

A study of ECG as a Diagnostic tool for Electrolyte imbalance in Hemodialysis Patients of Chronic Kidney Disease

Dr. Sudhir kumar Bhoi¹, Dr. Rupendra Kumar Sao², Dr. Bavinder Chugh³

1. Dr. Sudhir kumar Bhoi, Assistant Professor, Department of Physiology, Chandulal Chandrakar Memorial Medical College, Kachandur, Durg, CG, sudhirbhoi41@gmail.com
2. Dr. Rupendra Kumar Sao, Assistant Professor, Department of Biochemistry, SSIMS, Junwani, Bhilai, CG
3. Dr. Bavinder Chugh, Senior Resident, Department of General Medicine, Sri Balaji Institute of Medical Sciences, Raipur, CG, drbavinderchugh@gmail.com

Corresponding author:

Dr. Rupendra Kumar Sao, Assistant Professor, Department of Biochemistry, SSIMS, Junwani, Bhilai, CG, rupendrakumarsao@gmail.com

Abstract

Background: Patients with Chronic Kidney Disease (CKD) require dialysis to artificially remove metabolic waste products from the blood. Despite significant advances in dialysis technology and pharmacotherapy, mortality among dialysis patients remains high, with approximately 9–13% of hemodialysis patients in India dying within one year. Electrocardiographic (ECG) abnormalities are commonly observed in CKD patients, often related to electrolyte imbalances. **Objectives:** To evaluate changes in serum electrolytes following hemodialysis and to determine the frequency of various ECG abnormalities in CKD patients. **Materials and Methods:** This cross-sectional study included 120 patients with CKD undergoing hemodialysis. All patients underwent 12-lead ECG recordings. Blood samples were collected before and after hemodialysis to assess serum electrolyte levels. Statistical analysis was performed using the Z-test, and a p-value <0.05 was considered statistically significant. **Results:** Post-hemodialysis, serum sodium levels showed a significant increase, while serum potassium and chloride levels decreased. Left ventricular hypertrophy and atrial fibrillation were observed in 20.2% and 10.1% of patients, respectively. **Conclusion:** Electrolyte abnormalities, particularly in sodium, potassium, and chloride, have important prognostic implications in CKD patients undergoing hemodialysis. Routine ECG evaluation is recommended for all hospitalized CKD patients to facilitate early detection of cardiovascular complications.

Keywords: Chronic kidney disease, electrocardiography, hemodialysis, left ventricular hypertrophy, serum electrolytes.

Introduction

The kidneys play a vital role in maintaining electrolyte balance and acid–base homeostasis. In Chronic Kidney Disease (CKD), these regulatory mechanisms are impaired, leading to significant metabolic and cardiovascular complications. CKD affects approximately 5–10% of the global population [1], with an estimated prevalence of around 800 per million in India [2]. Dialysis is a life-sustaining therapy

that removes excess fluid, uremic toxins such as urea, and corrects electrolyte imbalances using dialysate with physiological mineral concentrations [3]. Hemodialysis (HD) is particularly effective in managing hyperkalemia, uremia, and elevated serum creatinine levels in renal failure. However, despite advancements in dialysis techniques and pharmacological care, mortality among hemodialysis patients remains high, with 9–13% of patients in India dying within one year.[2]

In CKD, total body sodium and water content is often increased, even when not clinically evident [8]. Although glomerular filtration rate (GFR) declines, potassium homeostasis is relatively maintained through aldosterone-dependent secretion in the distal nephron and enhanced gastrointestinal excretion. Nevertheless, Hyperkalemia may develop abruptly due to increased dietary intake, hemolysis, hemorrhage, blood transfusion, protein catabolism, metabolic acidosis, or medications that impair renal potassium excretion [4–5,9].

Metabolic acidosis is a common complication in advanced CKD, primarily due to reduced ammonia production, which limits renal acid excretion. Hyperkalemia further suppresses ammonia synthesis, worsening acidosis. In conditions such as diabetic nephropathy, tubulointerstitial disease, and obstructive uropathy, hyperkalemia and hyperchloremic metabolic acidosis may occur even in early stages of CKD (stages 1–3), typically presenting as non-anion-gap metabolic acidosis [5].

Electrolyte disturbances, particularly during and after dialysis, are strongly associated with adverse cardiovascular outcomes, including life-threatening arrhythmias and sudden cardiac death [6,10]. Hypokalemia following dialysis is a well-recognized cause of severe arrhythmias, while dysnatremias—both hyponatremia and hypernatremia—are associated with increased mortality in CKD and end-stage renal disease (ESRD) [6]. Hyponatremia is often dilutional due to excess free water intake, whereas hypernatremia may occur in patients with impaired thirst or inadequate water intake.

Electrocardiography (ECG) abnormalities are frequently observed in CKD patients and serve as important predictors of cardiovascular morbidity and mortality [7,9–11]. However, the reported prevalence of these abnormalities varies widely across studies. Following hemodialysis, patients are particularly vulnerable to rapid shifts in internal milieu, including electrolyte imbalances and blood pressure fluctuations, which may precipitate serious cardiac events. Therefore, the present study was undertaken to evaluate changes in serum electrolytes following hemodialysis and to determine the prevalence of various ECG abnormalities in patients with CKD.

Materials and Methods

This cross-sectional study was conducted in the Departments of Physiology and Medicine at Chandulal Chandrakar Memorial Medical College, Kachandur, Durg, Chhattisgarh. The study included 120 consenting adult patients diagnosed with Chronic Kidney Disease (CKD) who were undergoing Hemodialysis either at the study center or were referred from other institutions.

Inclusion criteria:

Patients aged ≥ 18 years with CKD stage 4 or stage 5 attending the dialysis unit of the Department of Medicine were included in the study.

Exclusion criteria:

Patients with acute kidney injury, active malignancy, or pregnancy were excluded.

- A non-probability sequential sampling technique was used. After obtaining approval from the Institutional Ethics Committee and written informed consent from all participants, detailed sociodemographic and clinical data were recorded in a structured proforma.
- Venous blood samples were collected under aseptic conditions before and after hemodialysis on the same day of the procedure. Serum electrolyte levels, including sodium, potassium, and chloride, were measured. A 12-lead Electrocardiography (ECG) was performed for all patients, and interpretations were made by a qualified physician experienced in ECG analysis.
- Electrolyte abnormalities were defined as follows: hyponatremia (serum sodium <135 mEq/L), hypernatremia (>145 mEq/L), hypokalemia (serum potassium <3.5 mEq/L), hyperkalemia (>5.5 mEq/L), and hyperchloremia (serum chloride >95 mEq/L).

Statistical Analysis

Data were entered into Microsoft Excel 2010 and analyzed using IBM SPSS Statistics. Continuous variables were expressed as mean \pm standard deviation, while categorical variables were presented as frequencies and percentages. Comparisons of continuous variables before and after hemodialysis were performed using the Z-test. A p-value ≤ 0.05 was considered statistically significant.

Observation and result

A total of 120 patients with Chronic Kidney Disease undergoing Hemodialysis were included in the study. The mean age of the participants was 49.4 ± 7.3 years, and 33.3% were female. The mean pre-dialysis body weight was 62.9 ± 5.8 kg, while the mean post-dialysis weight was 46.8 ± 6.0 kg. As shown in Tables 1 and 2, the pre-dialysis weight was significantly higher than the post-dialysis weight, and this difference was found to be statistically significant ($p < 0.05$).

Table 1: Basic characteristics of study participants (n-120)

Characteristics	Frequency	Percentage (%)	
Age group	21-30	15	12.5
	31-40	28	23.3
	41-50	21	17.5
	51-60	28	23.3
	61-70	23	16.2
	71-80	3	2.5
	81-90	2	1.7
	Mean \pm SD	49.4 \pm 7.3	
Gender	Male	80	66.7

	Female	40	33.3
Hypertension	Yes	75	62.5
	No	45	37.5

Table 2: Comparison of blood pressure and weight between pre and post Dialysis (n- 120)

Parameter	Pre Dialysis	Post Dialysis	P-value
Weight (kg)	62.9±5.8	46.8±6.0	0.0001
SBP (mmHg)	148.4±12.2	148.9±12.2	0.751
DBP (mmHg)	78.6±6.0	77.7±6.3	0.258

Table 3: Comparison of electrolytes between pre and post Dialysis (n-120)

Electrolyte	Pre Dialysis	Post Dialysis	P-value
S. Na+ (mEq/L)	137.6±9.5	139.1±10.6	0.877
S. K+ (mEq/L)	4.7±0.6	4.1±0.6	0.0001
S. Cl- (mEq/L)	106.8±3.5	105.7±3.5	0.016

Post-dialysis serum sodium levels (139.1 ± 10.6 mEq/L) were slightly higher than pre-dialysis levels (137.6 ± 9.5 mEq/L); however, this difference was not statistically significant ($p = 0.877$). In contrast, serum potassium levels showed a significant reduction following Hemodialysis, decreasing from 4.7 ± 0.6 mEq/L pre-dialysis to 4.1 ± 0.6 mEq/L post-dialysis ($p < 0.001$). Similarly, serum chloride levels were significantly lower after dialysis compared to pre-dialysis values ($p < 0.001$), as shown in Table 3. These findings indicate that hemodialysis effectively reduces serum potassium and chloride levels, while changes in sodium levels are not statistically significant.

Table 4: ECG findings among of study participants (n-120)

Heart rate	Frequency	Percentage (%)
Normal	108	90
Bradycardia	8	6.7
Tachycardia	4	3.3
Other abnormalities		
Atrial fibrillation	10	8.3
RBBB	18	15
LBBB	12	10
Left axis deviation (LAD)	10	8.3
Right axis deviation (RAD)	9	7.5
Left ventricular hypertrophy (LVH)	23	19.2
Left atrial enlargement (LAE)	9	7.5
Right ventricular hypertrophy (RVH)	5	4.2
Right atrial enlargement	4	3.3

(RAE)		
ST depression or elevation	15	12.5
Tall T wave	4	3.3
T inversion	1	0.8

Following Hemodialysis, the majority of patients (108; 90%) had a normal heart rate. Bradycardia and tachycardia were observed in 8 (6.7%) and 4 (3.3%) patients, respectively. Atrial Fibrillation was identified in 10 patients (8.3%). Conduction abnormalities included right bundle branch block (RBBB) in 18 patients (15%) and left bundle branch block (LBBB) in 12 patients (10%). Axis deviations were also noted, with left axis deviation (LAD) in 10 patients (8.3%) and right axis deviation (RAD) in 9 patients (7.5%). Structural abnormalities such as left ventricular hypertrophy (LVH) and left atrial enlargement (LAE) were observed in 23 (19.2%) and 9 (7.5%) patients, respectively. In comparison, right ventricular hypertrophy (RVH) and right atrial enlargement (RAE) were less common, seen in 5 (4.2%) and 4 (3.3%) patients, respectively. ST-segment changes, including depression or elevation, were reported in 15 patients (12.5%). Additionally, tall T waves were observed in 4 patients (3.3%), while T-wave inversion was noted in 1 patient (0.8%), as shown in Table 4. These findings highlight the spectrum of Electrocardiography (ECG) abnormalities present in CKD patients following hemodialysis.

Discussion

Chronic Kidney Disease (CKD) is a major global health problem and an important cause of morbidity and mortality, particularly in developing countries. Cardiovascular disease remains the leading cause of death in CKD patients [2]. With increasing access to Hemodialysis (HD) worldwide, it is essential to better understand the biochemical and electrophysiological changes occurring during and after dialysis to optimize patient management and dialysate prescription. The present cross-sectional study, involving 120 CKD patients undergoing hemodialysis, demonstrated significant changes in serum electrolytes following dialysis. Serum potassium and chloride levels decreased significantly, while serum sodium showed a mild, statistically non-significant increase.

Hyperkalemia is commonly observed in CKD and is associated with serious cardiovascular complications, including conduction abnormalities such as QRS widening and PR interval prolongation. Rapid shifts in potassium levels during dialysis can lead to Hypokalemia, which is equally dangerous and may precipitate life-threatening arrhythmias. In the present study, serum potassium levels significantly decreased after HD (4.7 ± 0.6 vs. 4.1 ± 0.6 , $p < 0.001$), consistent with findings reported by Ajam WH et al. [13] and other studies [14–15]. Tandukar et al. [16] recommend maintaining serum potassium levels between 4.0 and 5.0 mmol/L in CKD patients to reduce arrhythmic risk.

In this study, serum sodium levels showed a slight increase post-dialysis, although the change was not statistically significant. Similar findings have been reported by Ajam WH et al. [13] and Nauman et al. [17]. Sodium balance in hemodialysis patients is influenced by dietary intake, dialysate sodium concentration, and interdialytic fluid accumulation. A positive dialysate-to-serum sodium gradient may contribute to

increased post-dialysis sodium levels, whereas negative sodium balance may lead to hemodynamic instability [19–23].

Serum chloride levels showed a significant reduction following dialysis in the present study, which is in agreement with findings by Correa S et al. [5]. Changes in chloride levels are closely linked to acid–base balance. Hemodialysis helps correct metabolic acidosis primarily by reducing unmeasured anions and phosphate levels, while chloride levels may vary depending on pre-dialysis status and underlying metabolic disturbances [24]. Maintenance of electrolyte balance within a narrow physiological range is crucial to prevent life-threatening complications [25]. Electrolyte shifts during dialysis are closely associated with Electrocardiography (ECG) changes and increased risk of arrhythmias. In the present study, left ventricular hypertrophy (LVH) was the most common ECG abnormality, followed by conduction defects and atrial fibrillation. These findings highlight the high cardiovascular risk in CKD patients and underscore the importance of routine ECG monitoring.

Conclusion

Left ventricular hypertrophy was the most common electrocardiographic abnormality observed in this study. Significant reductions in serum potassium and chloride levels were noted after hemodialysis, while serum sodium showed a non-significant increase. Regular monitoring of electrolyte levels—particularly potassium—is essential in CKD patients undergoing hemodialysis, as these abnormalities have important prognostic implications. Routine ECG evaluation should be performed in all CKD patients to detect cardiovascular complications early. Furthermore, individualization of dialysate composition based on pre-dialysis electrolyte status is recommended to prevent adverse outcomes and improve patient prognosis

References

1. Amato AA, Santos GM, Neves F. Thyroid hormone action in chronic kidney disease. *Curr Opin endocrinology Diabetes Obes.* 2008; 15459-65.
2. Agarwal SK, Srivastava RK. Chronic Kidney disease in India. Challenges and Solutions. *Nephron Clin Pr.* 2009;111197–203.
3. Ahmad S, Misra M, Hoenich N, Daugirdas J. Hemodialysis Apparatus In: *Handbook of Dialysis.* 4th ed New York, NY;200859-78.
4. What do ECG findings indicate in hyperkalemia (high serum potassium level)?[Internet]. Latest Medical News, Clinical Trials, Guidelines - Today on Medscape.2021 Available from: [https:// www.medscape.com/answers/240903-11014/what-doecg-findings-indicate-](https://www.medscape.com/answers/240903-11014/what-doecg-findings-indicate-) .[Accessed 1st Mar 2023].
5. Correa S, Scovner KM, Tumlin JA, Roy-Chaudhury P, Koplan BA, Costea AI et al. Electrolyte Changes in Contemporary Hemodialysis: A Secondary Analysis of the Monitoring in Dialysis Study. *Kidney.* 360:2021 Apr 4;2(4)695.
6. Chiu DY, et al: Sudden cardiac death in haemodialysis patients: preventative options. *Nephrol.* 2014; 19 740–9.
7. Park S, Yum Y, Cha JJ, Joo HJ, Park JH, Hong SJ et al. Prevalence and Clinical Impact of Electrocardiographic Abnormalities in Patients with Chronic Kidney Disease. *J Clin Med.* 2022 Sep 15;11(18):5414.
8. Combs S, Berl T. Dysnatremias in patients with kidney disease. *Am J kidney Dis.* 2014 Feb 1;63(2)294-303.

9. Shafi S, Saleem M, Anjum R, Abdullah W, Shafi T. ECG Abnormalities In Patients With Chronic Kidney Disease. *J Ayub Med Coll Abbottabad*. 2017;29(1)61-4.
10. Kestenbaum B, Rudser KD, Shlipak MG, Fried LF, Newman AB, Katz R, et al. Kidney function, electrocardiographic findings and cardiovascular events among older adults. *Clin J Am Soc Nephrol*. 2007; 2(3):501-8
11. Nwankwo EA, Ummate I, Wudiri W. Prevalence of electrocardiographic left ventricular hypertrophy among incident dialysis patients in Maiduguri Nigeria. *Res J Med Med Sci* 2007;21– 4.
12. Webster A, Brady W, Morris F. Recognizing signs of danger: ECG changes resulting from an abnormal serum potassium concentration. *Emerg Med J* 2002;19(1)74–81.
13. Ajam WH. Evaluating of Serum Electrolyte Changes in Chronic Renal Failure Pre and Post Dialysis. *Medicolegal Updat* 2020 Oct;20(4)981.
14. Abdul-Majeed H, Al-Saffer; Pre and post Hemodialysis: The effect of Electrolyte imbalance on ECG of patients with end-stage renal disease. *Med J Babylon*, 2011; 8(2)221-9.
15. Seethalakshmi C, koteeswaran D, Chiranjeevi V; Correlation of serum and salivary biochemical parameters in end stage disease patients undergoing hemodialysis in pre and post dialysis state. *Jclindign res* 2014; 8(12)12-14.
16. Tandukar, S., & Fried, L. F. Dyskalemia in Chronic Kidney Disease: How Concerned Should We Be?. *Nephron*2018;140(1): 58-62.
17. Tarif N, Yamini H, Bakhsh AJ, et al; Electrocardiography and serum potassium before and after hemodialysis sessions. *Saudi j kidney disses transpl*, 2008;19(1)47-53.
18. Andrews L, Vegada BN, Gosai HA. Evaluating Levels of Urea, Creatinine and Electrolytes in Patients with Chronic Kidney Failure Pre and Post Dialysis: A Retrospective Analysis. *Sch Int J Biochem* March 2019; 2(3) 79-82.
19. Santos SFF, Peixoto AJ; Sodium balance in maintenance hemodialysis. *Semin Dial*, 2010;23 549-5.
20. Petitclerc T, Jacobs C. Dialysis sodium concentration: what is optimal and can it be individualized? *Nephrol Dial transplant*, 1995;10596-9.
21. Hwang KS, Choi EY, Park JS, Lee CH, Kang CM, Kim GH. Postdialysis serum sodium changes and systolic blood pressure in patients undergoing online hemodiafiltration and high-flux hemodialysis. *Kidney Res Clin Pr* 2013 Jun;32(2)62-5.
22. Kimura G., Van Stone J.C., Bauer J.H., Keshaviah P.R. A simulation study on transcellular fluid shifts induced by hemodialysis. *Kidney Int* 1983;24542– 8.
23. Kimura G., Van Stone J.C., Bauer J.H. Prediction of postdialysis serum sodium concentration and transcellular fluid shift without measuring body fluid volumes. *Artif Organs* 1983; 7:410–5.
24. Kirschbaum B; The effect of hemodialysis on electrolytes and acid base parameters. *Clin* 2003;336109-13.
25. Vadakedath S, Kandi V. Dialysis: a review of the mechanisms underlying complications in the management of chronic renal failure. *Cureus* 2017 Aug 23;9(8).e1603.