

Original Article

Electrolyte Imbalances In End-Stage Renal Disease (ESRD) Patients Undergoing Maintenance Hemodialysis.

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ABSTRACT

Background: Patients with End-Stage Renal Disease (ESRD) who are on maintenance hemodialysis frequently experience electrolyte disturbances due to the combination of unregulated fluid shifts with poor kidney function and the dialysis procedure itself. These disturbances particularly increase the cardiac and neuromuscular morbidity risks, thus requiring consistent monitoring to reduce the risks. Adverse outcomes are almost unavoidable without regular monitoring.

Objectives: to assess the distribution and prevalence of electrolyte disturbances in patients on maintenance dialysis.

Methodology: This observational cross-sectional study was conducted in the Nephrology Department of Nephrology MTI.LRH Peshawar from January 2023 to Jan 2024. The study included a participant cohort of 100 ESRD patients on dialysis. All participants were undergoing hemodialysis treatment three times a week, as was standard practice. The study included pre-dialysis blood samples and then measured the serum electrolytes Na⁺, K⁺, Ca²⁺, and PO₄³⁻. A 24.0 version of SPSS was employed for the analysis, with p < 0.05 as the level of significance.

Results: A 100-patient sample showed a mean age of 54.3 ± 12.7 years with a predominantly male population. 42% of patients presented with hyponatremia, 38% with hyperkalemia, 35% with hypocalcaemia, and 47% with hypophosphatemia. There were significant associations between hypophosphatemia and the duration of dialysis, and between parathyroid hormone/calcium levels and the serum measurement of calcium (p=0.032, p=0.019, respectively). For patients with more than two years of dialysis, the severity of electrolyte abnormality significantly increased.

Conclusion: Hyponatremia and hypophosphatemia have the highest prevalence of occurrence among electrolyte abnormalities. Overall, ESRD patients receiving dialysis suffer from a high prevalence of electrolyte abnormalities. Greater outcomes with fewer medical complications result from continual patient monitoring and the development of tailored dialysis prescriptions.

Keywords: ESRD, hemodialysis, electrolyte imbalance, hypophosphatemia

INTRODUCTION

End-stage renal disease (ESRD) is the result of chronic kidney disease (CKD) damaging renal function to the point that intermittent hemodialysis becomes a necessary life-sustaining practice. The condition is characterized by a near-total failure of the kidneys to excrete metabolic waste products and maintain homeostasis of bodily fluid and electrolytes. The efficacy of hemodialysis in removing uremic toxins and excess fluid is often coupled with a rapid drop of potentially life-threatening electrolytes, including sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), phosphate (PO_4^{3-}), and bicarbonate (HCO_3^-) [1]. The uncontrolled fluctuations of these electrolytes lead to serious and life-threatening complications, including arrhythmias, myopathy, osteopathy, and death [2]. Dialysis procedures, coupled with the use of hypotonic fluids, often lead to excess water and sodium (Na^+) retention. During treatment, many patients suffer hyponatremia, which is linked to neurological and lethal cardiovascular complications in hemodialysis patients [3]. Patients are more commonly diagnosed with hyponatremia when the dialysate sodium level is raised or when there is excessive sodium retention in the body. As stated previously, potassium is another important electrolyte. Hyperkalemia is a life-threatening condition characterized by excessive potassium, reduced potassium elimination, and sometimes a diet higher in potassium. Such a condition requires dialysis without question. Hypokalemia, as described previously, can also result from malnutrition, potassium-eliminating drugs, and dialysis. The kidney regulates the metabolism of calcium and phosphate in concert with PTH and vitamin D, as well as fibroblast growth factor-23. The primary disturbances of ESRD, which lead to secondary hyperparathyroidism and renal osteodystrophy, are hypocalcaemia and hypophosphatemia multiplex. The heightened phosphate in the blood brings severe consequences such as pronounced vascular calcifications, increased risk of cardiovascular events, and even death. Dietary phosphate control combined with phosphate binders is suboptimal in many patients undergoing dialysis. The likely contributor to End Stage Renal Disease patients, primarily on maintenance hemodialysis, is the increasing prevalence of diabetes and hypertension without early, appropriate nephrology intervention, which is routine in developing countries. The predominant renal replacement therapy practiced in the region is hemodialysis. Ignorance is given to the mental and technical challenges presented in electrolyte balance maintenance. Though electrolyte balance disorders have been documented, the scope of the disorders and the clinical implications underlying them are poorly understood. Recognition of the imbalances is important in maintaining and improving hemodialysis patients' care while minimizing the adverse outcomes. The imbalances call for the need

for clinical intervention and appropriate medical adjustments. Improving the quality of life of patients is achieved through prompt steps to prevent complications. Clinical and administrative delay is the focus of this study, which is heavily and frequently discussed within the literature. Prescribed awesome maintenance hemodialysis therapy, which is the therapy administered three times a week. The therapy is heavily documented regarding its challenges of hyponatremia, hyperkalemia, hyperkalemia, and hypophosphatemia. The literature is lacking regarding their associated factors.

Materials & Methods

This observational cross-sectional study was conducted at the Nephrology Department of Nephrology MTI.LRH Peshawar from January 2023 to Jan 2024. 100 patients who are captured for this study using the non-probability consecutive sampling technique. Their clinical and laboratory integration assessments are done. Medical records facilities are documented. Blood samples were primarily taken during Wednesday afternoon dialysis sessions to facilitate more consistent interval measurements. For each patient, clinical labs were able to set up automated analyzers for the routine assessments of sodium, potassium, calcium, and phosphate, and those results were included in the study. The study also collected demographic data and information regarding the duration of the dialysis treatment, along with medical history, concomitant medications, and comorbidities.

Inclusion Criteria:

Older patients diagnosed with End-Stage Renal Disease who were undergoing hemodialysis for more than three months were invited to participate in the study.

Exclusion Criteria:

Patients with the following conditions were also excluded: acute kidney injury, recent hospitalization, active infection, malignancy, peritoneal dialysis, and a substantially disrupted dialysis schedule.

Data Collection:

A pre-designed data collection form was used for the study. Data for laboratory results and dialysis history were cross-validated with hospital records and logbooks, respectively. Clinical information was gathered from patients. In each dialysis session, the clinical staff noted all electrolytes and their corresponding values to record the baseline for each session and identify the session starting levels.

Statistical Analysis

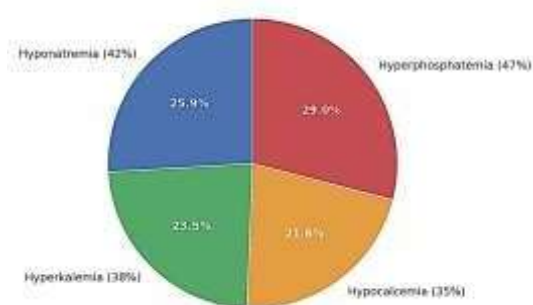
To conduct the analysis, SPSS software version 24.0 was used. Descriptive statistics showing means and standard deviations were the first analyses performed. The analyses employed were Chi-square

and independent t-tests. The study determined the significance of results when p-values were below 0.05. Results were presented in tabular and chart diagram formats for clarity.

RESULTS

Out of 100 patients 60 males and 40 females, whose mean age was 54.3 ± 12.7 years. 76%, 42% and 3.5 ± 1.2 years were the percentages and mean age with standard deviation of years the patients reported receiving dialysis, and were diagnosed with hypertension, diabetes mellitus, and were on dialysis, respectively. Of the patients, 42% and 12% of the cases experienced hyponatremia (serum $\text{Na}^+ < 135$ mmol/L) and hypernatremia, respectively. For 38% of patients, serum potassium levels exceeded 5.5 mmol/L, while 10% of the patients had potassium levels below this. 35% of the patients with hypocalcaemia (serum Ca^{2+} level below 8.5 mg/dL) and 47% of the subjects with hypophosphatemia (serum PO_4^{3-} greater than 5.5 mg/dL) constituted the data in this study. Prolonged dialysis > 2 years was established in the study to directly contribute to the development of hypophosphatemia with a statistically significant p-value of 0.032. Hypocalcaemia patients with a statistically higher p-value of 0.019 were shown to have increased levels of parathyroid hormone. There was no significant difference between male and female subjects showed no relevant difference. Diabetic patients and those with sporadic phosphate binder usage were documented with heightened electrolyte concerns. The evidence suggests that individualizing electrolyte monitoring in patients with ESRD will improve outcomes of dialysis and mitigate adverse outcomes.

Figure 1. Prevalence of Electrolyte Imbalances in ESRD Patients on Hemodialysis



This figure shows the distribution of electrolyte abnormalities among patients with end-stage renal disease (ESRD) receiving hemodialysis. Hypernatremia was the most common (42%), followed by hyperkalemia (38%), hypocalcaemia (35%), and hypophosphatemia (47%). Percentages represent the proportion of patients affected by each imbalance.

Table 1: Demographic Characteristics of Patient

Variable	Frequency (n)	Percentage (%)	Mean $\pm$ SD
Gender			
Male	60	60.0	—
Female	40	40.0	—
Age (years)	—	—	54.3 ± 12.7
Duration of dialysis (years)	—	—	3.5 ± 1.2
Duration of dialysis > 2 years	—	—	Significant for hypophosphatemia ($p = 0.032$)

This table summarizes the baseline demographic details of all patients included in the study. The cohort comprised 60 males and 40 females with a mean age of 54.3 ± 12.7 years. The average duration of dialysis was 3.5 ± 1.2 years. Prolonged dialysis duration (> 2 years) was found to be significantly associated with hypophosphatemia ($p = 0.032$).

Table 2. Clinical Characteristics and Comorbidities

Variable	Frequency (n)	Percentage (%)
Patients on dialysis	76	76.0
Hypertension	42	42.0
Diabetes mellitus	42	42.0
Sporadic phosphate binder use	—	—
Elevated parathyroid hormone (with hypocalcemia)	—	— ($p = 0.019$)

This table presents the distribution of major clinical characteristics and comorbid conditions among end-stage renal disease (ESRD) patients. Hypertension and diabetes mellitus were each observed in 42% of patients. Elevated parathyroid hormone levels were significantly associated with hypocalcemia ($p = 0.019$), while sporadic use of phosphate binders and the presence of diabetes correlated with higher frequencies of electrolyte imbalance.

Table 3. Electrolyte Imbalances among ESRD Patients

Electrolyte Parameter	Normal Range	Abnormality	Frequency (n)	Percentage (%)	Statistical Significance
Serum Sodium (Na^+)	135–145 mmol/L	Hyponatremia (< 135)	42	42.0	—
		Hypernatremia (> 145)	12	12.0	—
Serum Potassium (K^+)	3.5–5.5 mmol/L	Hyperkalemia (> 5.5)	38	38.0	—
		Hypokalemia (< 3.5)	10	10.0	—
Serum Calcium (Ca^{2+})	8.5–10.5 mg/dL	Hypocalcemia (< 8.5)	35	35.0	$p = 0.019$ ($\uparrow$ PTH)
Serum Phosphate (PO_4^{3-})	2.5–5.5 mg/dL	Hyperphosphatemia (> 5.5)	47	47.0	$p = 0.032$ (prolonged dialysis > 2 years)

This table illustrates the frequency and distribution of major electrolyte disturbances in the study population. Hyponatremia (42%) and hypernatremia (12%) were observed for sodium, hyperkalemia (38%) and hypokalemia (10%) for potassium, while hypocalcemia (35%) and hyperphosphatemia (47%) were the predominant calcium and phosphate abnormalities. Significant associations were identified between hypocalcemia and elevated parathyroid hormone levels ($p = 0.019$), and between prolonged dialysis (> 2 years) and hyperphosphatemia ($p = 0.032$).

DISCUSSION

Our study demonstrated that there are many problems patients with end-stage renal disease face; however, on maintenance hemodialysis, one of the most common issues is disordered electrolyte functions. In our study, hypophosphatemia and hypernatremia were the most prominent disorders, affecting 47% and 42% of patients, respectively. Conditions involving elevated potassium and low calcium levels were present in 38% and 35% of participants, respectively. The results we obtained in this study confirm the extent of the problem of electrolyte disorders within the population on maintenance dialysis as documented in the literature. Hypophosphatemia has been confirmed as a persistent dominant condition in patients on dialysis, as documented in our cohort, and multiple studies indicate similar rates within the 40-60% range [10,11]. Research notes that there is a higher risk of cardiovascular mortality in patients with hyperphosphatemia due to vascular calcification and arterial stiffness [12]. The length of dialysis treatments, at 0.032, was statistically connected to hypophosphatemia ($p=0.032$). This is in accordance with studies that state phosphate accumulation within a person undergoing dialysis increases due to poorly controlled phosphate levels, diet inconsistency, and insufficient dialysis clearance [13]. The presence of hypernatremia in 42% of patients is clinically significant. Chronic hypernatremia has been associated with negative cognitive impact, increased risk of falls, and higher mortality among patients with end-stage renal disease (ESRD) [14]. Some of the main contributors include low sodium levels in the dialysate, fluid overload, and diminished ability to excrete water. Fluctuating sodium levels cause unstable blood pressure, which aggravates intradialytic symptomatology [15]. The 38% prevalence of hyperkalemia within our subjects corresponds with comparable dialysis populations, which range from 30% to 50% [16]. Patients' hyperkalemia, which is part of the triad of life-threatening complications within this patient population, is likely due to the dietary potassium, medical potassium-sparing directors, ACE-inhibitors, and inadequately adjusted dialysis. Rapid identification and effective treatment of hyperkalemia is one of the most important elements of ESRD management due to the associated risk of sudden death. Of the patients evaluated, 35% of the cohort with secondary hyperparathyroidism also had hyperparathyroidism and hypocalcaemia. As demonstrated in the study, higher levels of PTH hormone and more severe deregulation of calcium in the body ($p=0.019$) suggest a more severe chronic kidney disease stage. The advanced stage confirms chronic kidney disease deregulation of calcium with PTH of greater focal point to phosphate, leading to the bone mineral disorder and chronic cardiovascular risk. [17] Most studies of individuals' phosphate dysregulation in

electrolyte disorders, along with the phosphate binder were attributed to poor dietary guideline compliance related to the education and multidisciplinary care at the center of the care. The increased laboratory assessments and the tailored, focused care on outcomes are the first step to the improvement of electrolyte-related morbidity.[18-19]

Limitations

Insufficient duration, small sample size, and a single study center contributed to the study limitations. A further understanding of the electrolyte outcomes and dialysate concentration, and poor adherence to the medication, dietary, and phosphate binder prescriptions, integration of a systematic evaluation of the electrolytes in the diet would make the study stronger.

Conclusion

Routine assessments alongside steady adherence to the dietary guidelines and prescribed medications are critical to prevent complications of hypernatremia and hypophosphatemia.

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Authors Contribution

Concept & Design of Study: **Waqas ur Rehman¹**

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Critical Review: **Waqas ur Rehman¹**

Final Approval of version: **All Authors Approved the Final Version.**

Accountability: All authors agree to be accountable for all aspects of the work. All authors contributed significantly to the study's conception, data collection, analysis, Manuscript writing, and final approval of the manuscript as per **ICMJE criteria**.

Research Ethics Statement

There were no animal studies conducted. This study was approved by the **Institutional Review Board** (IRB/LRH/MTI/468/04/2022) and conducted in accordance with the ethical principles of the Declaration of Helsinki (2013). All participants or legal guardians signed written informed consent. No recognizably identifiable human data were included. As described in the article and supplementary materials, data that that under or findings are held in online repositories.

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