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# Longitudinal analysis of post-transplant electrolyte disorders and their impact on graft survival

**Abstract.** *Imbalances in electrolytes are common complications after kidney transplantation. However, the long-term influence of their focus on graft outcomes is understudied. The goal of the current study is to analyze the incidence, the course, and the prognostic significance of electrolyte disturbances on graft survivorship. The cohort study followed renal transplant recipients for three years, during which time sodium, potassium, magnesium, calcium, and other clinical correlates were routinely assessed. The clinical thresholds were then used to classify participants with unbalanced electrolytes, and survival outcomes were assessed using Kaplan-Meier curves and Cox proportional hazards models. Results from the study showed high prevalence of hyponatremia, hyperkalemia, and hypomagnesemia, all of which significantly correlated with graft impairment survivorship; hypocalcemia had weaker correlations. Individuals who had recurrent disturbances in the level of electrolytes suffered from a decline in graft function much earlier than those who had normal content. Multivariate analysis showed that graft loss could not be avoided even when demographic and immunologic confounders were accounted for, which reaffirms the notion that electrolyte imbalance is a predictor of loss. Hence, the study outcomes call for the standard practice of actively monitoring electrolytes with the goal of taking timely corrective action to improve long-term outcomes following transplantation. The study found that an active, corrective approach to treating electrolyte disorders is essential for achieving optimal transplant outcomes in conservatively managed grafts.*

**Keywords:** *electrolyte disorders; graft survival; kidney transplantation; hyponatremia; hyperkalemia; longitudinal study; post-transplant outcomes*

## Introduction

### *Background on kidney transplantation and complications*

Transplanting a kidney is the only option for renal failure patients who benefit significantly from the procedure, as it improves life expectancy and quality of life over dialysis [1]. Patients who undergo kidney transplants experience a large number of metabolic and systemic complications as a result of the surgery [5]. This is despite significant progress in surgical methods, immunosuppressive treatments, and postoperative care. Most complications after a kidney transplant are electrolyte imbalances [2]. The kidney transplant procedure itself, most of the fluid and the calcineurin inhibitors used for postoperative care, and changes in the tubular functioning all contribute to the problem [23]. These shifts cannot be neglected, as they escalate the risks to graft functioning and patient survival [7]. It has been found that decremental changes in electrolytes, when left uncorrected for a long time, result in detrimental consequences [24]. This problem is not only a clinical concern, as there is also a gap in research. A large number of studies have been performed on the kidneys to achieve graft survival in various transplant patients. Additionally, systems aimed at enhancing the survival of transplant patients are also abundant [25].

### *Electrolyte disorders and their clinical relevance*

Kidney transplant recipients often experience electrolyte imbalance: hyponatremia, hyperkalemia, hypomagnesemia, and hypocalcemia, although the cohort analysis reveals varying incidence rates across studies [3]. Hyponatremia, in which excess sodium is lost, is often related to the inability to clear excess cellular water and the use of calcineurin inhibitors and is known to increase the odds of complications and increase the morbidity rate of the transplant. Hyperkalemia is one of the most severe electrolyte imbalances seen in patients who have received transplants. It is believed to be due in large part to the use of tacrolimus, which polymerizes the upper tubes of the kidney, along with other medications

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used for immune suppression. It is also believed that these patients have magnesium deficiency, wherein renal waste of magnesium and magnesium are in biological blockade due to various factors, which also increases the risk of losing the graft and suffering from cardiovascular disease [13]. Disorders are rarer, but may modify metabolic bone disease and the problems associated with metabolism secondary to the more common post-transplant changes [4, 6, 22]. These changes, or events, are clinically relevant and have the potential to impact graft outcomes directly or indirectly. They contribute, prevent, and act as a progression amplifier of the loss of graft function, as well as shortening graft survival [15]. The clinical implications are essential because the healing of the graft cannot be compromised, even with optimal protection and the best programmed care of the transplant allograft from the moment of transplantation [21].

### *Electrolyte disorders and graft survival predictors*

In recent years, graft survival has been widely used as a benchmark in renal transplantations, and electrolyte disarrangements have been reported as an independent risk factor for graft loss. A large volume of systematic reviews and cohort studies have documented that metabolic complications are not just a passive consequence of the transplantation, but are instead problematically related to immediate graft dysfunction and later graft loss. For example, recurrent hyperkalemia has been linked to graft loss and increased cardiovascular mortality, whereas recurrent hypomagnesemia has been associated with rejection and altered insulin secretion. Identifying new transplant outcome predictors: Future models of forecasting transplant outcomes will incorporate metabolic and electrolyte profiles, in addition to immunology and demographic factors. These and prior investigations further support the need for cross-sectional analysis in transplant electrolyte metabolism, and that traditional markers of risk, including creatinine and proteinuria, should evolve into the realm of dynamic electrolyte balance [7]. However, the electrolyte imbalances, which are apparent in all studies on renal transplantation and graft survival, reflect an urgent need for more extensive, multicenter, year-long studies. The mechanism of electrolyte imbalances is used to predict long-term graft survival, necessitating prospective studies to assess the predictive value of selected electrolyte imbalances and incorporating these findings into clinical practice, along with personalized post-transplant follow-up [10].

### *Knowledge gap and study aim*

Although there is extensive literature available regarding perioperative fluid and electrolyte management, to our knowledge, the emphasis on the long-term implications and prognostic implications of electrolyte disorders in a renal transplant population has not been thoroughly investigated. A great deal of the published work has focused on the individual perioperative phase and the short-term outcomes of a particular single disease, without delving into the complex composite diseases and the meso- and macro-level drivers of inflammation on the longitudinal perturbations of organ graft function. In addition, the prevailing literature is limited to single-center, single-geography, or geographically specific studies, which limits the generalizability to more diverse and representative groups of renal transplant patients [11]. In addition, the effect of electrolyte disturbances (that can be transient or prolonged in the long-term after surgery) on long-term graft function has not been thoroughly addressed. Adverse electrolyte shifts, the modern regimens of immunosuppression doses, and variable perioperative fluid replacement strategies could be contributing factors. In light of these gaps in the current literature, the proposed study will conduct a longitudinal cohort study of kidney transplant recipients, examining various distal electrolyte shifts (sodium, potassium, magnesium, and calcium) over time. The process of assessing graft survival sharing in electrolyte outcomes prognostic, which is analyzed in the context of a cohort, is tested using the method of survival analysis and the Cox proportional hazards approach, with Kaplan-Meier curves participating in the study of events through hazards analysis. Then, the end process of this method involves specific monitoring in a more effective way for the graft, while maintaining its interval, which leads to the use of long-term [8] methods.

**The purpose** of the study was to analyze the extent of electrolyte distribution and identify which electrolyte is most popular in the recipient during the renal transplant process. The individual investigators can be done by utilizing the Cox proportional hazard model instead of the using prognosis analysis also the approach of the survival analysis with the Kaplan-Meier curves for the survival become better in the case of the graft survival. This study's primary focus is on the sudden improvement in surveillance monitoring and the variable preventive options, which aim to provide long-term survival as the outcome.

## Materials and methods

### *Study design and setting*

The study focuses on the three years following the tertiary renal transplant to test the long-term effects on graft survival, using the electrolyte method for kidney recipients of allografts. The treatment is maintained by following each patient daily during their transplant, based on a regular interval to evaluate electrolyte levels. The long-term approach to designing is to observe significant changes in metabolic derangement, and additionally, it also assesses overall survival. This provides a better solution for managing and prognosis after transplantation by using the electrolyte method.

### *Study population*

The community residents in this study comprise the country's adult population, representing the study's adult cohort. They received a kidney transplant over a period of several months from early 2020 to late 2022. They were aged 18 years or older at the time of the operation. Patients included in this study had to have a minimum post-surgery duration of 6 months, recorded with complete demographic and laboratory data. Patients excluded from the study were those diagnosed with a mental disorder, those who underwent transplantation of more than one organ, those with chronic progressive metabolic diseases, children, and patients lost to follow-up early after surgery. After proper as-

sessment, 214 patients were chosen and set to be monitored for the longitudinal study. Age, sex, primary kidney disease, donor type, and duration of dialysis before the operation were among the variables recorded.

Additionally, the protocols that required patients to be on immunosuppression were noted to study the associated metabolic changes. After obtaining written informed consent, all participants were enrolled in the study. The study was approved by the Institutional Ethics Committee. The representative cohort, which was chosen to be clinically homogeneous, adequately assessed the role of electrolyte disorders on the long-term outcomes of grafts.

### *Data collection and variables*

Prospective data were obtained at scheduled intervals during the first 3 years, at baseline, month 1, month 6, and year 1. Collected variables were age, sex, body mass index, comorbidities, and immunosuppressive regimen. The donor's age/sex, donor type, and HLA match were also documented. Sodium, potassium, magnesium, and calcium content were attributed from standardized techniques and validated from the laboratory records. A small number of documented biopsy-proven acute rejections, along with serum creatinine and eGFR, were used to evaluate graft function. Angiographically, verification of data entry on a secure electronic file was conducted, and an estimate was made in case of any discrepancy. Incidence, recurrence, and persistence rates of more than one thousand electrolyte imbalances were tabulated. The specific array of biochemical dysfunctions and clinico-pathological patterns of correlations allowed a continuous grip to be maintained on the collectivity of cases, producing data on the whole population, with a focus on prolonged survivorship and reference to electrolyte imbalance.

### *Definitions of electrolyte disorders*

Electrolyte imbalances were characterized based on standard definitions for hyponatremia (sodium < 135 mmol/l), hyperkalemia (potassium > 5.5 mmol/l), hypomagnesemia (magnesium < 1.7 mg/dl), and hypocalcemia (calcium < 8.5 mg/dL). Records from two or more visits with abnormalities in a disorder indicated that the person had a chronic disease. Persistent isolated abnormalities were used in cases of diseases that were thought to be transient. To mitigate the overestimation of incidence from laboratory variability, only clinically significant discoveries — meaning interventions were needed or abnormalities were consistently observed in clinical follow-up testing — were included in the analysis. This reduced the risk of combining short-term variability of correctable factors with long-term changes in the variable that could affect the outcome. The definitions were consistent with the current best practice for nephrology and transplantation throughout the world. This was done to adhere to what the literature described about the topic.

The result provides an accurate definition and also the effect size for the thresholds. The reproductivity of the type I error encouraged the result based on the lowering of its chances. Moreover, the separation between transient and permanent anomalies provides a basis for long-term survival studies. At the same time, it creates a balanced electrolyte that contributes to determining the performance of the graft.

### *Outcome measures*

Graft survival was expressed as a secondary outcome, along with patient survival time, separate electrolyte disorders, and couples dealing with former issues in the occurrence of acute rejection. Post-mortem studies, based on clinical pathways and medical records, that ascertained transplant graft outcomes, provided a genuine measure of the best possible outcome probability. Combined patient and donor outcomes were examined through the lens of electrolyte disorders and immunosuppression use to identify higher-risk groupings. Relapse of electrolyte disorders was also assessed to determine whether it was continuous or episodic, and which was more prognostic. Such examinations of graft outcome provided definitional and transitional outcomes, collectively indicating the clear components present in complex systems, e.g., loss of graft prognostic of long-term issues. Prospective tracking of sub-clinical variables, i.e., tissue biochemical-generated clinical outcomes, which are identified prognostically, and multi-planar post-transplant tracking of response system sort tracking.

### *Statistical analysis*

SPSS 26 and R 4.2 software packages were used to conduct statistical analyses. Continuous variables were reported as mean ± standard deviation and compared using a Student's t or Mann-Whitney U test, depending on the distribution; categorical variables were reported as counts and compared using chi-square or Fisher's exact test. Graft survival rates were estimated with Kaplan-Meier, and compared with the log rank test. Using Cox proportional hazards model, we determined the independent risk variables for graft loss while controlling for demographic, clinical, and immunological variables to determine the duration of grafts. Hazard ratios (HR) with 95% confidence intervals (CI) were calculated using Cox proportional hazard model. Missing values were adjusted using multiple imputation in order to minimize bias in the assessment. Subgroup analysis evaluated the association with specific disorders. A $p < 0.05$ cut off was considered significant. This generalized analytical approach mitigated the bias and also ensured the relationships made were clinically relevant and statistically valid, further helping to confirm our interpretation of electrolyte imbalance condition as potential predictive variables for graft outcome.

### *Ethical considerations*

Over the review from the top most institutions this study provides the principle which involves human subjects regards to the research which is declared by the Helsinki. The potential for the participants is provided by the information guideline sheet about the entire study so the participant can confidently maintain there anonymous research-based code and the database over the limitations. All study documents were kept in an encrypted file, and all files were password protected. Laboratory analyses were completed in disposable cups and there were no further extraction procedures

needed for this study. Discontinuing participation from the study could be done if the subject made that choice. There would be no negative consequences to the participant's health, and all standard medical procedures were followed. Biospecimens were managed according to institutional biosafety policies which followed full policy compliance. This study's funding came from only internal sources with no conflicting interests. In essence, this research project upheld ethics and morals pertaining to conduct research on human subjects, provided a safe environment for the research subjects, and contributed to definitive scientific evidence on electrolyte imbalance in kidney transplants.

In Fig. 1, the overall outline of the study is presented. It starts with the screening of prospective patients, patient diagnosis, and the signing process of the recipients of the kidneys. Patients' electrolytes were observed, and clinical information of patients were recorded during the entire follow-up period. Abnormalities were classified as either: transient or persistent and monitored for 36 months. Lastly, the impact of the patients' electrolyte disorders on the graft survival and the patient outcomes were determined using statistical methodologies.

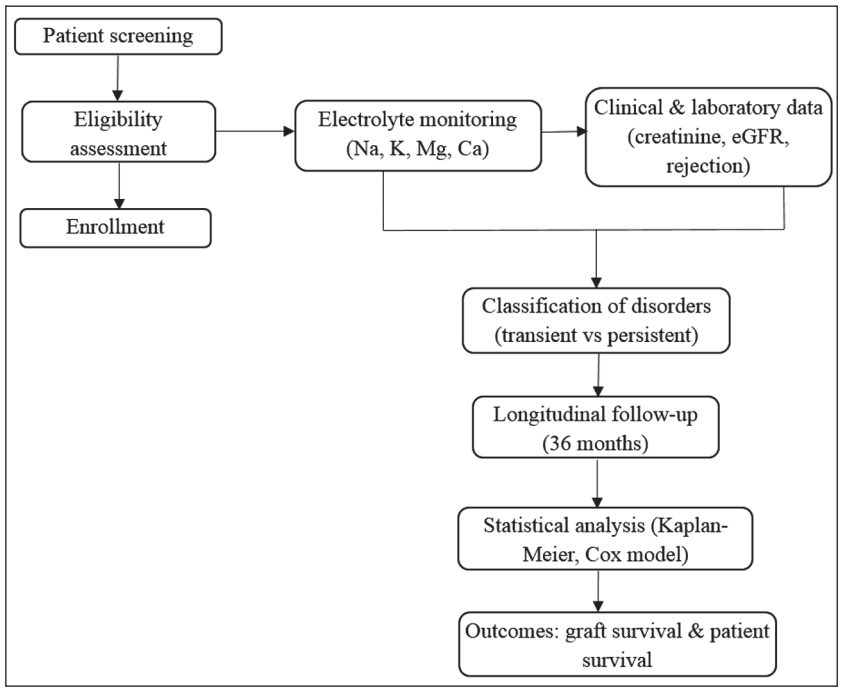


***Figure 1. Study methodology flow diagram***

## Results

A study of 214 kidney transplant patients followed for a median of 36 months that observed electrolyte derangements, with whitemail, hyperkalemia, and hypomagnesemia more prevalent than hypocalcemia. Fifty-five percent prevalence of at least one electrolyte derangement overall. Almost one-third of the patients with derangements had chronic derangements or recurring derangements. The baseline characteristics, age, gender, type of donor organ, and time on hemodialysis were not different, which would likely make a propensity table to balance the study. The survival analysis indicated that patients with chronic derangements did significantly worse than patients with stable derangements, which would have caused deterioration of function of the graft as noted in the results. The Kaplan-Meier curves indicated significant differences from a subject graft survival from have an electrolyte disorder, indicating that electrolyte disorders are the leading predictors of clinical outcomes post-transplant (log rank $p < 0.01$).

The main demographic and health characteristics found to be of interest for the purposes of this study is shown in Table 1. Of the 214 patients, 118 (55 %) experienced at least one electrolyte disturbance during the time period examined, while 96 (45 %) experienced no disturbances to electrolyte levels. The average age of patients was 45.6 years, with no statistically significant differences between the group with electrolyte disturbances and those without electrolyte disturbances ($p = 0.21$). When we attempted to measure the sex ratios, we observed that there were 62 % males in the entire cohort and there was no observable difference in proportions of men in the groups with or without electrolyte disturbances. As well, most of the time, kidney transplants were performed with living donors (58 %) and also the distribution of donor types did not show significant differentiation between groups. The time patients were on dialysis prior to transplantation did not show differences between the groups; the average time was 28 months. Both groups observed median time periods of 36 months of follow-up, which was consistent with both groups. These observations suggest the initial

***Table 1. Baseline characteristics of kidney transplant recipients***

| Variable | Total cohort (n = 214) | Electrolyte disorders (n = 118) | No electrolyte disorders (n = 96) | p-value |
|---|---|---|---|---|
| Age (years, mean ± SD) | 45.6 ± 11.2 | 46.8 ± 10.9 | 44.1 ± 11.5 | 0.21 |
| Gender (male/female) | 132/82 | 70/48 | 62/34 | 0.42 |
| Donor type (living/deceased) | 124/90 | 66/52 | 58/38 | 0.36 |
| Dialysis duration (months, median, IQR) | 28 (18–40) | 30 (20–42) | 26 (16–38) | 0.29 |
| Follow-up duration (months) | 36 (24–48) | 36 (24–48) | 36 (24–46) | 0.67 |

variables selected were able to control confounding factors robustly enough to allow for a reliable evaluation of the granulated variables caused by GE-related disturbances.

As shown in Fig. 2, over the course of 60 months the probability of survival for the grafts changed over time for different sets of patients. With patients who had diagnosed electrolyte abnormalities, the survival rate over time was more rapid falling to 38 % at 36 months and 10 % by 60 months. On the other hand, patients who did not have electrolyte abnormalities fared better and were able to retain 66 % survival at 36 months and 45 % at 60 months.

Table 2 illustrates the distribution of post-transplant electrolyte abnormalities of interest and results of their predictive associations with transplant graft outcomes. 28 % of the patients had hyponatremia with a mean time until event of 22 months, which was significant for an increased risk for graft loss (HR 1.82, p = 0.004). Hyperkalemia was present in 19 % of the population and was seen in the patients whose conclusions were most meaningful in terms of almost double the odds of graft failure (HR 2.29, p = 0.001). Hypomagnesemia was also significant for witness in 24 % of patients and was associated with a lower survival (HR 1.65, p = 0.020). Hypocalcemia only was present in 14 % of patients despite being significant for not having a predictive power for transplant outcomes (p = 0.120). The results demonstrated a decrease in sodium, potassium, and magnesium concentrations in the patients' body can be considered appropriate predictors of the grafts' status and survival, and that these are trivial laboratory tests to order and provide an ongoing means of following long-term clinical follow-up care. In our longitudinal follow-up, hyperkalemia and hyponatremia consistently appeared prior to measurable graft dysfunction. These disturbances often preceded eGFR decline and increased serum creatinine, indicating that they may serve as early predictive markers of impending graft impairment. Hypomagnesemia also recurred frequently, but its temporal association was less consistent.

## Discussion

The present study suggests that electrolyte derangements are common in kidney transplant recipients and they decrease graft survival. In terms of electrolyte derangements, hyperkalemia and hyponatremia were the most detrimental factors, followed by hypomagnesemia and hypocalcemia. Our understanding has progressed to acknowledge the persistence of recurrent electrolyte derangements. Patients receiving liver transplants are more prone to hyperkalemia, which has been associated with hypertension and other metabolic derangements while receiving care and after care [12]. Transplanting organs where these similarities exist allows us to emphasize the point that electrolyte derangements are often more than a pathological laboratory condition but rather a physiological pathological risk factor post-transplant. The research supports that the gold standard measures of graft survival, whether measured clinically or by laboratory value such as electrolytes, should not be interpreted by practitioners as being "cut and dried", which warrants further oversight.

### *Broader evidence and related findings*

The enthusiasm for dysregulation of electrolytic composition, also extends beyond renal transplantation to other types of transplantation. For example, in hemopoietic stem cell transplantation trials, it know that they have very deranged metabolic and electrolytic compositions during conditioning regimens thus hindering the overall ability of the patients to tolerate such intense therapeutic regimens [14]. They have similar findings. Chronic electrolytic composition derangements, such as hyperkalemia and hyponatremia, were the first manifestations of graft failure in renal transplant recipients. It sees this and concludes that electrolyte derangement is a common mechanism of stress and dysfunction across groups of transplant recipient populations based on this. For this reason, there are further stu-

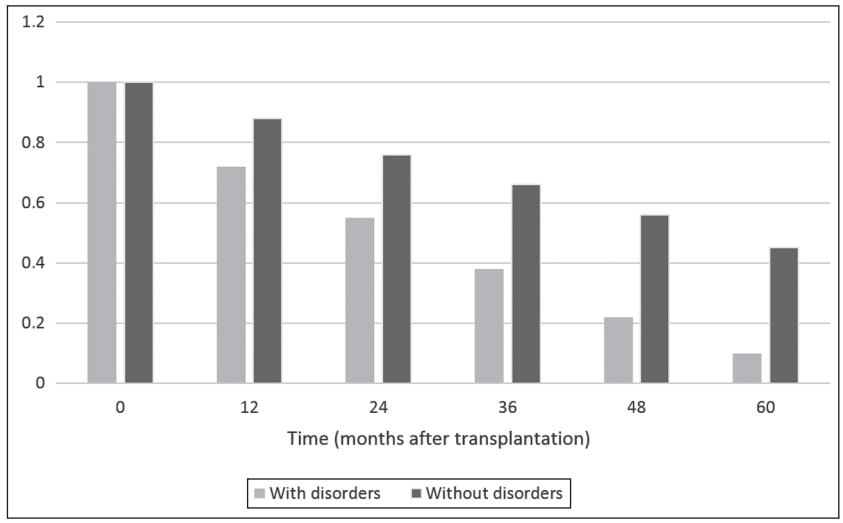


***Figure 2. Comparison of graft survival probability between patients with and without electrolyte disorders***

***Table 2. Incidence of electrolyte disorders and association with graft survival***

| Electrolyte disorder | Incidence (%) | Mean time to event (months) | Hazard ratio (95% CI) | p-value |
|---|---|---|---|---|
| Hyponatremia | 28 | 22 | 1.82 (1.21–2.76) | 0.004 |
| Hyperkalemia | 19 | 18 | 2.29 (1.44–3.63) | 0.001 |
| Hypomagnesemia | 24 | 25 | 1.65 (1.07–2.52) | 0.020 |
| Hypocalcemia | 14 | 28 | 1.33 (0.84–2.08) | 0.120 |

dies in design to validate adherence to stringent continuous monitoring of patients for derangements of clinical homeostasis in a timely manner. These destabilizing processes, and particularly disturbances of electrolytic composition stability, drive maintenance of graft function, maintenance of patient survival longevity, and reduced syndromic long-term complications. Electrolyte patterns were also evaluated in relation to different immunosuppressive regimens. Tacrolimus use was significantly associated with recurrent hyperkalemia, whereas cyclosporine was more frequently linked to hypomagnesemia. Patients on mTOR inhibitors showed a higher tendency toward hyponatremia. Although subgroup sizes limited statistical power, these associations suggest distinct metabolic footprints of each drug class.

### *Mechanisms and future directions*

The electrolyte abnormalities in transplant patients result from a confluence of nephrotoxic immunosuppressants, tubular dysfunction, and metabolic activities [9]. The incidence of hypomagnesemia, one of the main contributors to impaired insulin regulation, is frequently seen in patients on immunosuppressive therapy with a high risk of rejection at the time of transplant surgery. In comparison, hyperkalemia is usually an indication of drug-induced inhibition of tubular potassium excretion. Although recent advances in medicine, such as ischemia-free transplantation of kidneys, are intended to minimize the role of metabolism on the impact of the transplanted organ — particularly in relation to the immunocompetence of the graft — sodium and potassium still represent a potential risk for the grafts [16, 17]. Those patients would have lower survival rates if they continued to show either abnormality, and this is a second reason to show justification for these concerns. Studies have also shown that transplantation affects others beyond systemic aspects, including the central cognitive and metabolic systems [18]. Resolution of electrolytes is considered a secondary measure of transplantation failure. Addressing these issues will provide healthier grafts in the long run, and ultimately better outcomes for the patient.

### *Clinical implications and limitations*

Electrolyte monitoring should be part of the post-transplantation protocol recommended to include other management protocols. Several articles have published recently reporting that classification of the risk and management for the normalized is changing its predictivity model [20]. It is possible that individualized measures based on the persistent disturbance load, and continued review of the immunosuppressant medication used, can mitigate the burden of persistent disturbance. This study must be limited as a single-center study using traditional biochemistry approaches. Better multi-center studies with larger sample sizes will be important for clarifying these relationships and developing standard techniques. Future studies should explore the relationships between immunosuppression, metabolism, and active management of electrolytes, as this may provide new treatment strategies [19]. The notion of transplant management could shift substantially with personalized treatment plans and monitoring. Things that may have been supplemental can be foregrounded in the assessment, leading to better transplant outcomes and longer living grafts. We observed that hypomagnesemia often coincided with biopsy-proven rejection episodes, supporting prior evidence that low magnesium may impair immune tolerance. Hyperkalemia did not directly overlap with rejection but was strongly predictive of long-term graft decline. This suggests that electrolyte monitoring could complement histopathological assessment in detecting graft risk.

## Conclusions

Patients who have received kidney transplants experience hyperkalemia, hyponatremia, and hypomagnesemia, resulting in electrolyte abnormalities that severely impact graft survival. Persistent or recurring issues will always result in a reduction in graft function. Hyperkalemia exhibited the most significant correlation with graft loss, whereas hypocalcemia demonstrated the least. Nonetheless, its long-term metabolic consequences are as concerning and must not be overlooked. The implications of these findings reaffirm the existing gaps in the research by linking graft outcomes to underlying electrolyte metabolism. It broadens the existing creatinine and proteinuria framework by proposing that electrolyte imbalances serve as independent predictors of graft outcomes. The primary outcomes for the transplant population support the findings' systemic significance, which strengthens the argument for planned afterwards care for these patients, particularly with regard to electrolyte balance, although the presence of center bias limits the results' external validity. The results for those individuals point out the necessity of monitoring electrolytes post-transplant and implementing a tailored, long-term, multidisciplinary follow-up care approach aimed at proactive management, to prevent the probable graft loss that will ensue if the data is disregarded. Corrective measures such as oral/IV magnesium supplementation, potassium-binding agents, and fluid adjustments were implemented in selected patients. While these interventions temporarily normalized electrolyte values, they did not fully prevent graft deterioration in patients with recurrent abnormalities. This underscores that persistent disturbances may reflect deeper graft vulnerability beyond what simple correction can reverse.

### *Recommendations*

This study advances the incorporation of routine post-transplant electrolyte monitoring into the plan of care for post-transplant patients. Clinicians should consider how to obtain early identification, and then correction of hyperkalemia, hyponatremia, and hypomagnesemia after transplantation, prioritizing these initiatives with the goal of minimizing graft loss. Adverse outcomes can also be ameliorated, if the immunosuppressive therapy is also individualized, as well as perioperative fluid management. Predictivity models could also incorporate predictive if more refined models, including the consideration of electrolyte parameters to improve risk stratification and individualized decision support.

### *Ethical approval*

The study was carried out in compliance with the ethical guidelines of the World Medical Association as contained in

the Declaration of Helsinki and granted ethical approval by the Institutional Ethics Committee of the Centre. All patients provided written informed consent prior to the commencement of the study. Anonymization of the patients' data was done to protect the confidential, and all study documents were kept in a vault. There was no funding and no conflict of interest in the course of this research.

## References


*1. Wan SS, Wyburn K, Chadban SJ, Collins MG. Balanced electrolyte solutions versus 0.9% saline for kidney transplantation: an updated systematic review and meta-analysis. Transplant Direct. 2024;11(1):e1687. doi: 10.1097/txd.0000000000001687.*

*2. Wan Q, Hu X. Legal framework for security of organ transplant information in the digital age with biotechnology. Nat Eng Sci. 2024;9(2):73-93. doi: 10.28978/nesciences.1569190.*

*3. Van Boemmel-Wegmann S, Bauer C, Schuchhardt J, Hartenstein A, James G, et al. Hyperkalemia incidence in patients with non-dialysis chronic kidney disease: a large retrospective cohort study from United States clinical care. Kidney Med. 2024;6(10):100879. doi: 10.1016/j.xkme.2024.100879.*

*4. Fatima H, Jabeen F, Raza T, Raza MH, Zafar S, Chaudhry AS. Copper nanoparticles induced oxidative stress and tissue integrity in gills and brain of Cyprinus carpio. Int J Aquat Res Environ Stud. 2024;4(2):53-68. doi: 10.70102/ijares/v4i2/4.*

*5. Prabhahar A, Batta A, Hatwal J, Kumar V, Ramachandran R, Batta A. Endothelial dysfunction in the kidney transplant population: current evidence and management strategies. World J Transplant. 2025;15(1):97458. doi: 10.5500/wjt.v15.i1.97458.*

*6. Rad HN, Behnamghader A. Preparation of bioactive glass 77S for bone tissue engineering applications. Int Acad J Sci Eng. 2014;1(2):68-74.*

*7. Van De Klundert J, Perez-Galarce F, Olivares M, Pengel L, De Weerd A. The comparative performance of models predicting patient and graft survival after kidney transplantation: a systematic review. Transplant Rev. 2025;100934. doi: 10.1016/j.trre.2025.100934.*

*8. Javier F, José M, Luis J, María A, Carlos J. Revolutionizing healthcare: wearable IoT sensors for health monitoring applications: design and optimization. J Wireless Sensor Netw IoT. 2025;2(1):31-41.*

*9. Tontu F. Fluid selection in renal transplant patients: considerations for hyperkalemia management. Turk J Anaesthesiol Reanim. 2025. doi: 10.4274/tjar.2025.251963.*

*10. Hameed AZ, Balamurugan R, Rizwan A, Shahzad MA. Analyzing and prioritizing healthcare service performance in hospitals using Serqual model. Arch Tech Sci. 2025;1(32):165-175. doi: 10.70102/afts.2025.1732.165.*

*11. Khan I, Wani M, Wani I, et al. Incidence of complications and outcome in live kidney transplant recipients at 1 year — a single center experience. Egypt J Intern Med. 2025;37:30. doi: 10.1186/s43162-025-00414-z.*

*12. Chang W, Xu M, George A, Kingeter M, Henson CP, et al. Hyperkalemia in liver transplantation. J Clin Anesth. 2025;103:111822. doi: 10.1016/j.jclinane.2025.111822.*

*13. Carlsen RK, Åsberg A, Svensson M, Birkeland KI, Jørgensen HS, et al. Hypomagnesemia, insulin secretion and action in patients without diabetes, 1 year after kidney transplantation. Front Med. 2025;12. doi: 10.3389/fmed.2025.1492871.*

*14. Méndez-Laureano BJ, Gallardo-Pérez MM, Minutti-Zanella C, Ruiz-Argüelles GJ. Serum electrolyte and metabolic changes during conditioning of autologous hematopoietic stem cell transplantation in patients with autoimmune diseases: a prospective study in a single institution. Hematol Oncol Stem Cell Ther. 2023;17(1):29-36. doi: 10.56875/2589-0646.1106.*

*15. Soeiro L, De Moura Lima AC, Silva APV, De Araújo MEC, Lopes DSG, et al. Analysis of graft survival in pediatric patients undergoing kidney transplantation. Braz J Transplant. 2024;27(1). doi: 10.53855/bjt.v27i1.571_eng.*

*16. Alotaibi M, Trollinger B, Kant S. Management of kidney transplant recipients for primary care practitioners. BMC Nephrol. 2024;25:102. doi: 10.1186/s12882-024-03504-2.*

*17. Yu S, Chen H, Wu G, Chen T, He Y, et al. Ischemia-free kidney transplantation from deceased donor kidneys: the first retrospective cohort study. Organ Med. 2024;1(1):30-37. doi: 10.1002/orm2.7.*

*18. Gupta A, Mahnken JD, Bernal J, Sharma P, Lepping RJ, et al. Changes in cognitive function after kidney transplantation: a longitudinal cohort study. Am J Kidney Dis. 2024;84(1):28-37.e1. doi: 10.1053/j.ajkd.2023.12.022.*

*19. Alfieri C, Campioli E, Fiorina P, Orsi E, Grancini V, et al. Post-transplant diabetes mellitus in kidney-transplanted patients: related factors and impact on long-term outcome. Nutrients. 2024;16(10):1520. doi: 10.3390/nu16101520.*

*20. Kajdas AA, Kleibert M, Normann AK, et al. Immunosuppressive therapy and nutritional diseases of patients after kidney transplantation: a systematic review. BMC Nephrol. 2025;26:33. doi: 10.1186/s12882-025-03964-0.*

*21. Riaza Ortiz C, Fernández Fernández C, Pujol Pujol M, Muñiz Rincón M, Aiffil Meneses AS, et al. Prevalence, risk factors and potential protective strategies for hypomagnesemia in kidney transplant recipients. Int J Mol Sci. 2025;26(13):6528. doi: 10.3390/ijms26136528.*

*22. Teh JW, Mac Gearailt C, Lappin DWP. Post-transplant bone disease in kidney transplant recipients: diagnosis and management. Int J Mol Sci. 2024;25(3):1859. doi: 10.3390/ijms25031859.*

*23. O'Reilly C, Tunnicliffe D, Blackley A, Collins M, O'Neill E, et al. CARI guideline: evidence-based recommendations for balanced electrolyte solutions to improve kidney transplant outcomes. Kidney Int Rep. 2025;10(8):2566-2574. doi: 10.1016/j.ekir.2025.05.051.*

*24. Chang Y, Qin Y, Zou Y, Zeng H, Li C, et al. Plasma-lyte solution versus saline in kidney transplantation: a systematic review and meta-analysis of randomized controlled trials. PLoS One. 2025;20(4):e0320082. doi: 10.1371/journal.pone.0320082.*

*25. Aleysae NA, Kimawi A, Bamahmoud A, Alharbi N, Salem M, et al. Do the perioperative intravenous fluids affect kidney graft function and electrolytes in pediatric kidney transplantation? Res Square. 2024. doi: 10.21203/rs.3.rs-3983305/v1.*


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**Поздовжній аналіз електролітного дисбалансу після трансплантації та його вплив на виживаність трансплантата**

**Резюме.** Дисбаланс електролітів є поширеним ускладненням після трансплантації нирки. Однак довгостроковий вплив цих змін на функцію трансплантата досліджений недостатньо. Мета: аналіз частоти, перебігу та прогностичного значення електролітних порушень щодо виживаності трансплантата. У когортному дослідженні протягом трьох років спостерігали за реципієнтами ниркового трансплантата, регулярно оцінюючи рівні натрію, калію, магнію, кальцію та інші показники. Клінічні порогові значення потім використовували для класифікації учасників із дисбалансом електролітів, а виживаність оцінювали за допомогою кривих Каплана — Меєра та моделей пропорційних ризиків Кокса. Результати дослідження показали високу поширеність гіпонатріємії, гіперкаліємії та гіпомагніємії, які суттєво корелювали зі зниженням виживаності трансплантата; гіпокальціємія мала слабший зв'язок. У пацієнтів із рецидивуючими порушеннями електролітного балансу зниження функції трансплантата спостерігалося набагато раніше, ніж у тих, хто мав нормальні показники. Багатофакторний аналіз продемонстрував, що втрати трансплантата неможливо уникнути навіть з урахуванням демографічних та імунологічних факторів, що підтверджує значення електролітного дисбалансу як предиктора втрати. Отже, результати дослідження підкреслюють необхідність активного моніторингу рівня електролітів з метою своєчасної корекції для покращення довгострокових результатів після трансплантації. Доведено, що активний підхід до лікування електролітних порушень є важливим для досягнення оптимальних результатів трансплантації при консервативному веденні пацієнтів.

**Ключові слова:** порушення електролітного балансу; виживаність трансплантата; трансплантація нирки; гіпонатріємія; гіперкаліємія; поздовжнє дослідження; результати після трансплантації