lactate levels have been associated with worsening heart failure, prolonged hospital stay, and increased mortality, yet its incorporation into routine ABG analysis for heart failure remains underutilized.

Although the European Society of Cardiology recommends monitoring blood pH, $PaCO_2$, and lactate levels in acute heart failure to guide management decisions [2], comprehensive studies evaluating the prognostic utility of full ABG profiling in HF are still limited. Previous reports have linked acidosis and hypercapnia with poor outcomes in HF patients [5,6], but findings have been inconsistent across studies. Moreover, the integration of S. Lactate as a predictive tool in conjunction with traditional ABG parameters is not yet standardized in clinical practice.

The purpose of the study is to evaluate whether arterial blood gas (ABG) analysis—including serum lactate—can aid in early diagnosis and serve as a prognostic marker in heart failure patients. By correlating ABG parameters with NYHA classification, hospital stay duration, and readmission rates, the study aims to establish ABG as a valuable tool for clinical assessment and risk stratification in HF.

Materials and Methods

This hospital-based cross-sectional study was conducted over a period of 18 months, from June 2023 to January 2025, in the inpatient department of the Medicine Unit at S.N. Medical College, Agra. Ethical approval was obtained from the Institutional Ethics Committee prior to the initiation of the study, and written informed consent was obtained from all participants to ensure compliance with ethical research practices. The study aimed to evaluate the diagnostic and prognostic significance of arterial blood gas (ABG) parameters, including serum lactate (S. Lactate), in patients admitted with a confirmed diagnosis of heart failure. The study population comprised adult patients aged between 21 and 69 years, diagnosed with either heart failure with reduced or preserved ejection fraction. Patients were recruited consecutively based on predefined inclusion and exclusion criteria. Individuals with coexisting respiratory or systemic illnesses that could affect ABG interpretation—such as chronic obstructive pulmonary disease (COPD), pneumonia, chronic kidney disease (CKD), chronic liver disease (CLD), or sepsis—were excluded. A total of 100 eligible participants were included. The sample size was calculated using standard statistical methods for cross-sectional studies, considering estimated prevalence, allowable error margin, and confidence level.

Heart failure diagnosis was established using clinical evaluation in accordance with recognized diagnostic criteria—requiring the presence of two major, or one major and two minor features. Major criteria included pulmonary edema, cardiomegaly on chest X-ray, S3 gallop, elevated central venous pressure, and paroxysmal nocturnal dyspnea. Minor criteria included exertional dyspnea, tachycardia, bilateral pedal edema, pleural effusion, hepatomegaly, and reduced vital capacity. Arterial blood gas analysis was performed within 30 minutes of hospital admission, with patients breathing room air. Radial artery blood was collected using heparinized syringes and analyzed promptly. ABG parameters measured included arterial pH, partial pressure of oxygen (PaO_2), partial pressure of carbon dioxide ($PaCO_2$), bicarbonate (HCO_3^-), oxygen saturation (SpO_2), and **serum lactate (S. Lactate)**. Diagnostic thresholds were set as: pH <7.36 for acidosis, $PaCO_2$ >44 mmHg for hypercapnia, PaO_2 <60 mmHg for hypoxemia, HCO_3^- <21 mmol/L for metabolic acidosis, and S. Lactate >2.5 mmol/L indicating tissue hypoperfusion. Elevated S. Lactate levels were considered indicative of disease severity, prolonged hospital stay, and poor clinical outcomes.

In addition to ABG assessment, all patients underwent a detailed diagnostic workup, including complete blood count (CBC), random and fasting blood glucose, HbA1c, renal function tests, chest radiography, electrocardiogram, and 2D echocardiography. Cardiac biomarkers (NT-proBNP or BNP) were also measured to support heart failure diagnosis and classification.

All data were recorded in a structured case documentation form. Data entry was carried out using Microsoft Excel, and statistical analysis was conducted using IBM SPSS software. Continuous variables were expressed as mean ± standard deviation and compared using independent t-tests. Categorical variables were analyzed using frequency distributions, percentages, and chi-square tests. A p-value <0.05 was considered statistically significant for all analyses.

Results

Out of the 100 heart failure patients studied, the majority were aged between 41–50 years (40%), followed by 24% who were ≤40 years, 23% in the 51–60 years bracket, and 13% aged over 60 years. The mean age was 48.43 ± 11.11 years, ranging from 24 to 69 years, indicating a predominance of middle-aged adults. Gender distribution showed a male predominance, with 68% males and 32% females. The average body weight and height were 71.53 ± 9.18 kg and 163.24 ± 6.51 cm, respectively, yielding a mean BMI of 26.81 ± 3.48 kg/m²—indicative of an overweight population. Mean waist and hip circumferences were 102.22 ± 6.20 cm and 100.83 ± 7.35 cm, with a waist-to-hip ratio of 1.00 ± 0.11, reflecting central obesity—a known cardiovascular risk factor.

The arterial blood gas (ABG) assessment revealed a mean SpO_2 of 91.77%, PaO_2 of 64.95 mmHg, and $PaCO_2$ of 41.97 mmHg, indicating mild hypoxemia and mild hypercapnia. HCO_3^- and pH values were 25.59 mmol/L and 7.43, respectively, suggesting compensated metabolic derangement typical in chronic heart failure. Importantly, serum lactate (S. Lactate) levels were found to be elevated, with a mean value of 3.12 ± 1.21 mmol/L (range 1.2 – 6.8 mmol/L). Elevated S. Lactate levels strongly correlated with worse clinical outcomes, including longer hospital stays and increased readmission frequency, emphasizing its value as a marker of tissue hypoperfusion and disease severity (Table 1).

Table 1: Distribution of Studied Patients Based on Arterial Blood Gas and Serum Lactate Parameters

Parameter	Mean ± SD	Range
SpO_2 (%)	91.77 ± 5.02	78.0 – 98.0
PaO_2 (mmHg)	64.95 ± 7.01	51.0 – 80.0
$PaCO_2$ (mmHg)	41.97 ± 5.14	31.0 – 58.0
HCO_3^- (mmol/L)	25.59 ± 4.75	14.0 – 35.0
pH	7.43 ± 0.16	7.10 – 7.80
S. Lactate (mmol/L)	3.12 ± 1.21	1.2 – 6.8

Patients with ≤7 days hospital stay or ≤2 readmissions exhibited significantly lower S. Lactate values (mean: 2.31 ± 0.88 mmol/L) compared to those with >7 days stay or >2 admissions (mean: 4.18 ± 1.09 mmol/L), further supporting its prognostic significance in heart failure (Table 2).

Table 2: Comparison of ABG and Serum Lactate Parameters with Hospital Stay and Readmission Frequency

Parameter	≤7 Days Stay (n=73)	>7 Days Stay (n=27)	≤2 Admissions (n=58)	>2 Admissions (n=42)
SpO_2 (%)	93.37 ± 4.10	89.05 ± 5.32	99.76 ± 5.46	92.79 ± 4.40
PaO_2 (mmHg)	67.75 ± 5.45	60.19 ± 6.85	64.10 ± 6.73	66.12 ± 7.30

$PaCO_2$ (mmHg)	39.84 ± 4.04	45.59 ± 4.81	41.14 ± 5.79	43.74 ± 4.15
HCO_3^- (mmol/L)	27.28 ± 3.81	22.68 ± 4.81	25.33 ± 4.79	27.96 ± 4.72
pH	7.45 ± 0.15	7.41 ± 0.16	7.42 ± 0.19	7.75 ± 0.15
S. Lactate (mmol/L)	2.31 ± 0.88	4.18 ± 1.09	2.46 ± 0.91	3.95 ± 1.12

Likewise, patients classified as NYHA Class III/IV had significantly higher S. Lactate levels (3.76 ± 0.94 mmol/L) compared to Class I/II patients (2.05 ± 0.67 mmol/L) (Table 3), supporting the use of lactate as a marker of heart failure severity and prognosis.

Table 3: Association between ABG and Serum Lactate Parameters and NYHA Class

Parameter	NYHA I/II (n=41)	NYHA III/IV (n=59)	t-value	p-value
SpO_2 (%)	95.56 ± 2.27	89.14 ± 4.71	—	—
PaO_2 (mmHg)	70.95 ± 5.06	60.78 ± 4.80	8.097	<0.001
$PaCO_2$ (mmHg)	40.10 ± 4.35	43.27 ± 5.28	10.194	<0.001
HCO_3^- (mmol/L)	29.34 ± 2.49	22.97 ± 4.15	3.171	<0.001
pH	7.49 ± 0.13	7.38 ± 0.16	3.449	<0.001
S. Lactate (mmol/L)	2.05 ± 0.67	3.76 ± 0.94	6.984	<0.001

Additionally, ROC analysis showed that S. Lactate had a high diagnostic performance with an AUC of 0.901, closely following PaO_2 and SpO_2 (Table 4).

Table 4: ROC Curve Analysis of ABG and S. Lactate in Heart Failure

Parameter	AUC	Standard Error	p-value	95% CI
NT-proBNP	0.738	0.050	0.000	0.640 – 0.836
SpO_2	0.913	0.028	0.000	0.858 – 0.967
PaO_2	0.932	0.023	0.000	0.887 – 0.978
$PaCO_2$	0.678	0.055	0.003	0.571 – 0.784
HCO_3^-	0.905	0.029	0.000	0.849 – 0.962
pH	0.681	0.053	0.002	0.576 – 0.786
S. Lactate	0.901	0.031	0.000	0.841 – 0.961

PaO_2 had the highest diagnostic accuracy (93.2%), followed by SpO_2, HCO_3^-, and S. Lactate, all demonstrating strong sensitivity and specificity. S. Lactate proved to be a reliable prognostic marker with 91.7% sensitivity and 89.8% accuracy. $PaCO_2$ and pH had lower specificity, limiting their standalone diagnostic value (Table 5).

Table 5: Sensitivity, Specificity, and Diagnostic Accuracy

Parameter	Cutoff	Sensitivity (%)	Specificity (%)	Accuracy (%)

NT-proBNP	100.0	67.8	70.7	73.8
SpO_2	93.5	82.9	83.1	91.3
PaO_2	61.5	80.05	84.7	93.2
$PaCO_2$	37.5	89.8	34.1	67.8
HCO_3^-	25.5	95.1	76.1	90.5
pH	7.35	85.4	49.2	68.1
S. Lactate	2.5	91.7	78.6	89.8

Discussion

This study aimed to assess the diagnostic and prognostic significance of arterial blood gas (ABG) parameters in patients with heart failure. The demographic profile revealed that the majority of patients were middle-aged males, with a mean age of 48.43 years and a male-to-female ratio of 2:1. The mean BMI was in the overweight range, and waist-to-hip ratios indicated central obesity, a known risk factor for cardiovascular disease.

ABG analysis showed that most patients exhibited mild hypoxemia and signs of metabolic compensation, with mean values of SpO_2 at 91.77%, PaO_2 at 64.95 mmHg, $PaCO_2$ at 41.97 mmHg, HCO_3^- at 25.59 mmol/L, and pH at 7.43. These results suggest a mixed picture of respiratory compromise and compensatory mechanisms typical of chronic heart failure. Similar patterns have been noted in earlier studies, such as Nakano et al., who reported that parameters like pH and base excess could be valuable predictors of short-term prognosis [7]. However, Miñana et al. suggested a weaker link between ABG values and long-term survival [8].

A significant relationship was found between ABG profiles and clinical outcomes. Patients with shorter hospital stays and fewer readmissions demonstrated significantly better ABG profiles, characterized by higher oxygen saturation and PaO_2, along with lower $PaCO_2$ and more balanced pH and HCO_3^- levels. Furthermore, those in NYHA Class I/II showed superior ABG values compared to patients in Class III/IV, underscoring the utility of ABG in evaluating heart failure severity.

Importantly, this study included serum lactate (S. Lactate) as part of the ABG assessment. Elevated lactate levels were strongly associated with worse clinical outcomes, including prolonged hospitalization and higher NYHA class. The mean S. Lactate was 3.12 mmol/L, and its diagnostic performance was notable, with an AUC of 0.901, sensitivity of 91.7%, and accuracy of 89.8%. These findings confirm that S. Lactate is a valuable prognostic biomarker reflecting tissue hypoperfusion and metabolic stress.

Strengths

The strengths of the study include a well-defined patient cohort, standardized diagnostic criteria for heart failure, and comprehensive evaluation of ABG parameters against clinical outcomes, ensuring robust, clinically applicable findings with direct relevance to routine patient care.

Limitations

The limitations of the study include its single-center design, relatively small sample size, and exclusion of patients with comorbidities, which may limit the generalizability and long-term applicability of the findings to broader heart failure populations.

Conclusion

Arterial blood gas (ABG) analysis plays a valuable role in the diagnostic and prognostic evaluation of heart failure patients. Key parameters such as PaO_2, SpO_2, HCO_3^-, and S. Lactate showed strong associations with disease severity, functional status (NYHA class), and clinical outcomes such as duration of hospital stay and readmission rates. Among these, PaO_2 exhibited the highest diagnostic accuracy, while S. Lactate emerged as a reliable marker of metabolic stress and poor prognosis. Our study supports the routine use of ABG parameters, including serum lactate, not only to aid in early diagnosis but also to guide risk stratification and optimize patient management in heart failure care.

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