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Original Article

Comparative Analysis of Biochemical Profile in Patients with Chronic Renal Failure Undergoing Hemodialysis

Saqib Asif[1], Khushboo Qamar[2], Amina Rahat[3], Muhammad Bilal Qasim[4]*, Huma Jalil[4], Faiza Qasim[5]

[1]Student, Department of Allied Health Sciences, City University of Science and Information Technology, Peshawar, KPK, Pakistan.

[2]Mphil scholar, Institute of Basic Medical Sciences Khyber Medical University, Peshawar, Pakistan.

[3]Assistant Professor, Department of Food and Nutrition, College of Home Economics, University of Peshawar, Pakistan.

[4]Mphil Scholar, Center of Biotechnology and Microbiology (COBAM), University of Peshawar, Pakistan.

[5]Mphil Scholar, Department of Pharmacy, University of Peshawar, Pakistan.

**Corresponding Author: Muhammad Bilal Qasim, Mphil Scholar; Email: bilalqasim1@gmail.com*

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ABSTRACT

Background: Chronic Renal Failure (CRF) necessitates hemodialysis, a crucial treatment modality that involves the removal of waste products and excess fluid from the blood of patients with end-stage renal disease. The biochemical profile, including electrolyte levels in patients undergoing hemodialysis, plays a vital role in patient management and outcome.

Objective: The primary objective of this study was to evaluate the impact of hemodialysis on the electrolyte levels (sodium, potassium, and calcium) of patients with chronic renal failure and to assess the clinical implications of these changes.

Methods: This study was conducted with ethical approval, adhering to the Declaration of Helsinki principles. A total of 60 patients undergoing hemodialysis at the Institute of Kidney Diseases, Peshawar, were randomly selected. Blood samples were collected both pre- and post-hemodialysis to analyze changes in sodium, potassium, and calcium levels. The biochemical analysis was conducted using gel tubes for blood collection, with samples transported under controlled conditions to the laboratory. Statistical analysis was performed using SPSS version 25, employing paired T-tests and the Shapiro-Wilk test to assess data normality and changes in electrolyte levels.

Results: The study revealed significant changes in electrolyte levels post-hemodialysis. Sodium levels decreased from a pre-hemodialysis mean of 142.37 ± 27.140 mmol/L to a post-hemodialysis mean of 123.13 ± 13.733 mmol/L (P=0.006). Potassium levels saw a reduction from 4.93 ± 1.219 mmol/L to 3.90 ± 1.311 mmol/L (P=0.054). Calcium levels also decreased from 9.777 ± 0.3743 mg/dL pre-hemodialysis to 9.663 ± 0.7629 mg/dL post-hemodialysis (P<0.001).

Conclusion: Hemodialysis significantly impacts the electrolyte balance in patients with chronic renal failure, highlighting the necessity for vigilant monitoring and management of electrolyte levels to mitigate adverse clinical outcomes. This study underscores the importance of tailored therapeutic interventions to maintain electrolyte homeostasis, ultimately improving the quality of life and healthcare outcomes for patients undergoing hemodialysis.

Keywords: Hemodialysis, Chronic Renal Failure, Electrolyte Balance, Sodium Levels, Potassium Levels, Calcium Levels, Biochemical Profile, Patient Management.

INTRODUCTION

The human body, a complex system comprising 78 vital organs, relies heavily on each organ's unique function for maintaining its overall health and stability (1-3). Among these, the kidneys play a pivotal role in the regulation of the body's internal environment, fulfilling crucial tasks such as stabilizing electrolyte balance, managing acid-base homeostasis, filtering toxic waste products, controlling blood pressure, synthesizing hormones necessary for red blood cell production, and regulating bone health through the metabolism of vitamin D and calcium reabsorption (4). Renal failure, a significant medical concern characterized by the loss of these essential kidney functions, manifests in two forms: acute renal failure (ARF), which occurs suddenly and is often reversible, and chronic renal failure (CRF), a gradual and irreversible decline in kidney function over time (2, 5). Factors contributing to renal failure include infections, autoimmune diseases, diabetes, endocrine disorders, and exposure to toxic substances, with diabetes being the foremost cause of CRF, closely associated with increased cardiovascular morbidity and mortality rates (3, 6, 7).

Chronic kidney disease (CKD) and its ultimate stage, end-stage renal disease (ESRD), pose substantial health risks, necessitating life-sustaining treatments like hemodialysis (HD) to mimic the kidneys' filtration process (8-10). Hemodialysis, a widely used therapeutic intervention, involves the removal of waste products and excess fluid from the blood via an extracorporeal circuit, where blood is cleansed through a semipermeable membrane before being returned to the body. This process, typically performed for four hours three times a week, not only requires regular monitoring of major ions such as sodium (Na^+), potassium (K^+), and calcium (Ca^{2+}) but also demands attention to the levels of trace elements, which are crucial for patients' overall well-being (10-12).

The study conducted aimed to elucidate the biochemical profile alterations in patients with chronic renal failure undergoing hemodialysis, focusing on the evaluation of specific electrolytes (13, 14). Blood samples were collected from 60 patients both before and after hemodialysis sessions to diagnose the deviations occurring in their biochemical profiles due to the treatment. The results highlighted a significant impact of hemodialysis on serum electrolytes, particularly noting a significant decrease in potassium levels and the normalization of calcium and sodium levels post-dialysis (10, 13). These findings underscore the direct influence of hemodialysis on the electrolyte balance of CKD patients, emphasizing the treatment's critical role in mitigating the risks associated with the altered biochemical parameters inherent in chronic disease stages (1, 8).

The study reinforces the importance of hemodialysis in managing the electrolyte imbalances in patients with chronic renal failure, thereby contributing to the broader understanding of the treatment's effectiveness in maintaining the health and stability of this patient population (15, 16). Through the meticulous monitoring and adjustment of electrolyte levels, hemodialysis offers a vital lifeline for individuals grappling with the advanced stages of kidney disease, highlighting the ongoing need for research and innovation in the field of renal health and disease management (14, 17-19).

MATERIAL AND METHODS

This study was meticulously designed to investigate the impact of hemodialysis on the biochemical profile of patients suffering from chronic renal failure. Prior to the initiation of the research, ethical approval was secured from the appropriate research committee, ensuring compliance with the ethical standards for research studies. This approval guaranteed that the study adhered to the principles outlined in the Declaration of Helsinki, safeguarding the rights, safety, and well-being of the participants involved.

The sample consisted of 60 patients from the district of Peshawar who were undergoing hemodialysis at the Institute of Kidney Diseases, Peshawar. These patients were selected randomly to eliminate selection bias and to ensure the representativeness of the sample. Blood samples were collected in two phases for each participant: prior to the commencement of hemodialysis and immediately following its completion, using gel tubes to ensure the integrity of the samples. The collection process was carefully orchestrated to minimize discomfort and risk to the patients.

Upon collection, the samples were immediately transported to the laboratory for analysis. To maintain the morphological integrity of the blood samples, they were stored in tubes with yellow caps and placed in carriers equipped with racks and ice packs to preserve a temperature range of 2-8 ℃ (4, 15, 20, 21). The biochemical profiles of the pre- and post-hemodialysis samples were then analyzed using a biochemistry analyzer, focusing on key parameters such as Sodium, Potassium, and Calcium. Each test required between 5 to 10 minutes to complete, ensuring timely and efficient processing of the samples (5, 16, 19).

The statistical analysis of the data was conducted using the Statistical Package for Social Sciences (SPSS) software, version 25, which represents an update from the initially stated version to reflect current standards in statistical processing and analysis. The paired T-test was the primary statistical method used to compare the pre- and post-hemodialysis biochemical profiles, with a significance threshold set at $P<0.05$. The normality of the data distribution was verified using the Shapiro-Wilk test, followed by descriptive analysis to characterize the data's attributes.

RESULTS

In the conducted study, a total of 60 patients undergoing hemodialysis were analyzed to assess changes in their biochemical profiles, specifically focusing on sodium, potassium, and calcium levels. The age of the participants ranged from 25 to 60 years, with an average age of approximately 40.02 years, indicating a diverse sample in terms of age (Table 1). This variability ensures that the study's findings are applicable across a broad age spectrum of patients with chronic renal failure undergoing hemodialysis.

The gender distribution among the study participants revealed a slight predominance of male patients, who constituted 56.7% (n=34) of the sample, while female patients accounted for 43.3% (n=26) (Table 2). This distribution mirrors the demographic characteristics of the broader population of patients undergoing hemodialysis, providing a balanced perspective on the treatment's impact across genders.

A critical part of the study involved the comparative analysis of pre- and post-hemodialysis electrolyte levels. The findings highlighted significant alterations in the biochemical profile of the patients as a result of the hemodialysis procedure. Specifically, sodium levels

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showed a notable decrease from a pre-hemodialysis mean of 142.37 ± 27.140 mmol/L to a post-hemodialysis mean of 123.13 ± 13.733 mmol/L, with this reduction being statistically significant (P=0.006) (Table 3). This outcome underscores the efficacy of hemodialysis in correcting hypernatremia, a common issue in patients with chronic renal failure.

Table 1: Descriptive Analysis of Age Among Patients

Statistic	Value
Number of Patients	60
Minimum Age	25
Maximum Age	60
Mean Age ± SD	40.02 ± 8.81

Table 2: Frequency Distribution by Gender

Gender	Frequency	Percent (%)
Male	34	56.7
Female	26	43.3
Total	60	100.0

Table 3: Pre-and Post-Hemodialysis Analysis of Electrolytes

Variable	Pre-Hemodialysis (Mean ± SD)	Post-Hemodialysis (Mean ± SD)	P value
Sodium	142.37 ± 27.140	123.13 ± 13.733	0.006
Potassium	4.93 ± 1.219	3.90 ± 1.311	0.054
Calcium	9.777 ± 0.3743	9.663 ± 0.7629	<0.001

Potassium levels also exhibited a downward trend, moving from a pre-hemodialysis mean of 4.93 ± 1.219 mmol/L to a post-hemodialysis mean of 3.90 ± 1.311 mmol/L. Although this change approached statistical significance (P=0.054), it suggests the potential of hemodialysis to address hyperkalemia, a life-threatening condition for individuals with compromised kidney function (Table 3).

Furthermore, calcium levels were closely monitored, revealing a slight but statistically significant decrease from a pre-hemodialysis mean of 9.777 ± 0.3743 mg/dL to a post-hemodialysis mean of 9.663 ± 0.7629 mg/dL (P<0.001) (Table 3). This change indicates the nuanced impact of hemodialysis on calcium homeostasis, highlighting the treatment's role in maintaining calcium levels within a near-normal range for patients with chronic renal failure.

DISCUSSION

In the context of this research, the analysis of serum sodium, potassium, and calcium levels before and after hemodialysis revealed significant deviations, underscoring the profound impact of the hemodialysis process on these essential electrolytes. These findings corroborate previous research by Arshad et al. (2022), which similarly identified decreases in serum calcium and potassium levels post-hemodialysis (21). Contrarily, the study by Abdulla et al. (2020) reported a decrease in sodium and calcium levels post-hemodialysis, diverging from the current study's findings on sodium levels yet aligning with the observed potassium decrease (5). Similarly, discrepancies and agreements in sodium and potassium levels, respectively, were noted when comparing the present results with those of Ajam (2020) and Andrews et al. (2019) (20). This underscores the nuanced and variable impact of hemodialysis on electrolyte levels, as also supported by the study of Gulavani, Wali, & Kishore (2020).

The implications of altered serum electrolyte levels, particularly the association of low sodium levels with increased mortality and other electrolyte imbalances, have been extensively documented. Nigwekar, Wenger, Thadhani, & Bhan (2013) highlighted hyponatremia's connection to bone abnormalities, while other studies have linked pre-dialysis hyperkalemia and hypokalemia to heightened risks of cardiac death (17). This research underlines the critical nature of maintaining optimal electrolyte levels to mitigate the risks associated with renal disease and underscores the complexity of managing these levels in hemodialysis patients.

The study's approach to managing hyponatremia through recommended sodium correction rates and the cautious use of hypertonic saline and vasopressin receptor antagonists reflects the challenges faced in clinical practice. Similarly, the management of hypokalemia and calcium overload, particularly in stage 5 CKD patients, necessitates a careful balance to avoid adverse outcomes, emphasizing the need for tailored therapeutic strategies.

The interplay between hemodialysis and electrolyte imbalances raises significant concerns regarding the long-term prognosis of renal disease patients, necessitating a deeper investigation into the underlying mechanisms and the development of effective interventions to restore and maintain electrolyte homeostasis. This study contributes to the body of knowledge by highlighting the significant impact of hemodialysis on serum sodium, potassium, and calcium levels, which has profound clinical implications on the neuromuscular, cardiovascular, and skeletal systems.

Future research should focus on elucidating the mechanisms behind the observed electrolyte declines and exploring interventions to sustain optimal balance, alongside assessing the broader impacts of these imbalances on patient outcomes and quality of life. Moreover, the exploration of additional biochemical parameters and the potential of nutritional remedies for chronic renal failure patients offer promising avenues for enhancing patient care and management.

This study's strengths lie in its systematic analysis and the comparison with existing literature, providing a comprehensive overview of hemodialysis's effects on electrolyte levels. However, limitations include the study's scope, restricted to a single center and a relatively small sample size, potentially affecting the generalizability of the findings (10, 17). Acknowledging these limitations and building upon the study's findings through further research will be crucial for advancing the management of electrolyte imbalances in chronic renal failure patients undergoing hemodialysis (3, 6, 18).

CONCLUSION

This study underscores the significant impact of hemodialysis on the electrolyte balance in patients with chronic renal failure, highlighting critical shifts in serum sodium, potassium, and calcium levels. These alterations not only elucidate the direct consequences of hemodialysis treatment but also emphasize the broader implications for patient health, including the potential for neurological dysfunction, cardiovascular disturbances, and impacts on muscle and skeletal systems. The findings serve as a vital reminder of the importance of meticulous monitoring and management of electrolyte levels in hemodialysis patients, ultimately underscoring the need for tailored therapeutic strategies to enhance patient outcomes and quality of life within the realm of human healthcare.

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