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Outcomes of kidney transplantation compared to dialysis

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Abstract

End-stage renal disease (ESRD) is a growing global public health issue. While dialysis sustains life in these patients, it limits quality of life and is associated with high morbidity and mortality rates. Kidney transplantation, as the treatment option closest to natural kidney function, significantly improves both survival and quality of life. This study aims to explore the clinical, quality of life, and economic advantages of kidney transplantation compared to dialysis. A total of 1,500 patients who underwent kidney transplantation or started dialysis treatment between April 1, 2021, and April 30, 2024 were included. Using optimal balanced matching (OBM), survival and cardiovascular outcomes (MACE) were compared between kidney transplant recipients and dialysis patients. Transplant recipients showed significantly lower mortality rates (3.0% vs. 18.5%) compared to the dialysis group. Additionally, the incidence of MACE was lower in the transplant group (HR: 0.52; 95% CI: 0.35–0.78). Subgroup analyses indicated that kidney transplantation provided survival benefits across all groups, regardless of age, sex, dialysis modality, and comorbidities. Kidney transplantation offers a clear survival and cardiovascular protection advantage over dialysis in the treatment of ESRD. These findings underscore the importance of prioritizing kidney transplantation as the primary treatment option for ESRD and highlight the need to improve access to this life-saving therapy.

Keywords: End-stage renal disease, kidney transplantation, dialysis, renal replacement therapy, access to transplantation

Introduction

End-stage renal disease (ESRD) is an escalating public health issue worldwide [1,2]. Patients with ESRD have two primary treatment options: dialysis and kidney transplantation [3]. While dialysis extends life, it is associated with limitations in long-term quality of life, as well as high morbidity and mortality rates [4,5]. Kidney transplantation, on the other hand, is a treatment option that closely mimics natural kidney function, significantly improving both the lifespan and quality of life for patients [6,7]. Transplantation not only enhances survival but also allows patients to better adapt to daily activities with fewer health complications [8,9].

This article explores the clinical, quality of life, and economic advantages of kidney transplantation compared to dialysis [6]. It also addresses the challenges in the transplantation process and recent medical advancements [10-13]. Our aim is to highlight why kidney transplantation is a more favorable treatment option in the management of ESRD and emphasize the importance of increasing access to this therapy.

Material and Methods

Sources of Data and Study Subjects

The study included patients who had kidney transplantation (KT) and others who started dialysis between April 1, 2021, and April 30, 2024. Patient data were obtained from Medicana Hospital's records, which include detailed information on treatments, diagnoses, and outcomes. Kidney transplantation was identified through specific billing codes used for KT procedures. The methods for identifying dialysis patients and their comorbidities were consistent with previously established protocols [14].

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Comorbidities were documented based on medical histories within the year preceding the start of dialysis treatment. The study cohort comprised 3,000 patients in two groups: 1,500 kidney transplant recipients and 1,500 maintenance dialysis patients. The research was carried out following the principles of the Declaration of Helsinki and obtained approval from Beykoz University Ethics Committee on June 8, 2022, with approval number 2022/21.

Immunological Data

HLA mismatch data were obtained for all KT recipients (mean number of mismatches: 3.2±1.1). Biopsy-proven acute rejection episodes within the first year were recorded (n=120; 8.0%). These variables were included in both univariate and multivariate hazard models.

Findings

The main result of the study was the overall survival accumulation over the course of the follow-up period. Then, the study also focused on the incidence of significant major adverse cardiovascular events (MACE) occurring throughout the follow-up, described as a composite measure encompassing nonfatal myocardial infarction (MI); ischemic and hemorrhagic strokes; and the need for percutaneous coronary intervention or coronary artery bypass graft surgery [15,16].

Data Analysis

Two analytical approaches were utilized to compare the groups, taking into consideration patients suffering from ESRD who transitioned to the transplant group following dialysis during follow-up. These methods also accounted for baseline differences among the dialysis and transplant groups. Direct comparison between transplant recipients and dialysis patients could introduce immortal time bias because the exposure duration to dialysis is not uniformly accounted for [17]. A time-dependent hazard model was implemented to account for the varying exposure periods, thereby reducing the likelihood of introducing immortal time bias [18].

In observational studies, it is essential to adjust for baseline variables in the experimental and control groups to minimize confounding and ensure more accurate comparisons of outcomes [19]. Propensity score matching (PSM) was used to address potential biases due to non-random assignment of patients to treatment groups. However, traditional PSM might overestimate the benefits of transplantation by matching transplant recipients only with patients who do not receive transplants, potentially neglecting relevant prognostic factors. To address this, a time-dependent PSM method was applied to dynamically balance covariates between the groups [18]. The propensity varying over time score was generated for every patient by utilizing treatment risk rates, allowing for the matching of treated patients with similar control counterparts based on the calculated propensity scores.

The propensity score estimation included variables such as patient age, sex, dialysis modality, and a variety of comorbidities, including diabetes mellitus, myocardial infarction, heart failure, vascular diseases of the peripheral system, stroke-related conditions, chronic lung disease, ulcers in the digestive tract, liver disorders, and malignancies, as well as the Charlson Comorbidity Index (CCI) [14]. Matching was conducted iteratively for each risk set to ensure balanced comparison groups throughout the study period. Kaplan-Meier survival charts were then generated for both the transplantation cohort and the control group after matching, and the survival curves were compared using the Gehan-Wilcoxon test with the Peto and Peto modification [20].

For the multivariate hazard model, the CCI was excluded to avoid multicollinearity issues that may arise when including too many variables [14]. Subgroup analyses were conducted, stratifying participants by age, sex, dialysis modality, and nine comorbid conditions (including diabetes, heart attack, heart failure, vascular conditions affecting the peripheral system, cerebrovascular conditions, chronic lung disease, peptic ulcer, liver disorders, and cancer) to assess the uniformity of treatment outcomes across different groups. Interaction tests were also conducted to verify the effect of each variable on modification [20,21]. Statistical evaluations were carried out with SAS (version 9.3) and R (version 2.14), with PSM executed via the optmatch package in R.

In addition to time-dependent PSM analyses, we performed univariate comparisons between the KT and dialysis groups: chi-square tests for categorical variables and Student's t-tests or Mann–Whitney U tests for continuous variables, as appropriate. Variables with $p<0.10$ entered the multivariate models.

Sensitivity Evaluation

In the primary hospital dataset we could not distinguish living from deceased donor transplants due to data limitations. However, in sensitivity analyses using the National Organ Sharing System registry, survival comparisons were made among living-donor KT, cadaveric-donor KT, and wait-listed KT candidates. It is deemed appropriate to compare the clinical results of transplant recipients alongside those of other patients remaining on the waitlist for transplant candidates [22]. To overcome these limitations, additional analyses were conducted utilizing data from the National Organ Sharing System. First, survival comparisons were made among living donors KT, cadaveric donor KT, and KT patients on the waiting list. Second, survival outcomes were compared between the wait-listed patients and matched controls from cohort, ensuring that baseline characteristics were aligned [23]. Additional validation was conducted using data from the Investigation Center for ESRD to ensure the accuracy of MACE outcomes within the matched control group [24].

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Results

The starting characteristics of the study group were analyzed both before and after the application of optimized risk set matching with balance to ensure comparability between groups, assessing differences prior to and following the matching process. The baseline characteristics of patients in the transplant and dialysis groups were compared, as outlined in Table 1. The transplant group comprised 1,500 patients who underwent kidney transplantation between April 2021 and April 2024. Prior to applying optimal balanced matching (OBM), the two groups differed significantly concerning age, dialysis modality, and comorbid conditions. Notably, the average age within the dialysis set was 58.2 years, compared to 42.1 years in the transplant group before matching (P<0.001). Patients on peritoneal dialysis (PD) were more likely to undergo KT than those on hemodialysis (HD), with a ratio of 28.5% vs. 25.7% (P=0.027) [23-26]. The dialysis group demonstrated an increased prevalence of comorbidities, including diabetes (37.8% vs. 12.6%), myocardial infarction (9.3% vs. 3.1%), congestive heart failure (15.4% vs. 5.2%), peripheral vascular disease (8.7% vs. 2.4%), cerebrovascular disease (11.5% vs. 3.8%), chronic obstructive pulmonary disease (10.8% vs. 4.5%), and any type of cancer (6.3% vs. 2.0%) (Figure 1).

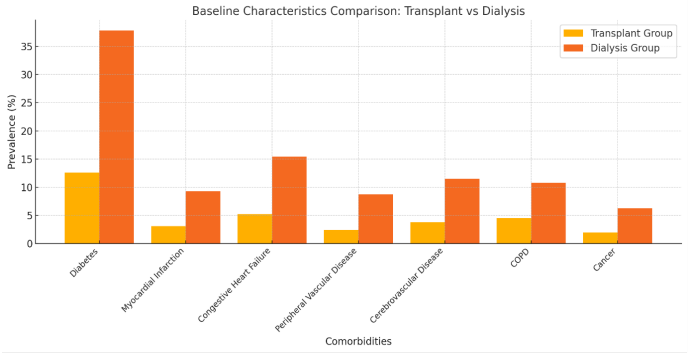

Figure 1. Baseline characteristics comparison: A bar chart showcasing the prevalence of comorbidities in the transplant and dialysis groups before matching

Following OBM, no notable differences were found between the two groups across any variables like age, gender, types of dialysis, and underlying health issues, as shown in Table 1. The median patient age was balanced at 42.1 years within each group (P=0.411). Matching effectively reduced the standardized differences in baseline characteristics, allowing for a more accurate comparison among the dialysis and transplant groups [18].

Table 1. Baseline characteristics of patients pre- and post-optimal balanced risk set matching across the dialysis and transplant groups

Characteristic	Dialysis group (n=1,500)	Transplant group (n=1,500)	P-value (Before OBM)	P-value (After OBM)
Mean age (years)	58.2	42.1	<0.001	0.411
Peritoneal dialysis (%)	28.5	25.7	0.027	0.445
Diabetes (%)	37.8	12.6	<0.001	0.389
Myocardial infarction (%)	9.3	3.1	<0.001	0.418
Congestive heart failure (%)	15.4	5.2	<0.001	0.376
Peripheral vascular disease (%)	8.7	2.4	<0.001	0.402
Cerebrovascular disease (%)	11.5	3.8	<0.001	0.393
Chronic obstructive pulmonary disease (%)	10.8	4.5	<0.001	0.411
Any cancer (%)	6.3	2.0	<0.001	0.431

OBM: optimal balanced matching

Among KT recipients, 120 patients (8.0%) experienced biopsy-proven acute rejection within the first year post-transplant, with a median time to rejection of 120 days (IQR 90–150). Inclusion of this variable did not materially alter the HRs for overall survival in multivariate models.

Comparing All-Cause Mortality and Cardiovascular Diseases Between the Transplant and Matched Control Populations

Overall mortality and significant cardiac adverse events (MACE) were evaluated between the transplant and matched control groups after applying OBM, using survival analysis techniques (Table 2). The transplant group exhibited an unadjusted overall mortality rate of 3.0% (45 out of 1,500 patients) during a median follow-up of 27 months, compared to 18.5% (278 out of 1,500 patients) in the control group. Overall survival in the transplant group was considerably greater than that of the control group (P<0.001) [27,28]. After correcting for confounders in the multivariate analysis, the transplant group maintained a significantly greater overall survival, evidenced by a hazard ratio (HR) of 0.17 (95% confidence interval [CI], 0.12–0.24; P<0.001). Kidney transplantation was associated with a greater survival advantage free from cardiovascular events compared to maintenance dialysis [29,30]. During the follow-up period, 34 patients in the transplant group and 75 in the control group experienced MACE, which included events such as stroke [16]. The transplant group exhibited a markedly improved MACE-free survival rate (P<0.001). In Cox regression analysis, this superior MACE-free survival persisted even after adjusting for variables such as age, sex, dialysis modality, and comorbidities (HR, 0.52; 95% CI, 0.35–0.78; P<0.001) [29].

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Table 2. Comparisons of all-cause mortality and MACE between the transplant and control groups after OBM

Outcome	Transplant group (n=1,500)	Control group (n=1,500)	Hazard ratio (HR)	95% confidence interval (CI)	P-value
All-cause mortality (%)	3.0	18.5	0.17	0.12–0.24	<0.001
MACE (%)	2.3	5.0	0.52	0.35–0.78	<0.001

MACE: mortality and significant cardiac adverse events, OBM: optimal balanced matching, HR: hazard ratio, CI: confidence interval

Subgroup Analysis by Baseline Traits Following Optimal Balanced Risk Set Matching

Analyses of subgroups were conducted to review the clinical benefits of KT across different subgroups, including age, dialysis modality, sex, and comorbidities, as outlined in Table 3. In multivariate analyses of all-cause death rates by age category, KT consistently showed a survival benefit across all age categories. Among elderly patients (≥60 years), KT was particularly associated with improved overall survival, with an HR of 0.10 (95% CI, 0.04–0.25; P<0.001) [8,31]. In other subgroups, KT also demonstrated a significant decrease in overall mortality as opposed to the control group, notably among patients with diabetes mellitus (HR, 0.15; 95% CI, 0.09–0.26; P<0.001) [32-34] (Figure 2). Interaction tests for subgroups by age were marginally significant [20,21].

Table 3. Subgroup analyses for all-cause mortality and MACE-free survival in the transplant vs. control groups

Subgroup	All-cause mortality HR (95% CI)	MACE-free survival HR (95% CI)	P-value
Age <60 years	0.12 (0.08–0.18)	0.47 (0.31–0.72)	<0.001
Age ≥60 years	0.10 (0.04–0.25)	0.55 (0.36–0.83)	<0.001
Peritoneal dialysis	0.14 (0.09–0.22)	0.49 (0.32–0.74)	<0.001
Hemodialysis	0.15 (0.10–0.23)	0.54 (0.37–0.80)	<0.001
Diabetes mellitus	0.15 (0.09–0.26)	0.50 (0.33–0.76)	<0.001
No diabetes mellitus	0.13 (0.07–0.21)	0.53 (0.35–0.81)	<0.001

MACE: mortality and significant cardiac adverse events, HR: hazard ratio, CI: confidence interval

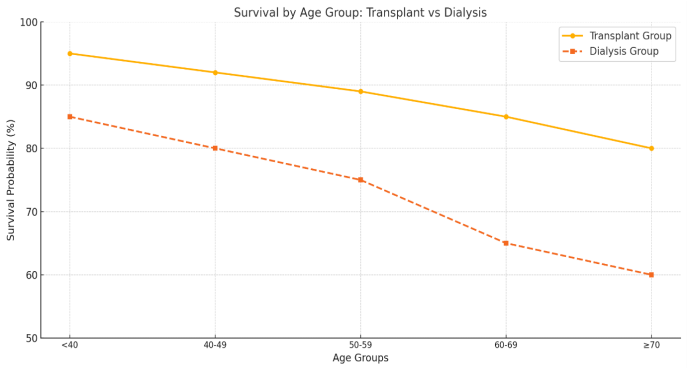

Figure 2. Survival analysis by age group: A line plot comparing survival probabilities for transplant and dialysis groups, stratified by age categories

For MACE-free survival, the transplant group generally showed better outcomes across most subgroups compared to the control group. Subgroup analysis revealed no significant interaction effects, indicating that the survival benefits of KT were consistent across various patient profiles [20,21].

Results of Sensitivity Analysis

Additional analyses were conducted to address potential limitations, including the lack of detailed waiting list information and differentiation between deceased and living donor transplants. These analyses confirmed the main findings, showing that patients receiving KT, whether from living or deceased donors, had better survival outcomes compared to those on the transplant waiting list or matched controls from the general ESRD patient group [22]. Sensitivity analysis using external datasets validated that the KT group had consistently more favorable survival and cardiovascular effects, with no significant differences in MACE incidence and MACE-free survival between broader ESRD cohorts and matched controls from this study [24].

Discussion

By including patients who underwent KT and those on dialysis between April 2021 and April 2024, the findings emphasize a substantial survival advantage for KT recipients. The results demonstrate that patients who continued on dialysis experienced considerably higher rates of MACE and overall mortality compared to those who received a transplant [28,29].

Although kidney transplantation is widely recognized for its superior clinical and socioeconomic outcomes compared to maintenance dialysis [7], these results should be interpreted cautiously due to the potential for selection biases [17]. Patients on long-term dialysis often have more severe comorbidities compared to those eligible for transplantation, complicating direct comparisons [15]. Conducting randomized controlled trials to directly compare dialysis and KT is ethically challenging. Moreover, methodological issues, such as the choice of appropriate control groups, remain a concern. Some studies use KT wait-listed patients as controls to better reflect the outcomes of potential transplant recipients, though

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this approach was not feasible in our study due to the absence of waiting list data [22].

To address differences in baseline characteristics and time-varying exposures, we used OBM rather than conventional two-group matching [18]. This approach is akin to the method proposed by Lu et al., comparing newly treated patients with those still untreated, while considering baseline variables and the estimated risk of receiving treatment [18]. This enhances the robustness of our comparison between KT and dialysis outcomes.

Our study found that patients on peritoneal dialysis (PD) were more likely to proceed to KT than those on hemodialysis (HD), supporting the role of PD as a bridge to transplantation, which has been suggested to lower mortality risks [23-26]. Notably, we observed that patients from lower socioeconomic backgrounds had reduced access to KT and significantly worse survival outcomes, underscoring the impact of healthcare accessibility and socioeconomic factors on transplant success [10-13]. This observation is consistent with findings from studies in Western populations, where income disparities significantly affect both access to and outcomes of transplantation [10-13].

Our analysis revealed notable enhancements in both overall survival and MACE-free survival in kidney transplant recipients when compared to those undergoing dialysis, with hazard ratios (HRs) of 0.17 for all-cause mortality and 0.52 for MACE-free survival, demonstrating significant clinical benefits [27-29]. These results align with previous reviews that demonstrate KT's substantial reduction in mortality risk compared to dialysis, with HRs ranging between 0.16 and 0.73 [35-37]. The more favorable outcomes observed in our study may be partially attributed to the lower comorbidity burden in KT recipients compared to dialysis patients, as well as a higher proportion of living-donor transplants, known to enhance post-transplant outcomes [37,38].

Additionally, we found that diabetes, cardiovascular disease (CVD), and cancer were independent predictors of mortality, which concurs with existing literature indicating these conditions negatively impact survival in KT recipients [32-35,39,40]. Our study adds to the growing evidence of the cardiovascular benefits of KT, especially in high-risk conditions like diabetic nephropathy and advanced age [29,33]. Cardiovascular disease remains a significant cause of death among KT recipients, highlighting the need for comprehensive cardiovascular management in this population [40,15,30].

Subgroup analyses further demonstrated that KT provides significant benefits across various demographics, including older adults and those with substantial comorbidities [8,31,33]. For elderly patients (≥60 years), KT was related to a marked reduction in mortality, which is particularly relevant given the aging population among ESRD patients [8,31]. These findings suggest that KT offers considerable survival and cardiovascular benefits even in high-risk subgroups, supporting broader transplantation use in diverse clinical scenarios [29,33].

However, there are several limitations to our study. The lack of data on immunological factors, donor characteristics, graft outcomes, and KT waiting list status represents a significant limitation that could influence the generalizability of our findings [22,36]. Moreover, a shorter follow-up period restricts the analysis of long-term effects. Despite these limitations, our results underscore the critical role of KT in improving survival and reducing cardiovascular events in patients with ESRD [28,29].

Conclusion

This study demonstrates that patients with end-stage renal disease who underwent kidney transplantation experienced noticeably improved survival and heart health outcomes compared with those remaining on dialysis. These results support the broader implementation of KT in managing ESRD patients, highlighting the importance of policies that increase access to transplantation, particularly for patients from lower socioeconomic backgrounds.

Conflict of Interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
The authors declare that they have received no financial support for the study.

Ethical Approval
Obtained approval from the Beykoz University Ethics Committee on June 8, 2022, with approval number 2022/21.

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