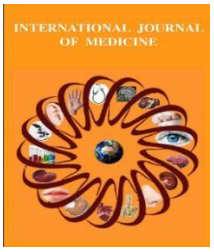

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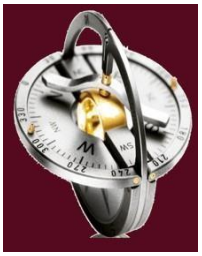

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Original Research

A Clinical Study of Electrolyte Abnormalities in Patients with Chronic Kidney Disease: A Cross-Sectional Observational Study.

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Abstract
Background: Chronic Kidney Disease (CKD) is a progressive disorder characterized by irreversible loss of renal function and impaired regulation of fluid, electrolyte, and acid-base homeostasis. Electrolyte abnormalities are common among CKD patients and are associated with significant cardiovascular, neuromuscular, and metabolic complications. Early identification and management of electrolyte disturbances play a crucial role in preventing adverse clinical outcomes and improving patient prognosis. *Aim:* To study the electrolyte abnormalities in patients with chronic kidney disease.
Objectives:
1. To determine the prevalence and pattern of electrolyte abnormalities among patients with chronic kidney disease.
2. To evaluate the association between electrolyte abnormalities and the severity of chronic kidney disease and associated clini cal parameters.

Materials and Methods: A hospital-based cross-sectional observational study was conducted among 100 patients diagnosed with chronic kidney disease. Detailed demographic and clinical data were collected, and laboratory investigations including serum sodium, potassium, calcium, phosphorus, magnesium, serum creatinine, blood urea, and estimated glomerular filtration rate were performed. CKD stag ing was carried out according to KDIGO guidelines. Statistical analysis was performed using SPSS version 26.0. Descriptive and inferential statistical tests including Chi-square test, Fisher's exact test, Independent Student's t-test, and correlation analyses were employed wherever appropriate. A p-value of less than 0.05 was considered statistically significant. *Results:* The mean age of the study participants was 54.6 ± 11.8 years, with a male predominance (64%). Advanced CKD (Stage 4 and Stage 5) was observed in 68% of patients. Hyperkalaemia (42%) was the most common electrolyte abnormality, followed by hyperphosphatemia (38%), hypocalcaemia (34%), and hyponatremia (28%). Multiple electrolyte abnormalities were observed in 52% of patients. A statistically significant association was identified between CKD stage and electrolyte abnormalities (p = 0.003), with advanced CKD demonstrating more severe biochemical derangements. Significant differences in serum sodium, potassium, calcium, phosphorus levels, and eGFR were observed between early and advanced stages of CKD. Elec trolyte abnormalities were significantly more prevalent among patients with diabetes mellitus and hypertension. *Conclusion:* Electrolyte abnormalities are highly prevalent among patients with chronic kidney disease and are closely associated with disease severity and systemic comorbidities. Hyperkalaemia, hyperphosphatemia, and hypocalcaemia represent the most common electrolyte disturbances encountered in clinical practice. Routine electrolyte monitoring and early therapeutic intervention are essential for preventing complications, optimizing patient care, and improving long-term outcomes in patients with chronic kidney disease.

Keywords: *Chronic Kidney Disease, Electrolyte Abnormalities, Hyperkalaemia, Hyperphosphatemia, Hypocalcaemia, CKD Staging.*

Introduction

Chronic Kidney Disease (CKD) is a progressive and irreversible disorder characterized by structural or functional abnormalities of the kidneys persisting for more than three months, with significant implications for overall health and survival. It represents a major global public health problem owing to its increasing prevalence, high morbidity, mortality, and healthcare burden. The Global Burden of Disease Study estimates that CKD affects approximately 850 million individuals worldwide and has emerged as one of the leading causes of mortality gl obally. Progressive loss of renal function adversely affects fluid, electrolyte, acid-base, and endocrine homeostasis, resulting in a wide spectrum of metabolic complications that substantially influence patient outcomes. [1]

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The kidneys play a critical role in maintaining electrolyte balance by regulating the excretion and reabsorption of sodium, potassium, calcium, phosphate, magnesium, and bicarbonate. As renal function declines, disturbances in electrolyte homeostasis become increasingl y common and contribute significantly to disease-related complications. Electrolyte abnormalities in CKD may occur early in the disease course and often worsen with advancing stages of renal impairment. Such abnormalities are associated with cardiovascular complications, neurom uscular dysfunction, bone mineral disorders, arrhythmias, and increased mortality. [2]

Among the various electrolyte disturbances encountered in CKD, hyperkalaemia, hyponatremia, hypocalcaemia, hyperphosphatemia, and metabolic acidosis are the most frequently observed. Hyperkalaemia is particularly important because of its potential to cause life-threatening cardiac arrhythmias, whereas disturbances in calcium and phosphate metabolism contribute to CKD-mineral and bone disorder (CKD-MBD). Hyponatremia has been associated with poor neurological outcomes and increased hospitalization rates, while magnesium abnormalities have increasingly been recognized as predictors of cardiovascular morbidity in patients with chronic kidney disease. [3]

The pathophysiology of electrolyte abnormalities in CKD is multifactorial and involves reduced glomerular filtration rate (GFR), altered tubular function, hormonal dysregulation, dietary factors, and medication use. Progressive nephron loss impairs the kidney's ability to excrete potassium and phosphate while simultaneously affecting calcium and sodium homeostasis. Secondary hyperparathyroidism, vitamin D deficiency, and disturbances in fibroblast growth factor-23 further contribute to abnormalities in mineral metabolism. The severity and pattern of electrolyte disturbances vary according to the stage of CKD and associated comorbidities. [4]

Globally, electrolyte abnormalities contribute substantially to the morbidity and mortality associated with chronic kidney disease. Numerous epidemiological studies have demonstrated that electrolyte disturbances are independently associated with adverse cardiovascula r events, prolonged hospitalization, progression to end-stage renal disease, and all-cause mortality. Early identification and appropriate management of these abnormalities are therefore essential components of comprehensive CKD care. Recent clinical practice guidelines emphasize routine monitoring of serum electrolytes across all stages of chronic kidney disease to facilitate timely intervention and improve patient outcomes. [5]

India bears a substantial burden of chronic kidney disease owing to the increasing prevalence of diabetes mellitus, hypertension, obesity, and aging populations. Community-based studies estimate that approximately 15–17% of Indian adults may have varying degrees of chronic kidney disease. Electrolyte abnormalities are commonly encountered among Indian patients with CKD, particularly those presenting to tertiary healthcare institutions. Hyperkalaemia, hyponatremia, hypocalcaemia, and hyperphosphatemia remain among the most frequently reported biochemical abnormalities. Regional variations in dietary practices, socioeconomic factors, delayed healthcare access, and treatment patterns may significantly influence the prevalence and severity of electrolyte disturbances in the Indian population. [6] Despite significant advances in nephrology care, electrolyte abnormalities remain under-recognized contributors to adverse clinical outcomes in patients with CKD. Comprehensive evaluation of electrolyte disturbances can facilitate early diagnosis, risk stratification, and individualized management strategies aimed at preventing complications and improving quality of life. Furthermore, hospital-based studies evaluating the clinical profile of electrolyte abnormalities among CKD patients are limited in several regions of India. Therefore, the present study aims to evaluate the spectrum of electrolyte abnormalities among patients with chronic kidney disease and to determine their c linical and biochemical associations. [7]

AIM

To study the electrolyte abnormalities in patients with chronic kidney disease.

OBJECTIVES

1. To determine the prevalence and pattern of electrolyte abnormalities among patients with chronic kidney disease.
2. To evaluate the association between electrolyte abnormalities and the severity of chronic kidney disease and associated clinical parameters.

Materials and Methods

Study Design

A cross-sectional observational study.

Inclusion Criteria

- Patients aged ≥18 years.
- Patients diagnosed with chronic kidney disease according to KDIGO guidelines (duration >3 months).
- Patients willing to provide written informed consent.

Exclusion Criteria

- Acute Kidney Injury.
- Patients receiving renal replacement therapy for acute indications.
- Patients with malignancy.
- Pregnant women.
- Patients with chronic diarrheal disorders causing electrolyte imbalance.
- Patients receiving medications known to significantly alter serum electrolyte levels (unless clinically indicated as part of CKD management).
- Patients unwilling to participate.

SAMPLE SIZE CALCULATION

The sample size was calculated using the formula:
$n = Z^2 \times P \times q / d^2$
Where:
n = Required sample size, Z = 1.96 at 95% confidence interval, P = Prevalence of electrolyte abnormalities among CKD patients (approximately 50%), Q = 50%, d = 10%
Substituting the values:
$n = (1.96)^2 \times 50 \times 50 /100$, n = 96.04
The minimum sample size calculated was 96.
Considering incomplete laboratory investigations and feasibility, the final sample size was rounded off to 100 participants.

Sampling Technique

Consecutive sampling.

STUDY PROCEDURE

The following information will be collected:

Demographic Variables: Age, Gender, Occupation, Body Mass Index.

Clinical Variables: Duration of CKD, Etiology of CKD, Blood pressure, Presence of diabetes mellitus, Presence of hypertension, CKD stage. Necessary laboratory investigations were done

CKD Staging (KDIGO Classification)

CKD Stage	eGFR (mL/min/1.73m²)
Stage 1	≥90
Stage 2	60-89
Stage 3	30-59
Stage 4	15-29
Stage 5	<15

STATISTICAL ANALYSIS

Data will be entered into Microsoft Excel and analysed using SPSS version 26.0. The following statistical methods will be employed: Mean ± Standard Deviation for continuous variables. Frequency and percentages for categorical variables. Chi-square test or Fisher's Exact test for categorical variables. Independent Student's t-test and ANOVA for continuous variables. Pearson's correlation coefficient for evaluating electrolyte levels and eGFR. Logistic regression analysis for predictors of electrolyte abnormalities. A p-value of <0.05 will be considered statistically significant.

Results

A total of 100 patients diagnosed with chronic kidney disease (CKD) were included in the study. The demographic characteristics, CKD staging, electrolyte abnormalities, and their association with disease severity and clinical parameters were analysed.

Table 1. Demographic Characteristics and CKD Staging of the Study Participants (n = 100)

Variable	Frequency (n)	Percentage (%)
Age Group (years)		
18-40	18	18.0
41-50	24	24.0
51-60	36	36.0
>60	22	22.0
Gender		
Male	64	64.0
Female	36	36.0
CKD Stage		
Stage 2	8	8.0
Stage 3	24	24.0
Stage 4	30	30.0
Stage 5	38	38.0
Mean Age (years)	54.6 ± 11.8	

Interpretation

The majority of patients belonged to the 51-60 years age group (36%). Males constituted 64% of the study population. Advanced stages of CKD (Stage 4 and Stage 5) were observed in 68% of patients.

Table 2. Prevalence of Electrolyte Abnormalities Among CKD Patients (n = 100)

Electrolyte Abnormality	Frequency (n)	Percentage (%)
Hyponatremia	28	28.0
Hyperkalaemia	42	42.0
Hypocalcaemia	34	34.0
Hyperphosphatemia	38	38.0
Hypermagnesemia	16	16.0
Multiple Electrolyte Abnormalities	52	52.0

p <0.001 (Highly significant).

Interpretation

Hyperkalaemia was the most common electrolyte abnormality (42%), followed by hyperphosphatemia (38%) and hypocalcaemia (34%). More than half of the study participants exhibited multiple electrolyte abnormalities, highlighting the complex metabolic derangements associated with chronic kidney disease.

Table 3. Association Between CKD Stage and Electrolyte Abnormalities (n = 100)

CKD Stage	Hyperkalaemia	Hypocalcaemia	Hyperphosphatemia	Total
Stage 2	1	1	1	8
Stage 3	6	5	4	24
Stage 4	12	11	13	30
Stage 5	23	17	20	38
Total	42	34	38	100

p = 0.003 (Statistically significant).

Interpretation

The prevalence of electrolyte abnormalities increased significantly with advancing stages of CKD. Hyperkalaemia, hypocalcaemi a, and hyperphosphatemia were predominantly observed among patients with Stage 4 and Stage 5 CKD, indicating progressive impairment in renal electrolyte regulation.

Table 4. Comparison of Biochemical Parameters According to CKD Severity

Parameter	Stage 2 & 3 CKD (Mean ± SD)	Stage 4 & 5 CKD (Mean ± SD)	p-value
Serum Sodium (mEq/L)	136.8 ± 3.2	132.6 ± 4.1	0.001
Serum Potassium (mEq/L)	4.6 ± 0.7	5.8 ± 1.1	<0.001
Serum Calcium (mg/dL)	8.7 ± 0.6	7.6 ± 0.8	<0.001
Serum Phosphorus (mg/dL)	4.1 ± 0.8	5.9 ± 1.2	<0.001
eGFR (mL/min/1.73m²)	42.4 ± 10.2	16.8 ± 5.4	<0.001

Interpretation
Patients with advanced CKD demonstrated significantly lower serum sodium and calcium levels and significantly higher serum potassium and phosphorus levels. These biochemical abnormalities reflect progressive nephron loss and worsening renal dysfunction.

Table 5. Association Between Electrolyte Abnormalities and Comorbidities (n = 100)

Comorbidity	Hyperkalaemia	Hyponatremia	Multiple Electrolyte Abnormalities	p-value
Diabetes Mellitus	24	16	28	0.024
Hypertension	30	18	34	0.018
Both DM and HTN	18	14	22	0.007
No Comorbidity	6	4	8	0.312

Interpretation
Patients with diabetes mellitus and hypertension demonstrated a significantly higher prevalence of electrolyte abnormalities compared with those without comorbidities. Multiple electrolyte abnormalities were particularly common among patients with both diabetes mellitus and hypertension, indicating the cumulative impact of systemic comorbidities on renal electrolyte homeostasis.

Overall Results Summary
The present study demonstrated that electrolyte abnormalities are highly prevalent among patients with chronic kidney disease, particularly in advanced stages of renal impairment. Hyperkalaemia, hyperphosphatemia, and hypocalcaemia were the most comm on abnormalities observed. Significant associations were identified between electrolyte disturbances and CKD severity, reduced eGFR, and assoc iated comorbidities such as diabetes mellitus and hypertension. These findings underscore the importance of routine electrolyte monitoring and early therapeutic intervention in patients with chronic kidney disease to prevent potentially life-threatening complications and improve clinical outcomes.

Discussion

The present cross-sectional observational study evaluated the spectrum of electrolyte abnormalities among 100 patients with chronic kidney disease (CKD). Electrolyte disturbances are among the most frequent metabolic complications of CKD and contribute significantly to morbidity, cardiovascular complications, and mortality. The findings of the present study highlight the progressive nature of electrolyte abnormalities with declining renal function and underscore the importance of routine biochemical monitoring in CKD patients. [8]

The majority of the study participants belonged to the 51-60 years age group, with a mean age of 54.6 ± 11.8 years. Males constituted 64% of the study population. Similar demographic patterns have been reported in several Indian and international studies evaluating CKD populations, wherein middle-aged and elderly males represented the predominant patient group. The higher prevalence among males may be attributable to greater exposure to traditional CKD risk factors such as hypertension, diabetes mellitus, and cardiovascular disease. [9] The present study demonstrated that Stage 4 and Stage 5 CKD accounted for 68% of the cases, indicating that most patients presented with advanc ed renal dysfunction. Delayed diagnosis and referral to tertiary healthcare centres remain significant challenges in developing countries, including India. Previous studies have reported comparable findings, emphasizing that advanced CKD is frequently associated with a greater bur den of metabolic complications and poorer clinical outcomes. [10]

Hyperkalaemia emerged as the most common electrolyte abnormality (42%) in the present study, followed by hyperphosphatemia (38%) and hypocalcaemia (34%). Hyperkalaemia is a clinically significant complication of CKD because of its potential to precipitate fatal cardiac arrhythmias. Several studies have demonstrated that reduced renal potassium excretion, metabolic acidosis, and the use of renin-angiotensin-aldosterone system inhibitors contribute significantly to hyperkalaemia in patients with advanced CKD. Similar prevalence rates have been reported among tertiary care nephrology cohorts worldwide. [11] Hyperphosphatemia and hypocalcaemia observed in the present study reflect disturbances in mineral metabolism associated with CKD-mineral and bone disorder (CKD-MBD). Progressive nephron loss results in phosphate retention, reduced vitamin D activation, and secondary hyperparathyroidism, ultimately leading to abnormalities in calcium and phosphorus homeostasis. These disturbances have been shown to contribute substantially to vascular calcification, cardiovascular morbidity, and skeletal complications in CKD patients. [12]

More than half of the study participants demonstrated multiple electrolyte abnormalities, highlighting the complex pathophysiological changes that accompany declining renal function. Previous investigations have established that simultaneous electrolyte disturbances significantly increase the risk of hospitalization and mortality among patients with chronic kidney disease. Comprehensive electrolyte assessment is therefore essential for timely diagnosis and individualized therapeutic intervention. [13] The present study demonstrated a statistically significant association between advancing CKD stage and electrolyte abnormalities ($p = 0.003$). Hyperkalaemia, hypocalcaemia, and hyperphosphatemia were predominantly observed among patients with Stage 4 and Stage 5 CKD. Similar observations have been reported in multiple nephrology studies, which have consistently demonstrated that electrolyte abnormalities become increasingly prevalent as estimated glomerular filtration rate declines. The progressive reduction in renal excretory capacity remains the principal determinant of these biochemical abnormalities. [14] Biochemical analysis further revealed significantly lower serum sodium and calcium levels and significantly elevated serum potassium and phosphorus levels among patients with advanced CKD. These findings are consistent with current KDIGO recommendations and publ ished literature highlighting the relationship between declining eGFR and worsening electrolyte imbalance. Electrolyte abnormalities not only reflect disease severity but also serve as important prognostic indicators in chronic kidney disease. [15]

A significant association was also observed between electrolyte abnormalities and the presence of diabetes mellitus and hypertension. Patients with both diabetes and hypertension demonstrated the highest prevalence of multiple electrolyte abnormalities. Di abetes mellitus remains the leading cause of CKD worldwide and is frequently associated with disturbances in potassium and sodium homeostasis . Hypertension contributes to progressive nephron loss and further exacerbates electrolyte abnormalities through alterations in renal hemodynamic and medication effects. [16] Hyponatremia observed among 28% of the study population is particularly important beca use it has been independently associated with increased mortality and adverse cardiovascular outcomes among CKD patients. Several large cohort studies have demonstrated that even mild chronic hyponatremia may contribute to impaired neurological function, increased hospitalization, and poorer long-term prognosis. [17]

Recent nephrology literature has increasingly recognized the prognostic significance of electrolyte disturbances in chronic kidney disease. Serum potassium, phosphorus, calcium, and sodium abnormalities have all been independently associated with cardiovascular events, progression to end-stage renal disease, and all-cause mortality. Early detection and appropriate management of electrolyte abnormalities may therefore substantially improve patient outcomes and reduce healthcare burden. [18] Routine monitoring of electrolyte status should form an integral component of CKD management across all stages of disease. Early intervention through dietary modification, pharmacological therapy, correction of metabolic acidosis, and appropriate nephrology referral may prevent life-threatening complications associated with electrolyte imbalance. [19]

The findings of the present study reaffirm that electrolyte abnormalities are highly prevalent among CKD patients and become increasingly severe with advancing renal dysfunction. Comprehensive biochemical assessment and multidisciplinary management are essential to optimize clinical outcomes and improve the quality of life of patients with chronic kidney disease. [20]

Conclusion

The present study demonstrated that electrolyte abnormalities are highly prevalent among patients with chronic kidney disease and become increasingly common with advancing stages of renal impairment. Hyperkalaemia, hyperphosphatemia, and hypocalcaemia were identified as the most frequent electrolyte disturbances. Significant associations were observed between electrolyte abnormalities and the severity of CKD, declining estimated glomerular filtration rate, and associated comorbidities such as diabetes mellitus and hypertension. Patients with advanced CKD exhibited more pronounced biochemical derangements, highlighting the progressive impairment of renal electrolyte regulation. Routine monitoring and early correction of electrolyte abnormalities are essential components of comprehensive CKD management. Timely identification and appropriate therapeutic interventions may reduce complications, improve clinical outcomes, and enhance the quality of life of patients with chronic kidney disease.

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