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PROGNOSTIC VALUE OF ARTERIAL BLOOD GAS (ABG) PROFILE IN PATIENTS WITH ACUTE HEART FAILURE IN TERTIARY CARE CENTRE IN WESTERN RAJASTHAN

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ABSTRACT

Background: Acute heart failure (AHF) remains a major burden on healthcare facilities, particularly in tertiary care centres. Effective prognostic tools are important in such conditions. Arterial blood gas (ABG) analysis, reflecting oxygenation, carbon dioxide levels, and acid-base status, may offer early insights into patient outcomes, yet its prognostic utility in AHF still remains underestimated.

Objective: This study aims to investigate the prognostic value of ABG parameters (pH, PaO2, PaCO2, HCO3-, lactate) in AHF patients, focusing on their association with mortality and ICU needs.

Methods: Conducted as a prospective cohort study in 2024-2025 at Dr S.N. Medical College, Jodhpur. This research enrolled 126 AHF patients upon admission for ABG analysis and further follow-up. Statistical methods, including t-tests and ANOVA, compared ABG values between survivors and non-survivors, and across varying ICU stay lengths.

Results: Non-survivor patients exhibited significant ABG deviations ($p < 0.05$): lower pH, PaO2, HCO3- alongside higher PaCO2 and lactate levels along with dyselectrolytemia (lower sodium and higher potassium). Metabolic acidosis and respiratory alkalosis correlated with increased mortality and longer ICU stays (>6 days), with notable associations for low sodium, high potassium, low PaO2, higher PaCO2 and elevated lactate ($p < 0.05$).

Conclusion: ABG parameters are reliable predictors of prognosis in AHF. Metabolic Acidosis, Respiratory Alkalosis, Electrolyte imbalances (serum sodium and potassium), elevated lactate levels and deviations from normal pH and PaCO2 are associated with worse clinical outcomes. Incorporating ABG data along with clinical assessment could improve risk stratification and guide therapeutic strategies better.

Keywords: Acute heart failure, arterial blood gas, pH, PaO_2, $PaCO_2$, bicarbonate, lactate, electrolytes, prognosis, in-hospital mortality.

INTRODUCTION

Heart failure (HF) is a complex clinical syndrome resulting from structural or functional impairments in ventricular filling or blood ejection, manifested by cardinal symptoms such as dyspnea, fatigue, and fluid retention.[1] International guidelines, such as ACCF/AHA and the European Society of Cardiology, emphasize that this state results in reduced cardiac output or elevated intracardiac pressures, both at rest and during stress.[2] Clinically, the term "heart failure" is now preferred over "congestive heart failure" to account for patients who may not show overt fluid overload. Heart failure represents the final common pathway for a spectrum of chronic cardiovascular diseases, most notably hypertension, coronary artery disease, and valvular pathologies.[3]

When this condition manifests as acute heart failure (AHF), characterized by rapidly progressive respiratory symptoms due to pulmonary congestion - termed as acute pulmonary edema[4] - prognosis becomes more guarded. This phase represents an advanced stage of disease where physiological reserves are exhausted under stress.

Globally, the burden is staggering, with approximately 56 million individuals affected.[5] In the Indian context, the challenge is particularly tough; estimates suggest between 1.3 million and 22.7 million cases of HF, with up to 1.8 million new diagnoses annually.[6] Patients often present at a younger age, with over 60% of deaths recorded in those under 70 years. Furthermore, the mortality risk is highest in the first three months post-hospitalization, reaching nearly 18%.[7] This

high morbidity is compounded by a significant economic burden, with the total cost per patient in India averaging over INR 1.3 lakhs, much of which is out-of-pocket.[8]

The pathophysiology of AHF involves hemodynamic congestion leading to disturbances in gas exchange, specifically hypoxemia and hypercapnia, while reduced cardiac output results in tissue hypoperfusion and metabolic acidosis. Arterial Blood Gas (ABG) analysis, therefore, emerges as a critical bedside tool. It serves as a dual marker of "backward" failure (pulmonary and systemic congestion) and "forward" failure (low output state), providing real-time data on acid-base balance and systemic perfusion.

Despite its availability and the critical information it provides—such as pH, PaO2, PaCO2, and lactate levels—there remains a significant lacuna in the literature regarding its comprehensive prognostic value specifically in AHF patients. Most existing studies focus on isolated parameters rather than the holistic ABG profile. This study, conducted in a tertiary care centre in Western Rajasthan, aims to bridge this gap by exploring the prognostic significance of the ABG profile in predicting clinical outcomes and ICU stay duration in patients with acute heart failure.

MATERIAL AND METHODS

We conducted this prospective observational cohort study at the Department of General Medicine, Dr SN Medical College, Jodhpur over a period of 6 months to decide significance of ABG as a prognostic tool in acute heart failure. After ethical approval a total of 126 patients were included in this study after diagnosing them on the basis of Framingham Criteria for heart failure. Assessments were made based on the Patient Outcome (Discharge vs. Expired) and length of ICU stay. Baseline demographic and clinical data (age, sex, address, comorbidities, prior heart failure), detailed physical examination (blood pressure, JVP, crackles, edema), and laboratory evaluation such as CBC, serum electrolytes, LFT, RFT, NT-proBNP and ABG parameters (pH, PaO_2, $PaCO_2$, HCO_3^-, lactate) were recorded upon admission. The ABG analysis performed at room air in the emergency setting within 30 min of the patients' admission after the initial assessment. The analysis includes measurement of pH, the partial pressure of Carbon Dioxide in arterial blood (PaCO2), and the partial pressure of arterial Oxygen (PaO2), Standard Bicarbonate (HCO3) and serum lactate. Acidosis and alkalosis were defined as pH < 7.36, and as pH > 7.44 respectively. Hypoxaemia, hypercapnia, and low bicarbonate were defined as PaO2 < 60 mmHg, PaCO2 > 44 mmHg, HCO3 < 21 mEq/L and Lactic Acidosis as >2mmols/L respectively. These are the thresholds for abnormal ABG values.[18] Data were collected using a per-structured proforma and subsequently tabulated in Excel sheet. Statistical analysis was carried out using statistical packages include Descriptive Statistics (Mean, SD), Independent Samples t-test, Chi-Square Test, One-way ANOVA, Pearson Correlation, Mann-Whitney U Test, IBM SPSS Statistics and Excel spreadsheets.

Primary outcome was all-cause in-hospital mortality or discharge (from ICU admission to discharge/death), while secondary outcomes included ICU stay duration (days), renal function

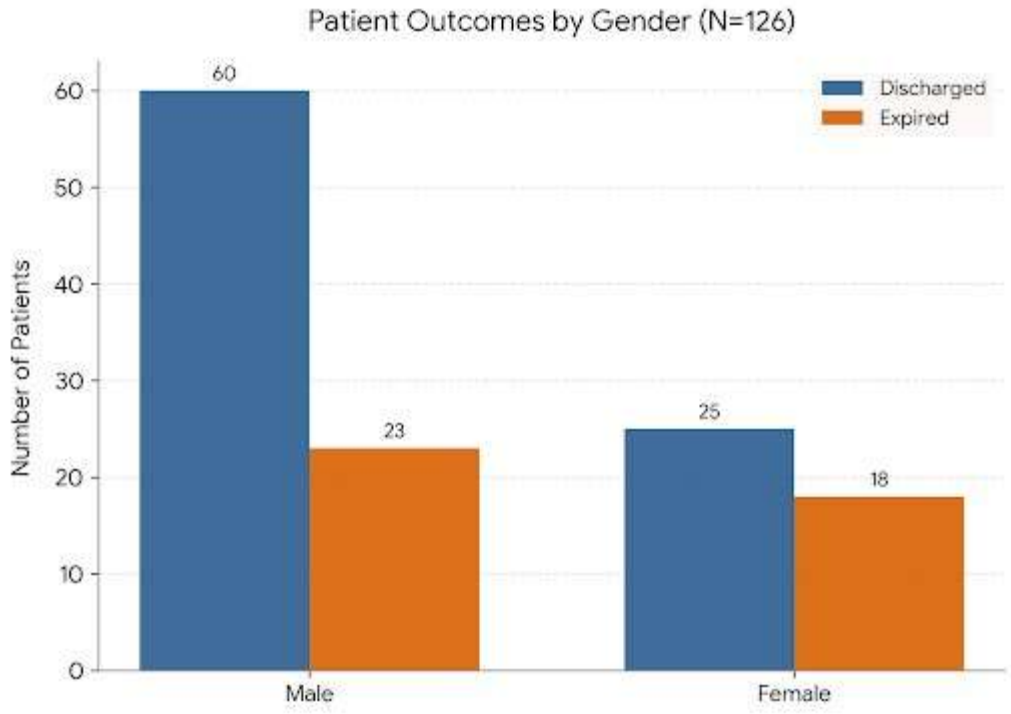
deterioration (serum creatinine changes and AKI), and clinical improvement based on symptoms (dyspnea, edema), examination findings, and biomarkers (BNP, NT-proBNP).

OBSERVATIONS AND RESULTS

The study analyzed a cohort of 126 patients admitted for Acute Heart Failure (AHF) to our tertiary care center. The demographics revealed a predominantly aging population, with ages ranging from 21 to 87 years (Mean: 62.60±12.94 years). A distinct negative skew was observed, indicating a higher concentration of cases in the 6th and 7th decades of life, which aligns with the progressive nature of heart failure.

Table 1: Patient Demographics and Outcomes

Parameter	Sub-category	Frequency (N=126)	Outcome: Discharged	Outcome: Expired
Gender	Male	83	60	23
	Female	43	25	18
	Total outcomes	126	85 (67.5%)	41 (32.5%)



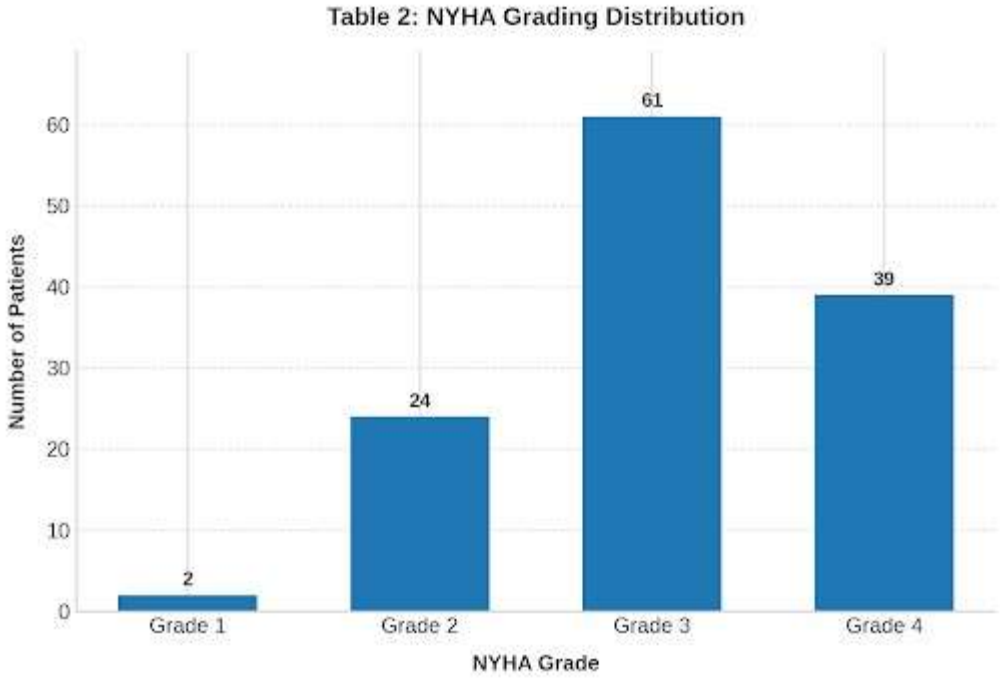
The overall in-hospital mortality rate was 32.5%. The average ICU stay was 4.60±2.92 days, with a median of 4 days. Notably, 75% of patients were discharged within 6 days, though outliers required up to 20 days of intensive monitoring.

Clinical and Echocardiographic Profile

The primary etiology for AHF in our subset was ischemic, with Anterior Wall Myocardial Infarction (AWMI) being the most common (n=47), followed by Inferior Wall MI (n=22). Functional severity was high; the majority presented with NYHA Class III (n=61) and Class IV (n=39) symptoms. Left Ventricular Ejection Fraction (LVEF) was severely impaired across the cohort, with a mean of 27.34% and a median of 25%.

Table 2: NYHA Grading Distribution

NYHA Grade	Number of Patients
Grade 1	2
Grade 2	24
Grade 3	61
Grade 4	39



Biochemical and Electrolyte Predictors

Arterial blood analysis and serum electrolytes proved to be highly significant prognosticators. Sodium levels were significantly lower in patients who expired (Mean: 130.88±4.94 mEq/L) compared to those discharged (Mean: 139.18±4.18 mEq/L; p=0.0000). Conversely, hyperkalemia was associated with mortality, with expired patients showing higher mean potassium levels (5.20±0.74 mEq/L) compared to survivors (4.20±0.68 mEq/L).

ABG Disorders and ICU Stay

The "Type of ABG Disorder" emerged as a primary determinant of the length of ICU stay (p=0.0005). Patients with a "Normal ABG" (n=65) had the shortest recovery periods (Mean: 3.23 days), while those with mixed disorders, such as combined Metabolic Alkalosis and Respiratory Acidosis, required significantly longer hospitalization (Mean: 9.0 days).

Table 3: ABG Disorder Type vs. ICU Stay Duration

Table 3

		ICU stay				
Types of disorder in ABG	count	mean	std	min	max	median
metabolic acidosis	17	5.88235	3.15995	2	12	5
metabolic acidosis+respiratory acidosis	6	5.66667	2.73252	2	9	6
metabolic acidosis+respiratory alkalosis	4	6.75	3.40343	2	10	7.5

metabolic alkalosis	3	7.66667	5.03322	3	13	7
metabolic alkalosis+respiratory acidosis	3	9	9.64365	2	20	5
normal abg	65	3.23077	1.16952	1	7	3
respiratory acidosis	2	4.5	2.12132	3	6	4.5
respiratory alkalosis	26	5.76923	2.86088	2	13	5.5

Clinical and Biochemical Parameters vs. Patient Outcome

This table compares all major parameters between the Discharged and Expired groups.

Table 4 shows that patients who expired had significantly lower BP, lower Ejection Fraction, and marked hyponatremia/hyperkalemia.

Parameter	Discharged (n=85)	Expired (n=41)	P-Value
Age (Years)	62.06 ± 13.56	63.73 ± 11.61	0.5015
Systolic BP (mmHg)	111.41 ± 18.23	100.24 ± 20.30	0.0022
Diastolic BP (mmHg)	70.82 ± 11.23	61.22 ± 15.68	0.0002
Heart Rate (bpm)	92.41 ± 16.32	101.95 ± 16.20	0.0025
LVEF (%)	28.59 ± 5.16	24.76 ± 4.54	0.0001
pH	7.40 ± 0.05	7.37 ± 0.11	0.0267

pCO_2 (mmHg)	37.89 ± 5.16	37.81 ± 9.47	0.9571
pO_2 (mmHg)	81.33 ± 9.20	72.82 ± 8.16	0
HCO_3^- (mEq/L)	22.18 ± 3.79	18.25 ± 6.13	0.0002
Lactate (mmol/L)	1.54 ± 0.67	3.77 ± 2.50	0
Sodium (mEq/L)	139.18 ± 4.18	130.88 ± 4.94	0
Potassium (mEq/L)	4.20 ± 0.68	5.20 ± 0.74	0
Creatinine (mg/dL)	1.27 ± 0.69	1.63 ± 0.38	0.0029
Trop I (ng/ml)	1.05 ± 1.84	5.75 ± 5.86	0
NT-ProBNP (pg/ml)	1756.12 ± 1493.30	4352.44 ± 2884.22	0
NYHA Grade (Frequency)	II: 21, III: 45, IV: 17, I: 2	II: 3, III: 16, IV: 22, I: 0	0
Type of MI (Frequency)	AWMI: 28, IWMI: 17, ASMI: 11	AWMI: 19, IWMI: 5, ASMI: 4	0.0461
ABG Disorder Type	Normal: 57, Mixed: 2	Normal: 8, Mixed: 11	0

Table 5: Parameters vs. Duration of ICU Stay

This table demonstrates how clinical variables correlate with the length of stay, highlighting the recovery trajectory in the ICU.

Variable	Statistical Measure	Correlation with ICU Stay (r)	P-Value
Overall ICU Stay (Days)	Mean ± SD	Discharged: 4.01 ± 2.21	Expired: 5.83 ± 3.79
Sodium	Correlation (r)	-0.638 (Strong Negative)	<0.05
Potassium	Correlation (r)	0.528 (Strong Positive)	<0.05
Lactate	Correlation (r)	0.536 (Strong Positive)	<0.05
pO_2	Correlation (r)	-0.407 (Moderate Negative)	<0.05
Creatinine	Correlation (r)	0.354 (Moderate Positive)	<0.05
Systolic BP	Correlation (r)	-0.366 (Moderate Negative)	<0.05
Diastolic BP	Correlation (r)	-0.320 (Moderate Negative)	<0.05
Trop I	Correlation (r)	0.655 (Strong Positive)	<0.05

NT-ProBNP	Correlation (r)	0.505 (Strong Positive)	<0.05
NYHA Class	Median Stay (Days)	Class II: 3 days, Class III: 4 days	Class IV: 6 days
ABG Disorder (Normal)	Mean Stay (Days)	3.23 ± 1.17	<0.001
ABG Disorder (Mixed)	Mean Stay (Days)	9.00 ± 9.64	<0.001

Table 4 confirms that higher levels of Troponin I (r=0.655) and Lactate (r=0.536) are the strongest predictors of a prolonged and complicated ICU stay.

Mixed ABG disorders (especially Metabolic Alkalosis combined with Respiratory Acidosis) resulted in the longest ICU stays, averaging 9 days.

DISCUSSION

The core finding of this study is the primacy of physiological markers—specifically ABG profiles and electrolytes—over demographic variables in predicting AHF outcomes. In our cohort, "Types of ABG Disorders" stood out as the most robust marker for both mortality risk and ICU resource consumption.

Prognostic Significance of ABG Profiles

A Normal ABG profile at admission was a strong predictor of survival and a shorter ICU stay (mean 3.23 days). In contrast, Metabolic Acidosis and Respiratory Alkalosis were significant markers of mortality risk.

Metabolic Acidosis: In AHF, this typically reflects tissue hypoperfusion and anaerobic metabolism (forward failure), leading to lactic acid accumulation. Our data confirms that patients with metabolic acidosis stay longer (mean 5.88 days) and have higher mortality.
Respiratory Alkalosis: Often a result of compensatory hyperventilation due to pulmonary congestion (backward failure), this state signals severe respiratory distress and was linked to prolonged ICU stays in our study.

These findings align with Khan MS et al. (2020)[9], who noted that pH and lactate abnormalities are significant in-hospital mortality predictors. Similarly, Harjola et al. (2017)[10] emphasized lactate as a critical marker for AHF outcomes, which our findings support through the association of metabolic acidosis with poor prognosis.

The Role of Electrolytes and Renal Function

Hyponatremia was a striking predictor of mortality in our patients (p=0.0000). This likely reflects advanced neurohormonal activation, where increased ADH levels lead to dilutional hyponatremia, a hallmark of end-stage heart failure. Furthermore, elevated serum creatinine emerged as a predictor of poor outcomes, underscoring the "Cardiorenal Syndrome" where heart failure leads to progressive renal decline.

CLINICAL IMPLICATIONS FOR RESOURCE CONSTRAINED SETTINGS

From a clinical standpoint, especially in high-volume centers, ABG analysis offers a rapid, bedside framework for risk stratification. Our results suggest that:

Fast-Tracking: Patients with a Normal ABG and stable electrolytes can be prioritized for early step-down from the ICU to save critical care resources.

Targeted Intervention: Patients presenting with Metabolic Acidosis or Respiratory Alkalosis require aggressive, immediate management of their underlying hemodynamic status to improve survival chances.

Limitations and Future Directions

While insightful, this study was a single-center prospective cohort with a modest sample size of 126 patients. We excluded patients with CKD and COPD, which may limit generalizability to "real-world" multi-morbid AHF populations. Additionally, ABG was measured only at admission; future research should focus on "dynamic" ABG monitoring to see how changes in acid-base status during treatment correlate with long-term survival.

Conclusion

Routine ABG analysis, combined with electrolyte and renal function monitoring, provides a powerful tool for predicting AHF severity. Normalization of acid-base status remains a key therapeutic goal that directly correlates with reduced ICU burden and improved patient survival.

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