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ECG Diagnostic Accuracy of Patients with Hyperkalemia Presenting to the Emergency Department: A Prospective Observational Study.

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Abstract

Background: Hyperkalemia is a potentially life-threatening electrolyte disorder commonly encountered in emergency department (ED) settings, particularly among patients with chronic kidney disease, heart failure, diabetes mellitus, and sepsis. The electrocardiogram (ECG) is widely used as a rapid, non-invasive tool for its initial detection; however, its diagnostic accuracy and limitations require further clinical evaluation. ***Aim:*** To evaluate the diagnostic accuracy of ECG in detecting hyperkalemia among patients presenting to the emergency department. ***Methods:*** A prospective, single-center, observational study was conducted over 12 months (December 2023–December 2024) at a tertiary care hospital in New Delhi, India. A total of 200 patients meeting predefined inclusion criteria were enrolled. Demographic data, ECG findings, and laboratory serum potassium levels were recorded and analyzed using SPSS v21. Sensitivity, specificity, and receiver operating characteristic (ROC) curve analysis were performed to assess diagnostic performance. ***Results:*** Of 200 patients, 107 (53.5%) were hyperkalemic. Hyperkalemia was most prevalent in patients aged ≥71 years (31.8%) and was significantly associated with chronic kidney disease ($p=0.010$), heart failure ($p=0.011$), liver failure ($p=0.001$), diabetes mellitus ($p=0.010$), sepsis ($p=0.001$), and hypertension ($p=0.001$). Peaked T waves, widened QRS complexes, and shortened QT intervals were significantly associated with rising potassium levels. ECG demonstrated a sensitivity of 89.7% and specificity of 47.3% for detecting hyperkalemia. The area under the ROC curve (AUC) was 0.731 (95% CI: 0.654–0.808; $p<0.001$). ***Conclusion:*** ECG is a valuable and rapid initial screening tool for hyperkalemia in the emergency setting due to its high sensitivity. However, its moderate specificity mandates confirmatory serum potassium testing. Integration of ECG-based screening with laboratory diagnostics can optimize timely management and improve patient outcomes.

Keywords: Hyperkalemia, Electrocardiogram, Emergency Department, Diagnostic Accuracy, ECG Changes, Potassium.

INTRODUCTION

Hyperkalemia, defined as serum potassium ≥5.5 mEq/L, is a common and potentially fatal electrolyte disorder affecting 1–10% of hospitalized patients and up to 2–3% of emergency department (ED) patients.[1–5] It is closely associated with chronic diseases including renal failure, heart failure, and diabetes mellitus, with an incidence approaching 50% in patients with severe renal impairment.

Under normal physiological conditions, potassium is predominantly an intracellular ion, with intracellular concentrations of approximately 140 mEq/L and extracellular concentrations maintained between 3.5 and 5.0 mEq/L by active Na-K-ATPase pumps and passive efflux.[6–7] This gradient is critical for maintaining the resting membrane potential required for cardiac, neuronal, and muscular function. Hyperkalemia disrupts this balance through mechanisms including reduced renal excretion, transcellular potassium shifts (due to metabolic acidosis, insulin deficiency, or beta-blocker use), excessive intake, or pseudohyperkalemia.[6–7]

The European Resuscitation Council classifies hyperkalemia as mild (5.5–5.9 mEq/L), moderate (6.0–6.4 mEq/L), or severe (≥6.5 mEq/L), with levels above 10 mEq/L typically considered lethal.[8] Its rising prevalence reflects ageing populations, increasing use of RAAS inhibitors, and growing incidence of chronic kidney disease.[9–10]

Clinically, hyperkalemia may present with neuromuscular symptoms such as paresthesia, muscle weakness, and ascending flaccid paralysis, as well as gastrointestinal symptoms including nausea, vomiting, and diarrhea.[11–13] The most critical manifestations are cardiac, including bradycardia, ventricular fibrillation, and asystole.[12–13] Because hyperkalemia affects both cardiac depolarization and repolarization, it produces characteristic ECG changes progressing from peaked T waves to QRS widening, conduction blocks, and sine-wave patterns in severe disease.[14–16]

The ECG represents the most rapidly available tool for early diagnosis in emergency settings; however, its sensitivity and specificity in clinical practice remain subjects of debate. Several studies have reported variable ECG sensitivity, with some reporting figures as low as 19%.[29] The present study was therefore conducted to evaluate the diagnostic accuracy of ECG for hyperkalemia among patients attending the emergency department of a tertiary care hospital in India.

MATERIALS AND METHODS

This was a prospective, single-center, observational study conducted over 12 months (December 2023 to December 2024) in the Emergency Department of Max Smart Super Speciality Hospital, Saket, New Delhi — a tertiary care referral center.

Sample Size

The sample size was calculated to detect a clinically meaningful difference of at least 20% between groups, based on ECG alteration rates reported by Verga et al. (43% in controls vs. 63% in hyperkalemia), at 80% power and 5% level of significance, yielding a minimum of 97 patients per group; 200 patients were enrolled in total.

Eligibility Criteria

Inclusion criteria: Patients ≥18 years of age presenting with a clinical history suggestive of hyperkalemia (CKD, heart failure, liver failure, diabetes mellitus, sepsis, cancer, hypertension, or dehydration), or with ECG changes suggestive of hyperkalemia.

Exclusion criteria: Patients <18 years of age; samples obtained using a tourniquet or showing evidence of in-vivo hemolysis.

Data Collection

Following institutional ethics committee approval and informed written consent, eligible patients were enrolled sequentially. A 12-lead ECG was performed on ED admission and interpreted by an emergency physician. Laboratory serum potassium levels served as the diagnostic reference standard. Hyperkalemia was defined as serum potassium ≥5.5 mmol/L.

Statistical Analysis

Data were analyzed using SPSS version 21 (IBM Inc.). Categorical variables were compared using the chi-square test; continuous variables by independent t-test. Normality was assessed using the Shapiro–Wilk test. Sensitivity, specificity, PPV, NPV, and ROC curve analysis were performed. A p-value <0.05 was considered statistically significant.

RESULTS

Age Distribution

A total of 200 patients were enrolled; 107 (53.5%) were hyperkalemic and 93 (46.5%) were normokalemic. As shown in Table 1, hyperkalemia was most prevalent in the ≥71-year age group (31.8%), while normokalemia was most common in those aged 41–50 years (40.9%).

A statistically significant association was found between age group and potassium status (p=0.001), indicating a progressive rise in hyperkalemia prevalence with advancing age.

Table 1: Distribution of patients according to age group and kalemia status

Age Group	Normokalemic N (%)	Hyperkalemic N (%)	Total N (%)
18–30 years	6 (6.5%)	16 (15.0%)	22 (11.0%)
31–40 years	11 (11.8%)	16 (15.0%)	27 (13.5%)
41–50 years	38 (40.9%)	14 (13.1%)	52 (26.0%)
51–60 years	31 (33.3%)	17 (15.9%)	48 (24.0%)
61–70 years	5 (5.4%)	10 (9.3%)	15 (7.5%)
≥71 years	2 (2.2%)	34 (31.8%)	36 (18.0%)
Total	**93 (100%)**	**107 (100%)**	**200 (100%)**
p-value		0.001 (Significant)*	

Chi-square test; significance set at $p<0.05$

Association with Comorbidities

Hyperkalemia prevalence was significantly higher across most comorbidity groups. Table 2 shows the association with diabetes mellitus; 42.1% of hyperkalemic patients had DM versus only 14.0% of normokalemic patients (p=0.010). Table 3 shows the association with sepsis, which was present in 45.8% of hyperkalemic patients compared to 19.4% of normokalemic patients (p=0.001). Similar significant associations were observed for CKD (p=0.010), heart failure (p=0.011), liver failure (p=0.001), and hypertension (p=0.001). No significant association was found with cancer (p=0.355) or dehydration (p=0.065).

Table 2: Distribution of patients according to diabetes mellitus and kalemia status

Diabetes Mellitus	Normokalemic N (%)	Hyperkalemic N (%)	Total N (%)
Absent	80 (86.0%)	62 (57.9%)	142 (71.0%)
Present	13 (14.0%)	45 (42.1%)	58 (29.0%)
Total	**93 (100%)**	**107 (100%)**	**200 (100%)**
p-value		0.010 (Significant)*	

Chi-square test; significance set at $p<0.05$

Table 3: Distribution of patients according to sepsis and kalemia status

Sepsis	Normokalemic N (%)	Hyperkalemic N (%)	Total N (%)
Absent	75 (80.6%)	58 (54.2%)	133 (66.5%)
Present	18 (19.4%)	49 (45.8%)	67 (33.5%)
Total	**93 (100%)**	**107 (100%)**	**200 (100%)**
p-value		0.001 (Significant)*	

Chi-square test; significance set at $p<0.05$

ECG Findings by Potassium Level

Table 4 presents the distribution of ECG findings across laboratory-confirmed potassium strata. P wave changes (disappearance and flattening) and prolonged PR interval dominated the lower potassium range (<5.49 mmol/L). Shortened QTc interval was the most prominent finding at 6.51–7.50 mmol/L (50.0%). At higher potassium levels (7.51–9.00 mmol/L), ST depression (17.1%), LBBB (14.3%), and RBBB (11.4%) emerged. In severe hyperkalemia (≥9.01 mmol/L), sinus tachycardia (26.7%), RBBB and SVT (20.0% each), and atrial fibrillation (13.3%) were prominent.

Table 4: ECG findings correlated with laboratory-confirmed potassium levels

ECG Finding	<5.49 N (%)	5.50–6.50 N (%)	6.51–7.50 N (%)	7.51–9.00 N (%)	≥9.01 N (%)	Total N (%)
Flattening of P wave	9 (9.7%)	3 (10.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	12 (6.0%)
Disappearance of P wave	34 (36.6%)	7 (24.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	41 (20.5%)
Prolonged PR interval (>200 ms)	30 (32.3%)	4 (13.8%)	0 (0.0%)	2 (5.7%)	0 (0.0%)	36 (18.0%)
Widened QRS complex (>120 ms)	18 (19.4%)	6 (20.7%)	2 (7.1%)	1 (2.9%)	1 (6.7%)	28 (14.0%)
Peaked T wave	1 (1.1%)	2 (6.9%)	5 (17.9%)	5 (14.3%)	2 (13.3%)	15 (7.5%)
Shortened QTc interval	0 (0.0%)	2 (6.9%)	14 (50.0%)	3 (8.6%)	0 (0.0%)	19 (9.5%)
ST elevation	0 (0.0%)	2 (6.9%)	5 (17.9%)	5 (14.3%)	0 (0.0%)	12 (6.0%)
ST depression	0 (0.0%)	1 (3.4%)	1 (3.6%)	6 (17.1%)	0 (0.0%)	8 (4.0%)
RBBB	1 (1.1%)	1 (3.4%)	1 (3.6%)	4 (11.4%)	3 (20.0%)	10 (5.0%)
LBBB	0 (0.0%)	1 (3.4%)	0 (0.0%)	5 (14.3%)	0 (0.0%)	6 (3.0%)
Atrial fibrillation	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (5.7%)	2 (13.3%)	4 (2.0%)
Sinus bradycardia	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (5.7%)	0 (0.0%)	2 (1.0%)
Sinus tachycardia	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (26.7%)	4 (2.0%)
SVT	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (20.0%)	3 (1.5%)
Total	**93 (100%)**	**29 (100%)**	**28 (100%)**	**35 (100%)**	**15 (100%)**	**200 (100%)**
p-value			**0.065 (NS)**			

Chi-square test; NS = Non-significant; significance set at p<0.05

ROC Curve Analysis

As shown in Table 5, ROC analysis revealed an AUC of 0.731 (95% CI: 0.654–0.808; p<0.001), indicating good discriminatory ability of ECG in distinguishing hyperkalemic from normokalemic patients. The standard error of 0.039 reflects low variability and reliability of the estimate.

Table 5: Area under the ROC curve for ECG in detecting hyperkalemia

Parameter	**Value**
Area Under the Curve (AUC)	0.731
Standard Error	0.039
Asymptotic Significance (p-value)	<0.001*
95% Confidence Interval – Lower Bound	0.654
95% Confidence Interval – Upper Bound	0.808

Statistically significant

Diagnostic Accuracy of ECG

Table 6 summarizes the overall diagnostic performance of ECG against laboratory-confirmed potassium levels. ECG demonstrated a sensitivity of 89.7%, correctly identifying 96 of 107 hyperkalemic patients. However, specificity was moderate at 47.3%, with 49 of 93 normokalemic patients misclassified as hyperkalemic. The NPV of 80.0% suggests reasonable but imperfect value of a normal ECG in excluding hyperkalemia.

Table 6: Summary of ECG diagnostic accuracy parameters

Diagnostic Parameter	**Value**
True Positives (TP)	96
True Negatives (TN)	44
False Positives (FP)	49
False Negatives (FN)	11
Sensitivity	89.7%
Specificity	47.3%
Positive Predictive Value (PPV)	66.2%
Negative Predictive Value (NPV)	80.0%
Area Under ROC Curve (AUC)	0.731
95% Confidence Interval	0.654 – 0.808
p-value	<0.001*

Statistically significant

DISCUSSION

Demographic Findings

The current study found hyperkalemia in 53.5% of the study population, with the greatest burden in patients aged ≥71 years (31.8%), consistent with the age-related decline in renal function and accumulation of comorbidities in elderly populations. Chon et al. (2013) similarly reported a mean age of 71.2 years in hyperkalemic patients presenting with symptomatic bradycardia.[31] Raffee et al. (2022) found a slightly younger cohort (mean age 63.9±15.1 years), emphasizing a broader age spectrum in hyperkalemic presentations.[27] No significant gender difference was observed (p=0.503), suggesting that renal and metabolic disease burden — rather than sex — primarily drives potassium dysregulation.

Association with Comorbidities

The significant associations between hyperkalemia and CKD (p=0.010), heart failure (p=0.011), liver failure (p=0.001), diabetes mellitus (p=0.010), sepsis (p=0.001), and hypertension (p=0.001) reinforce well-established pathophysiology. Raffee et al. (2022) reported similar patterns — hypertension in 71.6%, diabetes in 67.2%, and CKD in 64.2% of their hyperkalemic cohort.[27] The absence of significant association with cancer (p=0.355) and dehydration (p=0.065) likely reflects small cancer patient numbers and heterogeneous mechanisms by which dehydration affects potassium balance.

ECG Findings and Potassium Levels

ECG abnormalities exhibited a clear gradient across potassium strata. P wave disappearance and prolonged PR interval dominated in the lower range, while shortened QTc was most prominent at 6.51–7.50 mmol/L (50.0%). Advanced conduction abnormalities and arrhythmias emerged at higher levels, consistent with established electrophysiology.[14–16] Raffee et al. (2022) similarly reported peaked T waves significantly more common in severe hyperkalemia (87.5% vs. 12.5% in mild disease, p=0.041).[27] Tsai et al. (2023) demonstrated that QRS duration, T wave slope, and T/QRS amplitude ratios differed significantly between normokalemic and severe hyperkalemic ECGs.[22] Notably, several ECG changes were also present in normokalemic patients, reflecting the diagnostic overlap that reduces specificity.

Diagnostic Accuracy

The ECG demonstrated a sensitivity of 89.7% and specificity of 47.3% in this study, with an AUC of 0.731. Galloway et al. (2019) reported an AUC of 0.853–0.883 with 88.9–91.3% sensitivity using a deep learning model across 1.5 million ECGs.[30] Lin et al. (2025) demonstrated AI-assisted ECG potassium estimation achieving an AUC of 0.884 with 93.3% sensitivity.[18] In contrast, Rafique et al. (2020) found that emergency physicians relying on visual ECG interpretation achieved only 19% mean sensitivity,[29] underscoring the value of systematic or algorithm-assisted analysis. The AUC of 0.731 obtained in the current study — using standard clinical ECG interpretation — compares favorably with human physician performance and supports the potential role of computational ECG tools in routine emergency care.

Clinical Implications

These results reinforce current practice: ECG should be obtained promptly in any patient at risk of hyperkalemia, particularly those with CKD, heart failure, sepsis, or diabetes mellitus. A normal ECG does not exclude hyperkalemia, and laboratory testing remains essential. In resource-constrained or time-critical settings, ECG serves as a useful triage tool to prioritize urgent laboratory testing and initiate membrane-stabilizing therapy (e.g., intravenous calcium) while awaiting results. Integration of emerging AI-based ECG tools into clinical workflows represents a compelling pathway for improving specificity without sacrificing sensitivity.

CONCLUSION

This prospective observational study demonstrates that ECG has high sensitivity (89.7%) but only moderate specificity (47.3%) for detecting hyperkalemia in the emergency department, with an AUC of 0.731. Hyperkalemia was significantly associated with advanced age, CKD, heart failure, liver failure, diabetes mellitus, sepsis, and hypertension.

Rising potassium levels correlated with progressive ECG abnormalities — from peaked T waves and shortened QTc to QRS widening, bundle branch blocks, and life-threatening arrhythmias in severe disease.

These findings support ECG-based screening as a rapid and practical first step in the evaluation of at-risk patients. However, due to its moderate specificity and overlap with other ECG abnormalities, confirmatory serum potassium testing is mandatory.

Integration of ECG screening with advanced diagnostic technologies, including AI-assisted interpretation, may enhance diagnostic accuracy and improve outcomes in patients at risk of hyperkalemia-related cardiac complications.

Limitations

This study was conducted at a single tertiary care center, which may limit generalizability. Although the sample size was adequate for the primary objective, a larger cohort would enable more granular subgroup analyses. Observer variability in ECG interpretation was not formally quantified, and long-term outcomes of hyperkalemic patients were not assessed.

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