

Original Article

Association of Total Ischemic Time With Hospital Length of Stay and Early Graft Function After Living-Donor Kidney Transplantation: A Retrospective Cohort Study



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ABSTRACT

Background: Total Ischemic Time (TIT) is a critical determinant of graft survival in deceased-donor transplantation. However, its specific impact on hospital Length of Stay (LOS) and immediate postoperative renal function remains unclear in the context of living-donor transplantation, where ischemic intervals are typically shorter, and graft quality is higher.

Methods: This retrospective cohort study, reported according to STROBE guidelines, employed a total sampling technique to analyze 40 living-donor kidney transplant recipients at Dr. Sardjito Hospital. Adult patients with complete operative and laboratory records were included, while pediatric cases and incomplete datasets were excluded. We evaluated the relationship between the independent variable (TIT) and dependent variables (LOS and serum creatinine at Day 1 and Day 7) using Pearson correlation analysis to determine effect sizes and statistical significance.

Results: The mean TIT was 90.7 ± 24.0 minutes. Analysis revealed a statistically significant, moderate positive correlation between TIT and LOS ($r=0.58$, $p<0.001$). Conversely, the associations between TIT and serum creatinine at Day 1 ($r=0.22$, $p=0.17$) and Day 7 ($r=0.27$, $p=0.11$) indicated weak positive trends that did not reach statistical significance.

Conclusion: While prolonged ischemic time did not immediately compromise graft function in this living-donor cohort, it served as a significant predictor of extended hospitalization. These findings underscore that minimizing ischemic time is crucial not only for biological safety but also for optimizing Kidney Transplantation; Ischemia; Length of Stay; Creatinine; Graft Function.

Keywords: Kidney Transplantation; Total Ischemic Time; Length of Stay.

Implications for Practice:

- Optimization of Surgical Workflows: Surgical teams should prioritize minimizing total ischemic time through efficient coordination, as this directly reduces hospital length of stay and accelerates patient discharge.
- Risk-Stratified Discharge Planning: Clinicians could utilize ischemic time duration as a prognostic marker to tailor discharge planning, anticipating that patients with prolonged ischemia may require extended observation.
- Resource Allocation and Policy: Healthcare

Implications for Practice:

administrators should track ischemic time as a key performance indicator to optimize resource utilization and reduce the economic burden of transplantation surgery.

Introduction

Kidney transplantation remains the gold standard for End-Stage Renal Disease (ESRD), offering superior survival and quality of life compared to dialysis.



However, in Low- and Middle-Income Countries (LMICs), the sustainability of transplant programs is threatened by severe resource constraints and rising disease burden. In these settings, optimizing hospital resource utilization is not merely administrative but clinically vital. Consequently, reducing Length of Stay (LOS) has emerged as a primary metric for surgical efficiency and cost containment.

Central to surgical outcomes is Total Ischemic Time (TIT). In deceased-donor transplantation, the detrimental impact of prolonged TIT is well-documented, with extensive delays consistently linked to Ischemia-Reperfusion Injury (IRI), Delayed Graft Function (DGF), and reduced graft survival. Conversely, in living-donor transplantation, the clinical significance of TIT remains under-scrutinized. Because ischemic intervals are inherently shorter in living-donor procedures, the physiological insult is often assumed to be negligible. However, emerging evidence suggests that even brief ischemic windows may precipitate sub-clinical injury and systemic oxidative stress ([Bakhtiyar et al., 2023](#); [Bogaert et al., 2022](#)). Crucially, it remains unknown whether this sub-clinical injury triggers a systemic inflammatory response sufficient to impair immediate postoperative recovery—affecting pain management and hemodynamic stability—thereby prolonging LOS independent of the graft's filtration capacity.

This study addresses this critical gap by simultaneously evaluating the impact of TIT on systemic recovery (measured by LOS) and biochemical function (early postoperative creatinine) in a living-donor cohort. Unlike previous research focusing solely on graft survival, this study uniquely positions LOS as a composite marker of both surgical recovery and health system efficiency. By explicitly linking surgical timing to operational outcomes, this research offers novel, internationally

relevant evidence to support stricter time-management protocols, ultimately aiding LMIC centers in balancing clinical excellence with resource scarcity.

This study aimed to investigate the association of TIT with two key short-term outcomes: hospital Length of Stay, which serves as a surrogate for perioperative recovery and resource use, and early graft function (at Day 1 and Day 7), serving as an immediate marker of graft function.

Methods

Study Design

This observational study employed a retrospective cohort design with a correlational approach, reported in adherence to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines. The retrospective design was selected as the most appropriate method to investigate the existing relationship between intraoperative surgical timing and postoperative outcomes without introducing experimental intervention or disrupting standard clinical care. A correlational framework was specifically utilized to quantify the strength and direction of the association between TIT and key recovery metrics, enabling the identification of potential "dose-response" trends in a real-world clinical setting ([Du et al., 2021](#)).

Participants

The study was conducted at Dr. Sardjito Hospital in Yogyakarta, Indonesia, serving as a tertiary referral center for the region. To minimize selection bias and maximize the statistical power of the available cohort, a total sampling technique was utilized, incorporating the records of all patients who underwent living-donor kidney transplantation during the study period. The initial screening identified potential candidates from the transplant registry;

however, strict exclusion criteria were applied to remove pediatric patients (<18 years) and records with incomplete operative logs or missing postoperative creatinine data. Following this screening process, a total of 45 records were reviewed, and 5 were excluded due to incomplete data, resulting in a final analytical sample of 40 kidney transplant recipients

Instruments

Data were gathered using a structured extraction form specifically developed for this study to retrieve objective biological and temporal variables from medical records. The instrument captured demographic characteristics (age, sex), surgical metrics (total ischemic time in minutes), and clinical outcomes (pre- and postoperative serum creatinine, length of stay). To ensure the reliability of the data extraction process, the instrument underwent pilot testing on a random sample of five records before full data collection. This allowed for the refinement of variable definitions and the standardization of entry formats. Furthermore, consistency checks were implemented where a second investigator randomly cross-verified 10% of the extracted data against the original medical records to confirm accuracy and inter-rater reliability.

Data Collection

Data collection followed a rigorous, stepwise workflow to ensure integrity and accuracy. First, the research team, consisting of medical staff and research assistants, underwent a comprehensive training session focused on data abstraction protocols, variable definitions, and ethical handling of anonymized data. Following training, data were retrospectively retrieved from both physical medical records and the electronic transplant

registry at Dr. Sardjito Hospital. The extraction process involved a primary review of surgical reports to log ischemic times, followed by a secondary review of laboratory logs to record creatinine levels. Quality control procedures were systematized throughout the collection phase; all data points were verified against source documents, and any discrepancies were resolved through consensus by the lead researchers before being entered into the final dataset.

Data Analysis

Statistical analysis was performed to describe the cohort and test the study hypotheses. Descriptive statistics, including means and standard deviations (SD), were used for continuous variables, while frequencies and percentages were used for categorical variables. Before inferential analysis, the normality of the data distribution was assessed using the Shapiro-Wilk test, confirming that key variables (TIT, LOS, Creatinine) met the assumptions for parametric testing. Consequently, Pearson correlation analysis was employed to determine the relationship between TIT and outcome variables¹⁶. The resulting correlation coefficients (r) were interpreted as effect sizes to evaluate the magnitude of these associations, independent of sample size. Statistical significance was defined as a p -value < 0.05 ([Dube et al., 2019](#); [Joosten et al., 2021](#); [Kim et al., 2021](#)).

Ethical Considerations

This study was conducted in full accordance with the ethical principles outlined in the Declaration of Helsinki. Ethical approval was formally obtained from the Research Ethics Committee of Sardjito Hospital (Approval Number: 230/UN1/SPs. 1.1/AKM/PT/2025). Due to the retrospective nature of the study, which utilized pre-existing medical records

without direct patient interaction, the requirement for written informed consent was waived by the Ethics Committee. To ensure confidentiality and data protection, all patient information was fully anonymized at the source, and names or medical record numbers were replaced with unique research identification codes before analysis.

Results

Before analysis, data distribution was assessed using the Shapiro-Wilk test, which confirmed that key continuous variables (Age, Total Ischemic Time, Length of Stay, and Serum Creatinine) followed a normal distribution ($p > 0.05$). Consequently, parametric tests (Pearson correlation) and mean \pm standard deviation (SD) descriptors were utilized.

The study cohort consisted of 40 living-donor kidney transplant recipients. As summarized in Table 1, the population was predominantly male ($n=31$, 77.5%) with a mean age of 38.4 ± 12.3 years. The mean TIT was 90.7 ± 24.0 minutes, ranging from 59 to 162 minutes, which is consistent with standard operational timelines for living-donor procedures (Table 1).

Table 1. General Characteristics

Characteristic	Value
Age, years	
Mean \pm SD	38.4 \pm 12.3
Range (Min - Max)	19 - 65
Sex, n (%)	
Male	31 (77.5%)
Female	9 (22.5%)
Clinical Parameters	
Total Ischemic Time, minutes (Mean \pm SD)	90.7 \pm 24.0
Length of Stay, days (Mean \pm SD)	11.1 \pm 3.2
Pre-operative Creatinine, mg/dL (Mean \pm SD)	3.73 \pm 1.63
Postoperative Day 1 Creatinine, mg/dL (Mean \pm SD)	4.16 \pm 2.32

Characteristic	Value
Postoperative Day 7 Creatinine, mg/dL (Mean \pm SD)	2.52 \pm 2.14

To address the primary study objective regarding the impact of surgical duration on systemic recovery, we analyzed the relationship between TIT and hospital Length of Stay (LOS). A statistically significant positive correlation was found between Total Ischemic Time and LOS ($r = 0.58$, $p = 0.0001$) (Table 2). As shown in Figure 1, patients with longer ischemic times tended to require longer hospitalization.

Table 2. Association of Total Ischemic Time with Postoperative Outcomes

Outcome Variable	Correlation Coefficient (r)	p-value	Interpretation
Length of Stay	0.58	<0.001*	Moderate positive correlation (Significant)
Serum Creatinine (Day 1)	0.22	0.174	Weak positive correlation (Not significant)
Serum Creatinine (Day 7)	0.27	0.111	Weak positive correlation (Not significant)

*Note: Data analyzed using the Pearson correlation test. Statistically significant ($p < 0.05$).

However, as shown in Table 2, these associations did not reach statistical significance in this cohort, suggesting that while prolonged ischemia may exert sub-clinical stress, it did not precipitate frank functional decline in these high-quality living-donor grafts.

Association of TIT with Early Graft Function

We analyzed the relationship between TIT and serum creatinine at Day 1 and Day 7 post-surgery. Day 1 (H+1): There was a weak positive correlation ($r = 0.22$)

between TIT and Day 1 creatinine, which was not statistically significant ($p = 0.17$). Day 7 (H+7): Similarly, a weak positive correlation ($r = 0.27$) was observed for Day 7 creatinine, also not statistically significant ($p = 0.11$). While the trend indicates that

longer ischemia might be associated with slower graft recovery, the association was not robust in this sample size.

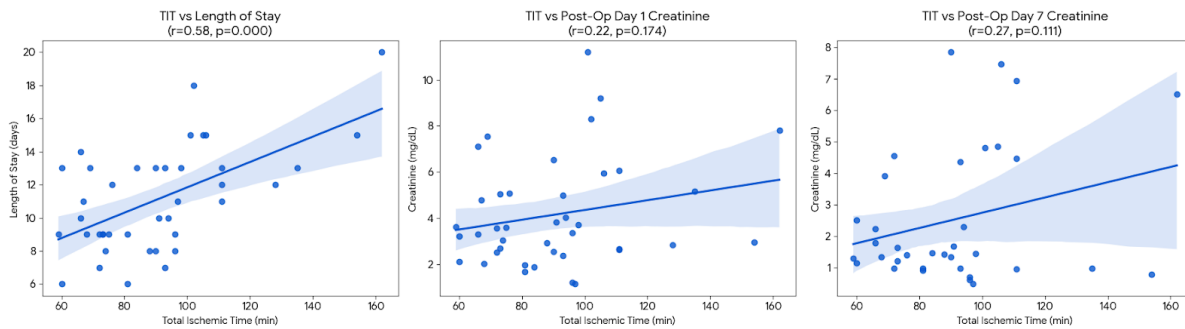


Figure 1. Scatter Plots of Total Ischemic Time vs. Clinical Outcomes (Left) Significant correlation between TIT and Length of Stay. (Center & Right) Positive trends between TIT and early graft function (Day 1 & 7) that did not reach statistical significance.

Discussion

Our findings primarily underscore the significant operational impact of surgical efficiency in the setting of living-donor kidney transplantation. The robust statistical association between Total Ischemic Time (TIT) and Length of Stay suggests that operative duration serves as a critical determinant of postoperative recovery trajectories, even when ischemic intervals are relatively short (mean ~90 minutes). While Length of Stay is a multifactorial metric influenced by administrative and social factors, its strong correlation with ischemic time in this cohort implies that prolonged operative duration may trigger a more pronounced systemic stress response. This likely necessitates a prolonged period of convalescence for pain management, bowel function recovery, and physical mobilization, thereby delaying discharge eligibility independent of graft function alone (Guinault et al., 2019; Moein et al., 2023; Kurniawaty et al., 2025). This may be attributed to sub-clinical ischemia-reperfusion injury or increased surgical

complexity, which Lee et al. (2024) recently identified as a key factor in predicting delayed discharge. Operative duration serves as a critical predictor of recovery trajectories, even when ischemic intervals are relatively short, averaging approximately 90 minutes. Thus, LOS should be viewed as a health-system outcome reflecting surgical complexity and perioperative stress, distinct from the biological success of the graft itself.

Regarding early graft function, the analysis revealed positive correlation coefficients between TIT and serum creatinine at Day 1 ($r=0.22$) and Day 7 ($r=0.27$). Although these findings align with the biological plausibility that increased ischemic insult hampers immediate renal clearance, the lack of statistical significance ($p>0.05$) likely reflects the specific characteristics of this living-donor cohort. Unlike deceased donor grafts, which often endure prolonged cold ischemia leading to significant cellular injury, living donor grafts in this study benefited from minimal ischemic exposure and optimized donor

quality ([Mendez et al., 2021](#); [Mikkelsen et al., 2022](#); [Privratsky et al., 2023](#)). Consequently, the mean creatinine levels remained favorable (trending down to 2.5 mg/dL by Day 7), suggesting that the renal reserve in these high-quality grafts is sufficient to buffer the varying degrees of ischemic stress encountered during surgery, preventing frank Delayed Graft Function (DGF) in most cases. Consistent with the work of [Novianti et al. \(2020\)](#), who found correlations between ischemic time and creatinine in a similar setting. However, our correlation did not reach statistical significance—likely due to the small sample size and the protective nature of living-donor grafts—the biological plausibility remains strong ([Serrano et al., 2019](#); [Sicova et al., 2024](#)). [Takamori et al. \(2025\)](#) recently reinforced that minimizing ischemic time is critical even in living-donor cases to optimize graft outcomes.

However, the biological mechanisms underlying the observed trends warrant careful consideration. The concept of IRI remains central to transplant physiology; even sub-clinical periods of warm ischemia during vascular anastomosis can induce oxidative stress and tubular epithelial cell injury. While this injury was not severe enough to cause statistical significance in this small sample size ($n=40$), the upward trend in creatinine with longer ischemia suggests a "dose-dependent" vulnerability. A threshold effect probably exists—where ischemic times exceeding a specific duration would precipitate a sharper decline in early function—a phenomenon that larger, multi-center studies, including marginal donors or complex vascular anatomy cases would be better positioned to detect.

Implications for Low- and Middle-Income Countries (LMIC) These findings hold particular relevance for transplant systems in Low- and Middle-Income Countries (LMIC), where resource

constraints often necessitate strict efficiency. In settings like Indonesia, prolonged hospitalization imposes a significant economic burden on both the healthcare system and patients, many of whom may have limited financial coverage for extended stays. By identifying TIT as a modifiable driver of LOS, this study suggests that investments in surgical efficiency—such as streamlined anesthesia protocols and coordinated retrieval-implantation workflows—could yield disproportionate cost-saving benefits in LMICs. Optimizing ischemic time is therefore not just a clinical goal but a strategic necessity to maximize the throughput and sustainability of developing transplant programs.

It is also important to consider potential confounders. Recent studies by Kurniawaty and Arovah (2025) and Sicova et al. (2024) highlight that intraoperative hemodynamic stability plays a significant role in early graft function, potentially interacting with ischemic time to exacerbate renal injury. Future research should aim to control for these hemodynamic variables to isolate the specific impact of ischemic duration, as intraoperative hypotension has been independently linked to postoperative AKI in broader surgical populations ([Joosten et al., 2021](#); [Xiao et al., 2024](#)).

Finally, it is essential to acknowledge that Total Ischemic Time often serves as a proxy for surgical complexity, which may independently influence outcomes. Cases with prolonged ischemic times often involve challenging vascular anatomy, requiring extensive reconstruction or difficult dissection, which inherently carries a higher risk of perioperative complications such as lymphatic leaks or hematomas. These surgical intricacies likely contribute to the observed increase in Length of Stay, separate from the direct ischemic hit to the kidney. Therefore, while minimizing ischemic time is crucial for graft health, it is equally representative of the broader goal

of surgical precision; reducing technical difficulty and operative duration facilitates not only better renal numbers but also a smoother, more cost-effective holistic recovery for the patient. Future research should aim to detect sub-clinical injury using more sensitive biomarkers like NGAL or KIM-1 and must control for intraoperative hemodynamic variables to isolate the specific impact of ischemic duration on renal recovery.

Implications and limitations

Scientifically, this study corroborates the fundamental principles of IRI within the specific context of living-donor kidney transplantation. However, the interpretation of these findings must be tempered by the study's single-center design, which significantly limits external validity. As surgical volumes, team expertise, and perioperative protocols vary widely across institutions, the associations observed here may not be fully generalizable to broader transplant populations or centers with different operational standards.

Furthermore, the reliance on retrospective registry-based data imposes specific constraints on the analysis. While total sampling was utilized to minimize bias, the study is inherently limited by the quality and completeness of existing medical records. This reliance restricts the ability to control for unmeasured confounders—such as specific intraoperative hemodynamic shifts—and prevents the establishment of definitive causal relationships. Consequently, these results should be viewed as site-specific evidence that warrants validation through larger, multi-center investigations to confirm their applicability in diverse clinical settings.

Relevance to Practice

These findings have direct implications for perioperative management and

institutional policy in kidney transplantation. Surgical teams must prioritize intraoperative efficiency and coordinated retrieval-implantation protocols to minimize TIT, as this modifiable factor significantly influences hospital length of stay and resource utilization. Intraoperative and PACU nurses should recognize prolonged TIT as an early prognostic indicator, necessitating intensified monitoring for signs of delayed graft recovery or potential complications. For nursing practitioners and discharge planners, the duration of ischemic time should serve as an early prognostic indicator; patients with prolonged TIT may require intensified monitoring for delayed graft recovery and anticipated extended hospitalization. Consequently, healthcare institutions should adopt TIT as a KPI to drive quality improvement initiatives, ensuring that surgical workflows are optimized to reduce costs and enhance early patient recovery. Future research could focus on NGAL and KIM-1, a more granular research path than relying on standard creatinine levels.

Conclusion

In this cohort of kidney transplant recipients, TIT was a significant predictor of hospital Length of Stay, highlighting the importance of surgical efficiency for healthcare resource utilization. While a trend toward higher early graft function with longer ischemia was observed, it was not statistically significant. Efforts to minimize ischemic time should continue to be a priority to optimize patient recovery and potential graft outcomes. Future research should aim to detect sub-clinical injury using more sensitive biomarkers like NGAL or KIM-1.

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CrediT Authorship Contributions Statement

Ardika Satria Kusuma: Conceptualization, Methodology, Supervision, Writing - Original Draft

Indrawarman: Software, Validation, Formal Analysis, Writing - Review & Editing

Tanaya Ghinorawa: Investigation, Resources, Data Curation, Project Administration

Conflicts of Interest

There is no conflict of interest.

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