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Biochemical Profiles and Clinical Correlates of Hyperkalemia and Metabolic Acidosis in Acute Kidney Injury Patients: A Cross-Sectional Analysis

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ABSTRACT

Acute Kidney Injury (AKI) is often complicated by biochemical disturbances, including hyperkalemia and metabolic acidosis. **Objective:** To examine the biochemical profiles and clinical consequences of hyperkalemia and metabolic acidosis in patients with AKI, with the goal of identifying correlations and prognostic markers to improve management strategies. **Methods:** The cross-sectional observational study analyzed 130 geriatric AKI patients with hyperkalemia and metabolic acidosis, assessing clinical outcomes through multivariable regression. **Results:** In 130 AKI patients with hyperkalemia and metabolic acidosis (mean age: 68.5 ± 10.2 years, 60% males), hypertension (45%) was the most common comorbidity. ICU admission was required in 25%, with an average hospital stay of 8.4 ± 4.5 days. Biochemical markers showed elevated serum potassium (6.2 ± 0.8 mEq/L), creatinine (3.5 ± 1.2 mg/dL), and reduced bicarbonate (18.5 ± 3.5 mEq/L). Serum creatinine ($r = 0.80$) and potassium ($r = 0.67$) correlated strongly with dialysis need, while lower blood pH ($r = -0.50$) was linked to ICU admission. Multivariable analysis identified serum creatinine (OR = 3.00, $p < 0.001$) as the strongest predictor of severe hyperkalemia and acidosis, with hypertension (OR = 2.15, $p = 0.015$) and advancing age (OR = 1.05, $p = 0.003$) also increasing risk. **Conclusions:** Hyperkalemia, metabolic acidosis, and elevated serum creatinine in acute kidney injury patients are strongly linked to worse outcomes, highlighting the need for early intervention.

INTRODUCTION

Acute Kidney Injury (AKI) is a serious medical condition characterized by a sudden weakening in kidney function that frequently results in significant injury and death, especially in hospitalized patients [1]. This also includes the many complications related to AKI, hyperkalemia, and metabolic acidosis which are chiefly notable due to their profound effects on different systems of the body among them cardiac, neuromuscular, and metabolic pathway disruption [2] are the most vulnerable ones. Elevated potassium levels, acknowledged by hyperkalemia, pose a danger of life-captivating cardiac arrhythmias [3]. In the meantime, metabolic acidosis, designated by reduced blood pH and bicarbonate levels, interrupts normal physiological courses and worsens the severity of AKI by promoting inflammation, endothelial dysfunction, and renal tubular injury [4]. Biochemical estimation in patients with AKI plays a crucial role in measuring the extent of renal damage and considerate the metabolic instabilities involved [5]. This information is dynamic for prompt mediation and operative risk stratification to predict outcomes, guide therapeutic decisions, and reduce morbidity [6]. Although several studies have discovered electrolyte imbalances in AKI, however, inclusive research directing specifically on the biochemical profiles and

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clinical outcomes of patients with coexisting hyperkalemia and metabolic acidosis remains limited with most studies focusing on either hyperkalemia or metabolic acidosis individually rather than their combined impact [7]. Additionally, recent studies highlight that persistent metabolic acidosis in AKI patients is linked to a higher risk of Chronic Kidney Disease (CKD) progression, emphasizing the need for early intervention to prevent long-term renal deterioration [8].

Moreover, hyperkalemia in AKI has been found to increase the likelihood of in-hospital cardiac arrest necessitating vigilant monitoring and timely therapeutic measures [9, 10]. To address this gap, the present study will analyze the biochemical characteristics and discover probable clinical associations in AKI patients with these complications. By targeting this specific subgroup, the study seeked to improve understanding, enable early identification of high-risk patients and subsidize the development of more precise management strategies, ultimately cultivating patient results [11].

METHODS

This was a cross-sectional observational study conducted at Khawaja Muhamamd Safder Medical College (KMSMC) Sialkot. The primary participants of this study were older adult patients diagnosed with Acute Kidney Injury (AKI), presenting with hyperkalemia and metabolic acidosis. The study was conducted over a period from February 2024, to June 2024, under the approval of the Institutional Review Board (IRB) with reference number 30/REC/KMSMC. Patients were included if they exhibited biochemical disturbances indicative of AKI, including hyperkalemia (serum potassium >5.0 mEq/L) and metabolic acidosis (serum bicarbonate <22 mEq/L or pH <7.35), with a minimum hospital stay of 48 hours for serial biochemical assessment. Exclusion criteria comprised pre-existing CKD or ESRD to focus on acute kidney dysfunction, as well as non-renal causes of electrolyte imbalance, such as adrenal insufficiency or diabetic ketoacidosis, to ensure the study's specificity to AKI-related disturbances. Prior Use of Potassium-Lowering or Bicarbonate Therapy – Patients receiving active treatment for hyperkalemia or metabolic acidosis before admission were excluded to prevent confounding effects on biochemical assessments. The KDIGO (Kidney Disease: Improving Global Outcomes) guidelines were used solely for classifying AKI severity in the included patients, ensuring standardized assessment of kidney function decline. Patients were stratified into KDIGO Stage 1, 2, or 3 based on changes in serum creatinine and urine output post-admission. Data were collected through an appraisal of patients' medical histories and their systemic records. However, blood sampling was conducted at the time of admission. The data that has been preserved comprised demographic information like the relevant medicinal history of hypertension, diabetes mellitus, cardiovascular disease, and their age and gender. The levels of serum potassium, serum bicarbonate, their blood pH and serum Creatinine considered at same time. Blood urea nitrogen and Estimated Glomerular Filtration Rate (eGFR) were also measured to ensure precise data collection. Clinical outcomes were also recorded, focusing on the length of hospital stay, the requirement for dialysis, ICU admissions, and the severity of AKI, categorized based on established guidelines. Data analysis was accomplished using SPSS version 26.0. Descriptive statistics were intended for demographic and clinical variables while continuous variables expressed as Mean ± Standard Deviation (SD) along median (interquartile range) as suitable. Definite variables were presented as frequencies and percentages. According to data distribution correlations between biochemical parameters and clinical results were assessed using Pearson's or Spearman's correlation coefficients. Additionally, multivariable logistic regression analysis was conducted to identify the predictors to determine severe hyperkalemia and metabolic acidosis. Therefore, proper adjustment for potential confounders such as age and comorbidities was done. The obtained results were displayed as adjusted Odds Ratios (ORs) beside with 95% confidence intervals to show the strength and consistency of the gained outcomes. Ethical consent for the study was approved by the hospital's Ethical Evaluation Board. All participants gave their informed consent before taking part in this study. Their individual information was kept personal during the investigation. Participants were also informed of their accurate rights to withdraw from the study at any time without facing any negative consequences.

RESULTS

Table 1 presents the demographic and clinical characteristics of the study population. A total of 130 patients with AKI and associated hyperkalemia and metabolic acidosis were included, with a mean age of 68.5 ± 10.2 years. Males comprised 60% of the cohort, while 40% were female. The most prevalent comorbidities were hypertension (45%), diabetes mellitus (30%), and cardiovascular disease (15%). Regarding AKI severity, 30% of patients were categorized as KDIGO stage 1, 40% as stage 2, and 30% as stage 3. ICU admission was required for 25% of patients, and the mean hospital stay was 8.4 ± 4.5 days. This table outlines the demographic and clinical characteristics of the study population, including age, gender, comorbidities, AKI severity, ICU admission, and length of hospital stay.

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Table 1: Demographic and Clinical Characteristics of AKI Patients with Hyperkalemia and Metabolic Acidosis (n = 130)

Variables	Frequency (%)/Mean ± SD
Age (Years)	68.5 ± 10.2
Gender	
Male	60 (60%)
Female	40 (40%)
Comorbidities	
Hypertension	45 (45%)
Diabetes Mellitus	30 (30%)
Cardiovascular Disease	15 (15%)
AKI Severity (KDIGO Staging)	
Stage 1	30 (30%)
Stage 2	40 (40%)
Stage 3	30 (30%)
ICU Admission	25 (25%)
Length of Stay (Days)	8.4 ± 4.5

Table 2 provides an outline of the biochemical parameters of AKI patients with hyperkalemia and metabolic acidosis. Serum potassium levels were markedly elevated (6.2 ± 0.8 mEq/L), exceeding the normal range (3.5-5.0 mEq/L). Serum bicarbonate was reduced (18.5 ± 3.5 mEq/L), and blood pH was lower than normal (7.29 ± 0.08). Serum creatinine (3.5 ± 1.2 mg/dL) and blood urea nitrogen (45.2 ± 15.3 mg/dL) were significantly increased, while estimated glomerular filtration rate (eGFR) was markedly reduced (25.3 ± 10.5 mL/min/1.73m^2), reflecting severe renal impairment.

Table 2: Serum Levels of Parameters in AKI Patients with Hyperkalemia and Metabolic Acidosis (n = 130)

Variables	Mean ± SD/Median (IQR)	Normal Range
Serum Potassium (mEq/L)	6.2 ± 0.8	3.5 - 5.0
Serum Bicarbonate (mEq/L)	18.5 ± 3.5	22 - 28
Blood pH	7.29 ± 0.08	7.35 - 7.45
Serum Creatinine (mg/dL)	3.5 ± 1.2	0.6 - 1.2
Blood Urea Nitrogen (mg/dL)	45.2 ± 15.3	7 - 20
Estimated Glomerular Filtration Rate (eGFR, mL/min/1.73 m^2)	25.3 ± 10.5	>90

This table shows the correlation between key biochemical markers (serum potassium, creatinine, blood pH) and clinical outcomes, including length of hospital stay, ICU admission, and need for dialysis. Table 3 illustrates the correlation between key biochemical markers and clinical outcomes. Serum potassium, creatinine, and blood pH exhibited significant correlations with hospital stay, ICU admission, and need for dialysis. Notably, elevated serum creatinine (r = 0.80) and potassium (r = 0.67) were strongly associated with dialysis requirement, while lower blood pH was inversely correlated with ICU admission (r = -0.50) and hospital stay (r = -0.55).

Table 3: Correlation between Biochemical Markers and Clinical Outcomes in AKI Patients with Hyperkalemia and Metabolic Acidosis (n = 130)

Clinical Outcomes	Serum Potassium (r)	Serum Bicarbonate (r)	Serum Creatinine (r)	Blood pH (r)
Length of Hospital Stay	0.45*	-0.50*	0.60*	-0.55*
Need for Dialysis	0.67*	-0.40*	0.80*	-0.45*
ICU Admission	0.55*	-0.35*	0.70*	-0.50*

*Note: Correlation coefficients (R-values) have been calculated using Pearson's or Spearman's correlation depending on data distribution

This bar chart presents the adjusted Odds Ratios (OR) with 95% Confidence Intervals (CI) for key predictor variables in Acute Kidney Injury (AKI), including age, hypertension, diabetes mellitus, serum creatinine, and blood pH. The x-axis represents the OR, where values greater than 1 indicate an increased risk, while values below 1 suggested a protective effect. The vertical dashed line at OR = 1 denoted no association. Serum creatinine (OR = 3.00, p < 0.001) is strongly associated with severe hyperkalemia and metabolic acidosis in AKI, reflecting impaired renal clearance. Hypertension (OR = 2.15, p = 0.015) significantly increases the risk of severe hyperkalemia in AKI, likely due to altered renal sodium and potassium regulation. Diabetes mellitus (OR = 1.78, p = 0.073) showed a potential but non-significant association with electrolyte disturbances in AKI. Age (OR = 1.05, p = 0.003) is significantly associated with worsening metabolic acidosis in AKI, suggested declining acid-base balance with age. Blood pH (OR = 0.50, p = 0.002) exhibits an inverse relationship with severe hyperkalemia in AKI, indicating that worsening acidosis increases the risk of electrolyte imbalances.

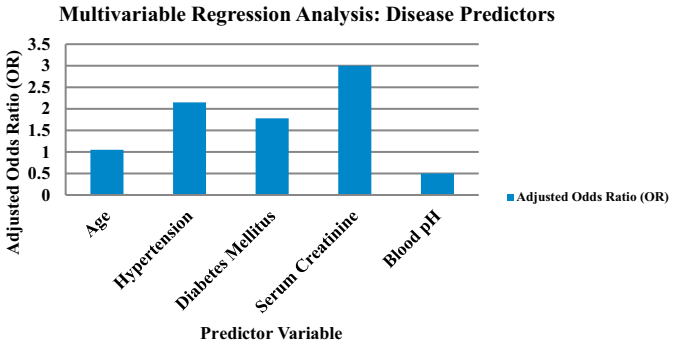


Figure 1: Multivariable Regression Analysis of Predictors for Severe Hyperkalemia and Metabolic Acidosis in Acute Kidney Injury (AKI)

This table 4 presented the results of a multivariate logistic regression analysis assessing the association between various predictor variables and a clinical outcome. The adjusted odds ratio (OR), 95% confidence interval (CI), and p-value for each predictor are reported. Statistically significant predictors (p < 0.05) include age, hypertension, serum creatinine, and blood pH, indicating their strong

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association with the outcome. Diabetes mellitus shows a non-significant trend (p = 0.073).

Table 4: Predictors of Clinical Outcomes: A Multivariate Analysis

Predictor Variables	Adjusted Odds Ratio (OR)	95% Confidence Interval (CI)	p-Value
Age	1.05	1.02 - 1.08	0.003
Hypertension	2.15	1.15 - 4.02	0.015
Diabetes Mellitus	1.78	0.95 - 3.35	0.073
Serum Creatinine	3.00	1.80 - 4.90	<0.001
Blood pH	0.50	0.30 - 0.80	0.002

DISCUSSION

This study was intended to clarify the biochemical outlines and clinical comparisons of hyperkalemia and metabolic acidosis in cases of critical kidney injury. These results indicated significant correlations between elevated serum potassium levels, diminished bicarbonate levels, and serious clinical consequences. These are consistent with existing literature stating the importance of these specific biochemical markers in AKI management [12]. The demographic facts demonstrated that the mainstream were older adults, with a mean age of 68.5 years. This brings into line with the predominant understanding that age is an important risk factor for AKI. All these factors had potentially increased the occurrence of comorbidities such as hypertension and diabetes mellitus in this population [13]. In particular, 45% of patients had a history of hypertension, and 30% were diabetics, representing an essential need for careful nursing and management of circumstances to alleviate the risk of AKI. Biochemically, results showed that the mean serum potassium level was significantly elevated at 6.2 mEq/L. This is well above the regular range. This is concerning, as most severe cardiac-related deaths are the consequence of hyperkalemia, plus arrhythmias, particularly in the background of AKI [14]. Moreover, the mean serum bicarbonate level was established to be 18.5 mEq/L, confronting metabolic acidosis. The observed blood pH of 7.29 supplements the presence of substantial acid-base disturbances. These findings stand prominent in establishing an interrelationship between hyperkalemia and metabolic acidosis in AKI patients. Ultimately requiring the necessity to timely monitor and intervene in further complications [15]. This analysis exposed that higher serum potassium levels correlated positively and confidently with longer hospital stays. Moreover, requiring an increased likelihood for urgent dialysis in acute cases. This correlation highlights the clinical significance as a prognostic marker for serum potassium in managing acute kidney [16]. The multivariable regression analysis recognized numerous interpreters of severe hyperkalemia and metabolic acidosis, with serum creatinine showing the strongest association. This highlights the role of kidney function in the directive of potassium and acid-base balance, supporting the importance of early recognition and treatment of deteriorating kidney function in at-risk populations [17]. Interestingly, the study also distinguished that older age and the presence of comorbidities such as hypertension significantly supported the danger of developing severe hyperkalemia and metabolic acidosis. These findings suggest that targeted interventions aimed at managing these risk factors hold importance in preventing AKI-related complications in older adults [18]. Boundaries of the study include its cross-sectional design, which limits the ability to infer causality, making its nature as single-center. It is therefore needed to conduct studies with larger, multicenter cohorts and longitudinal designs to elucidate this difficult relationship between parameters in AKI patients [19]. In conclusion, this study emphasizes the critical need for alert biochemical monitoring and management of hyperkalemia and metabolic acidosis in older patients with AKI. Healthcare providers can improve patient conditions by understanding the biochemical profiles and their clinical correlates. Therefore, through timely interventions, they can refine the management of AKI in this predisposed old population [20].

A major limitation of this study is its single-center cross-sectional design, which restricts causal inference and generalizability to broader populations. The relatively modest sample size and focus on hospitalized geriatric patients may also limit external validity. Future multicenter longitudinal studies with larger and more diverse cohorts are recommended to validate these findings, assess temporal biochemical changes, and develop predictive risk models for earlier intervention and improved AKI management.

CONCLUSIONS

This study emphasized the role of observing acidosis and hyperkalemia in patients presenting acutely particularly with older age. Elevated serum potassium and decreased bicarbonate levels have been intensely connected to adverse outcomes, including prolonged hospital stays and amplified dialysis needs. Targeted interventions and watchful biochemical assessments are vital and aimed at enlightening AKI management and patient outcomes.

Authors' Contribution

Conceptualization: MA
Methodology: MAT
Formal analysis: AM
Writing, review and editing: FI, HA, AK, MA
Review and Editing: FI, HA, AK, MA, MAT, AM

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflicts of Interest

All the authors declare no conflict of interest.

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