

ORIGINAL ARTICLE

Electrocardiogram with measurement of Serum Potassium :Better Clinical Assessment

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Introduction: Potassium plays a critical role in muscle contraction, maintenance of fluid and electrolyte balance, nerve conduction, cardiac rhythm. European Resuscitation Council (ERC) Guidelines defines hyperkalemia with a serum potassium(K) level of ≥ 5.5 mmol/L. Hyperkalemia is an electrolyte disorder which is potentially life-threatening with incidence ranging between 1.1 and 10% in hospitalized patients. The present study was conducted in adult patients to identify the various factors associated with hyperkalemia and proportion of hyperkalemic patients with Electrocardiogram (ECG) changes. **Material and Method:** We conducted a cross sectional study at our tertiary care hospital with 140 adult patients with incidentally detected hyperkalemia, visiting medicine out-patients(32) and in-patients department(108). ECG recordings and clinical, and biochemical parameters were performed for them along with assessment of records to identify associated disorders. **Results:** Hyperkalemia was associated with chronic kidney disease (51.4%), Acute kidney injury (15%), drugs related (29.3%) and others with tumor necrosis, Systemic Lupus Erythematosus etc. (4.3%). Hyperkalemia was noted as Mild (77.9%), Moderate (15%), and Severe (7.1%) patients. Abnormal ECG changes were seen in sixty-eight patients, (48.6%) with tall T wave in (39.7%), tall T wave along with prolonged PR interval in (20.6%), prolonged PR interval in (5.9%), and pseudo-ST elevation, sinus bradycardia in (16.4%) patients and normal ECG findings in 72 patients (51.42%). **Conclusion:** Hyperkalemia was found in out-patients and in-patients with chronic kidney diseases, Acute Kidney diseases, drugs related and may present with or without associated ECG changes. Hyperkalemia needs to be investigated by direct serum

potassium measurement and treated aggressively irrespective to normal ECG recordings.

Keywords: Hyperkalemia, Electrocardiogram, Clinical assessment.

Introduction:

Potassium is an essential electrolyte that plays a critical role in muscle contraction, maintenance of fluid and electrolyte balance, nerve conduction, and cardiac rhythm. Changes in potassium levels significantly affect cardiac and skeletal muscle functions with hyperkalemia as predisposing factors for cardiac arrhythmia. According to the 2005 established and current European Resuscitation Council Guidelines, hyperkalemia is defined as a serum potassium level of ≥ 5.5 mmol/L. Further classifications include mild (5.5–5.9 mmol/L), moderate (6.0–6.4 mmol/L), and severe (≥ 6.5 mmol/L) hyperkalemia. [1] In hospitalized patients, hyperkalemia is one of the most common, potentially fatal electrolyte disorders. As reported in a survey, estimates for the incidence range between 1.1 and 10 percent of hospitalized patients. [2] The most common cause of hyperkalemia is associated with reduced renal excretion followed by redistribution and reduced tissue uptake. Excessive intake of potassium is a rare cause but can have a major impact in susceptible patients with diabetes and chronic kidney diseases. Hyperaldosteronism and severe tissue deterioration, such as seen in rhabdomyolysis, tumor lysis are common conditions that result in hyperkalemia in addition to acute and chronic renal failure. Drugs affecting renin angiotensin aldosterone mechanism is also a major cause for hyperkalemia. [3] Hyperkalemia leads to various ECG changes that range in severity from non-specific repolarization abnormalities seen in mild elevations of serum potassium to the classic sine-wave rhythm, which

appears in severe hyperkalemia. [4] ECG changes that wave, prolonged o PR segment, reduction, or “flattening” of the P-wave, prolonged QRS complexes, have been noted in numerous studies are Tall “tented” T-axis Deviation and bundle branch blocks (right / left). The gradually widening QRS eventually merges with the T wave to form a sine wave pattern, later ventricular fibrillation (VF) or asystole may follow.[5]. ECG findings progress as serum levels rise. Although ECG findings generally correlate with serum potassium levels, hyperkalemia can result in potentially life-threatening arrhythmias without warning. Few studies have also proven the low sensitivity and specificity of ECG in diagnosing the case of hyperkalemia. [2] Such studies based on hyperkalemia are relatively less in Indian population and suffer from some limitations, such as the retrospective nature, the variable definitions of hyperkalemia, and the different type of analyses used. Most of the information comes from case reports or small case series or from the admitted patients who undergo serum electrolytes estimations often. Hence this study was conducted to identify the various factors associated with hyperkalemia in out-patients and in-patients, as well as to find any hyperkalemia associated ECG changes in these patients.

Material and Methods:

The cross-sectional study was conducted in a tertiary care hospital in southern Maharashtra. The study was approved by the institutional ethics committee following the CPCSEA and World Medical Association Declaration of Helsinki on Ethical Principles for Medical Research. Adult patients visiting out-patients department of Medicine or admitted in the hospital wards were first screened for hyperkalemia (serum potassium level of more than 5.5 mmol/L) and with prior informed written consent. A total of 140 patients willingly participated in the study. The study was conducted over a period of 18 months. Demographic data, drug history, and clinical history of these patients was recorded to document conditions such as acute renal failure, chronic renal insufficiency, congestive heart failure, diabetes etc., The electrocardiogram of each patient was recorded to check for changes. These patients were further investigated for related laboratory tests including hemogram, blood urea, and serum creatinine etc. All hyperkalemia patients with or

without ECG changes were treated with either Calcium Glucometer ,Glucose Insulin drip, nebulization, and/or oral potassium binders, or change in drug regime. All data collected was tabulated, and statistically analyzed using software SPSS version 28. Quantitative data was expressed by appropriate means, and qualitative data was expressed as frequencies (number) and percentage. The percentage of categorical variables was compared using the Chi-square test. The means of continuous variables were compared by independent’s test. The p-value of <0.05 was considered significant.

Results:

Among these 140 patients, 32 patients were from out-patients, and 108 patients were from in-patients. Majority of patients were males 91 (65%) and 49 (35%) were females, with male: female ratio of 1.86:1. The age group of study population was in the range of 20 to 90 yrs with mean age as 56.13 ± 13.91 years. Out of these, 32.85% were below 50 years, while ninety-six patients were above 50 years of their age. In the present study, chronic kidney disease was found to be the most commonly associated disorder to hyperkalemia.

Table 1: Potassium levels among study group population.

	Potassium levels		
	Mild	Moderate	Severe
mEq/L	5.5-5.9	6.0-6.4	above 6.5
No. of patients	109	21	10
Percent	77.9	15.0	7.1

Total 72 (51.4%) patients were of chronic kidney disease. Out of these chronic kidney disease patients, 19 (26.4%) patients had diabetes mellitus, 22 (30.6%) had only hypertension and 19 (26.4%) had presence of both diabetes mellitus and hypertension. Remaining patients were from Acute kidney injury 21 (15%), drugs related 41 (29.3%) and others with tumor necrosis, Systemic Lupus Erythematosus etc. 6 (4.3%). We have distributed patients according to their serum potassium levels in the three groups and are shown in Table 1. Hyperkalemia noted was mild (5.5 to 5.9 mEq/L), Moderate (6.0 to 6.4 mEq/L) and severe (≥ 6.5 mEq/L). There were 109 patients in Mild hyperkalemia category, 21 patients in Moderate category and 10 patients were in Severe

category which is depicted in Table 1. Table 2 shows the distribution of patients according to specific ECG findings noted with respect to with tall T wave in (39.7%), tall T wave along with prolonged PR interval

Table 2: ECG recordings in Study Population

ECG findings in Study Population					
ECG changes Recorded	Tall 'T' wave	Prolonged PR interval	Tall 'T' wave with Prolonged PR interval	With in Normal Limit	Other : Sinus Tachycardia, Left Ventricular Hypertrophies, etc.
No. of patients	27	04	14	72	23
Percent	19.2	2.85	10	51.4	16.4

in (20.6%), prolonged PR interval in (5.9%), and pseudo-ST elevation, sinus bradycardia in (16.4%) patients and normal ECG findings in 72 patients (51.42%). Distribution of patients, their hyperkalemia

Table 3: Association of category of potassium to ECG changes

		ECG Changes			p-value
		Yes	No		
Potassium	<6.5 (Mild and Moderate)	59	71	130	0.008*
	≥6.5 (Severe)	9	1	10	
Total		68	72	140	

Figure 1: Tall T wave

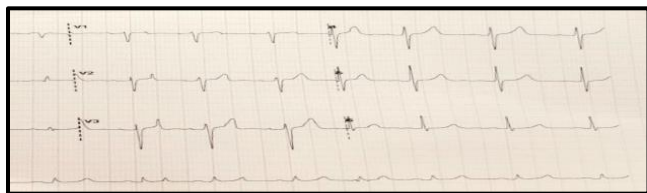
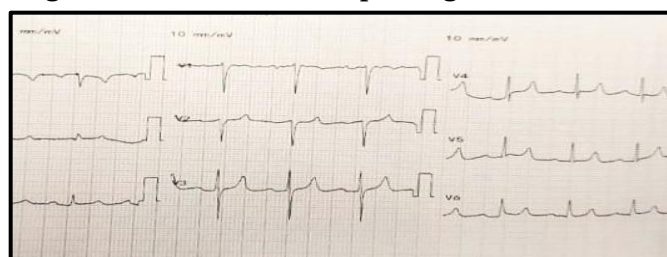


Figure 2: Tall T wave with prolonged PR interval



range, and ECG recordings has been shown in Table 3. This table shows the significant population was with serum potassium levels below 6.4 mEq/L, whose ECG was normal. Patients were grouped as Mild, Moderate hyperkalemia (<6.5 mEq/L) and Severe hyperkalemia (≥6.5 mEq/L) on the basis of serum potassium levels and observed ECG changes. Out of 140 hyperkalemia patients, seventy-two patients (12 out-patients and 60 in-patients) ECG recordings were within normal limits as compared to 68 patients with abnormal ECG findings, which is shown in Table 3.

Discussion:

Present cross-sectional study conducted in tertiary care hospital identified conditions associated with hyperkalemia as renal failure, (obstructive and non-obstructive), diabetes, hypertension, chronic renal insufficiency, and associated with drugs used for related clinical treatments. Out of total 140 patients, 19 (26.4%) had the presence of diabetes mellitus along with chronic kidney disease, 22 (30.6%) had hypertension along with chronic kidney disease, and 19 (26.4%) had chronic kidney disease with the presence of both diabetes and hypertension. The potassium level in the present study population was ranging from 5.50 to 7.30 mEq/L along with higher levels of blood urea and serum creatinine levels this may be because of the majority (66.4%) of study population suffered from kidney disease, including chronic kidney disease 72 patients and Acute Kidney Injury 21 patients. Raffle LA [10] et al. reported a mean serum potassium level of 6.5 ± 0.6 mmol/L, with a range of 5.6 and 9.0 mmol/L, in their study on hyperkalemia patients. Among other etiologies of hyperkalemia, drugs contributed to (29.3%) patients, and other minor causes were (4.3%) patients. In the present study, among forty-one cases of hyperkalemia, 25 (61%) patients were on Angiotensin Converting Enzyme Inhibitors (ACEi) / Angiotensin Receptor Blocking drugs (ARB's), 8 (19.5%) patients were taking spironolactone, and other drugs such as heparin, 8 (19.5%) patients were on digoxin. Out of total 140 patients, 19 (26.4%) had the presence of diabetes mellitus along with chronic kidney disease, 22 (30.6%) had hypertension along with chronic kidney disease, and 19 (26.4%) had chronic kidney disease with the presence of both diabetes and hypertension. Montagne BT [2] et al. found that adrenergic blockers, aspirin, angiotensin-converting enzyme inhibitors, and

loop diuretics were the drugs that were frequently associated with hyperkalemia. According to Raffle LA [10] et al., significant proportions of patients with hyperkalemia took statins (64.2%), proton pump inhibitors (58.2%), non-steroid analgesics (53.8%), beta-blockers (52.2%), calcium channel blockers (41.8%), angiotensin converting enzyme inhibitors (31.3%), and Angiotensin Receptor Blockers (28.4%). The types of medications used in this study did not significantly affect the severity of hyperkalemia. In experimental settings, hyperkalemia has been linked to a specific set of electrocardiograms (ECG) abnormalities, such as QT interval shortening, T wave peaking, QRS prolongation, PR interval shortening, P wave amplitude reduction, loss of Sino atrial conduction, onset of a wide-complex "sine wave" ventricular rhythm, and a systole. [17-19] The typical ECG alterations manifest in a characteristic order as serum potassium levels rise. Tall T waves, peaked/tented T waves, or mildly elevated potassium levels (5.5–5.9 mmol/L) may be present. While severe hyperkalemia (> 7.0 mmol/L) may cause ventricular fibrillation and asystole on the ECG, moderate hyperkalemia (6.0–7.0 mmol/L) typically causes PR interval prolongation, decreased P wave amplitude, disappearance of the P wave, widening of the QRS complex, or conduction blocks with escape beats. [8, 9] In the present study, out of 140 patients with hyperkalemia, ECGs changes were seen in 68 (48.6%) patients were treated immediately. The most common findings were tall T wave and tall T wave and prolonged PR interval, some only had prolonged PR interval; apart from these, some other findings such as pseudo-ST segment elevation, sinus bradycardia, QTc prolongation, Left Bundle Branch Block in 16.4% of patients. In this study, 72 (51.4%) patients, though were hyperkalemic, showed ECG findings within normal limits. Out of that twelve patients were from out-patients and 60 patients from in-patients were treated immediately on the basis of their potassium values. Contrary to the present study, study conducted by RaffeeLA [10] et.al showed normal ECGs in 25.4% of hyperkalemic patients and abnormalities were more prevalent in 74.64% of patients. Eight of those ECGs had peak T waves; eight had widened QRS complexes; seven had lengthened PR intervals; seven had flattening P waves, four had ST-segment depressions; three had

Right Bundle Branch Block; two had disappearing P waves; and two had Left Bundle Branch Block. On the other hand, one ECG for each showed shortened QTc intervals and ST-segment elevations. Compared to patients with mild severity of hyperkalemia, there were more patients with moderate severity. In the present study, patients were divided as per the severity of hyperkalemia with mild (5.5 to 5.9 mEq/L), Moderate (6.0 to 6.4 mEq/L) and severe (≥ 6.5 mEq/L) including 109 (77.9%) and 21 (15%) and 10 (7.1%) patients, respectively with an increase in the potassium level among patients with ECG changes compared to those without ECG changes as shown in Table no 1. The distribution of patients according to potassium severity also differs significantly, showing a higher number of patients with ECG changes and a potassium level of ≥ 6.5 mEq/L compared to the number of patients without ECG changes. The distribution of Tall T wave, prolonged PR interval, or combined Tall T wave and prolonged PR interval among the groups based on severity of hyperkalemia did not differ. According to Montague BT [2] et al, of the ninety cases reviewed, 16 patients met strict criteria for ECG changes, and 47 showed some ECG change. Twenty-nine patients had peaked T waves, and twenty-eight patients were noted to have symmetric T waves. Varga C [9] et al reported significantly more patients with severe hyperkalemia, wide QRS, bradycardia, peaked T-waves, and first-degree AV block as compared to patients having normal potassium levels. In both the normokalaemia group and the patients with severe hyperkalemia, a wide QRS was the most frequent ECG abnormality. Hyperkalemia, moderate hyperkalemia, and normokalaemia groups did not differ in terms of the overall frequency of ECG alterations. However, when compared between normokalaemia and all (moderately severely) hyperkalemic patients, the findings about wide QRS alone were significant. Only hyperkalemic patients had an AV junctional rhythm, while patients with moderate and severe hyperkalemia had prolonged QTc. In hospitalized patients, hyperkalemia is a common and potentially fatal electrolyte disorder. Depending on the survey, estimates for the incidence range between 1.1 and 10 percent of hospitalized patients. [2,19]. Hyperkalemia in patients often causes cardiac arrhythmias which may be fatal. It is crucial to rule out reversible causes, of which hyperkalemia is one of the most frequent, in pre-arrest

and during resuscitation situations. The European Resuscitation Council recommends correcting electrolyte imbalances like hypo and hyperkalemia, preferably before cardiac arrest occurs. [9, 11-13] Potassium levels that are too high are often not reflected in ECGs, and situations that lead to arrest can happen quickly. [14] Similar observations were noted in our study for 10 patients who were having potassium levels 6.5 mEq/L and above. Limitations: Present study was conducted with inclusion of limited patient size and duration. Cohort study with larger population size, duration and clinical outcome is required to set up some guidelines for routine serum potassium estimation to predict and avoid future critical emergencies in such patients.

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Conclusion:

Hyperkalemia is one of the potential risks for cardiac dysfunction and patients with hyperkalemia need to be treated aggressively irrespective to normal ECG recordings. Significant association between hyperkalemia and ECG changes existing routinely visiting out-patients or in-patients with chronic kidney disease, diabetes mellitus, acute kidney incidence, hypertension, or patients taking drugs as treatment (Angiotensin converting enzyme inhibitors, Angiotensin receptor inhibitors, Heparin). All the hyperkalemia patients do not reflect with associated changes in ECG recordings and may be at considerable risk for cardiac arrhythmia. Inclusion of serum potassium testing as a routine investigation for such potentially high-risk patients visiting out-patient and in-patient set up without clinical sign may be beneficial.

Conflicts of Interest: Nil

Sources of supports: Nil

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