Clinical Research

Impact of intraoperative blood pressure hypotension on kidney transplant recipients: a retrospective analysis

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ABSTRACT

BACKGROUND Kidney transplantation improves survival and quality of life in end-stage renal disease. However, intraoperative hypotension remains common and may reduce graft perfusion. The optimal intraoperative blood pressure (BP) target remains unclear. This study aimed to evaluate the association between intraoperative BP trends and kidney transplant outcomes.

METHODS A retrospective cohort study was conducted among adult living donor kidney transplant recipients (≥18 years) at Cipto Mangunkusumo Hospital, Jakarta, Indonesia, from July 2023–April 2025. Intraoperative BP was recorded every 15 min to calculate average, minimum, and hourly systolic blood pressure (SBP), diastolic blood pressure, and mean arterial pressure (MAP). The primary outcomes were 3-month mortality, delayed graft function (DGF), and acute allograft rejection. Secondary outcomes included early graft function parameters, including serum creatinine levels, estimated glomerular filtration rate (eGFR), and time to first diuresis. Associations between BP and outcomes were analyzed using multivariate logistic regression in SPSS software version 27.0, with $p<0.05$ considered significant.

RESULTS Of 79 transplant recipients, the 3-month mortality was 6.3%, DGF was 7.6%, and acute rejection was 3.8%. Lower intraoperative MAP was associated with increased odds of DGF, with MAP <80 mmHg showing the strongest association (odds ratio [OR]: 88.239; 95% confidence interval [CI]: 2.720–2,092.86). Each 10-mmHg increase in overall SBP was associated with a reduction in the odds of DGF (OR: 0.360; 95% CI: 0.155–0.838). No BP measures were linked to serum creatinine levels ($p = 0.083–0.271$) or eGFR ($p = 0.151–0.791$).

CONCLUSIONS Lower intraoperative MAP and SBP were associated with higher odds of DGF, highlighting the importance of maintaining adequate BP to optimize kidney transplant outcomes.

KEYWORDS blood pressure, delayed graft function, graft rejection, kidney transplantation, mortality

Kidney transplantation is the preferred treatment option for patients with end-stage renal disease, offering longer survival and a better quality of life than long-term dialysis.[1,2] Transplant outcomes are influenced by multiple factors, including pre-transplant recipient condition, donor-related characteristics, immunological compatibility, and intraoperative hemodynamic disturbances.[3–5] Among these, intraoperative hemodynamic disturbances represent a potentially modifiable risk factor that can be optimized to improve postoperative outcomes.[6,7] In particular, intraoperative hypotension is a common complication of major surgery and has been consistently associated with adverse outcomes, including postoperative acute kidney injury (AKI), myocardial injury, and increased overall morbidity.[8,9] In kidney transplant recipients,

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intraoperative hypotension may be particularly detrimental because compromised systemic perfusion can directly impair blood flow to the renal allograft, where adequate perfusion is essential for early graft function.[10]

Evidence from non-transplant surgical populations suggests that mean arterial pressure (MAP) thresholds of 55–65 mmHg are associated with an increased risk of postoperative AKI, whereas prolonged exposure to MAP values below 80 mmHg has been linked to increased mortality.[11,12] However, kidney transplant recipients comprise a unique physiological population. Denervation of the transplanted kidney abolishes intrinsic autoregulatory mechanisms, rendering renal perfusion highly dependent on systemic arterial pressure. In addition, perioperative renal tissue edema may further impair microvascular perfusion by compressing the intrarenal capillaries, thereby increasing susceptibility to ischemic injury. These pathophysiological considerations underscore the importance of precise intraoperative blood pressure (BP) control in this population.

However, evidence defining optimal intraoperative BP targets in kidney transplant recipients remains limited. Existing studies have largely extrapolated thresholds from non-transplant populations, whereas individual BP requirements may vary according to baseline cardiovascular status and comorbidities. Furthermore, most studies have focused on single BP cutoffs rather than evaluating dynamic intraoperative BP trends over time, which may better reflect the cumulative ischemic burden.

Therefore, this study aimed to investigate the association between intraoperative BP trends and early post-transplant outcomes in kidney transplant recipients. The primary outcomes were 3-month mortality, delayed graft function (DGF), and acute allograft rejection. The secondary outcomes included early graft performance parameters. By analyzing BP measurements at multiple intraoperative time points, this study sought to characterize clinically relevant BP patterns associated with adverse transplant outcomes.

METHODS

Study design and data sources

This retrospective observational study followed a cohort of renal transplant recipients at Cipto Mangunkusumo Hospital, a tertiary hospital in Jakarta, Indonesia. Eligible participants were adult transplant recipients aged ≥18 years who received a kidney from living donors between 2023 and 2024. Electronic medical records were retrospectively analyzed to obtain patient characteristics and outcomes. Patients with incomplete anesthetic records and outcome data were excluded from the study. The research protocol was approved by the Ethics Committee of the Faculty of Medicine, Universitas Indonesia – Cipto Mangunkusumo Hospital (No: KET-476/UN2.F1/ETIK/PPM.00.02/2025). No formal sample size calculation was performed because this study included all eligible renal transplant recipients who met the inclusion criteria during the specified study period (total sampling).

Assessment of intraoperative BP

Intraoperative BP data were extracted from anesthetic records. To assess organ perfusion, MAP was calculated by adding diastolic blood pressure (DBP) to one-third of the difference between systolic blood pressure (SBP) and DBP. Based on the data distribution and prior literature, patients were stratified into groups using threshold values of <80 mmHg, <85 mmHg, <90 mmHg, and <95 mmHg. Additionally, to assess time-dependent variations in BP, measurements at 15-min intervals during surgery were recorded and used to calculate the first, sixth, and overall intraoperative average BP. Furthermore, the lowest systolic and diastolic BP values were recorded during surgery.

Variables and outcome

Baseline variables were extracted from the medical records, including age, sex, body mass index (BMI), presence of hypertension, baseline kidney function, biological relationship with the donor, and sex mismatch with the donor. Intraoperative variables such as warm ischemic time (WIT) and cold ischemic time (CIT) were also analyzed.

Transplantation records were assessed to determine primary outcomes, including mortality at 3 months, DGF, and acute allograft rejection. DGF was defined as the need for dialysis immediately after transplantation. Acute rejection was defined as a biopsy-proven or clinical diagnosis of acute rejection, characterized by a >10% rise in serum creatinine level responsive to adjunctive immunosuppressive therapy, diagnosed within 28

days of transplantation. The secondary outcome was graft function, measured using serum creatinine values at 2 days, 1 week, 1 month, and 3 months post-transplant, as well as time to first diuresis. Serum creatinine values were categorized into groups using the cutoff values ≥1.5 mg/dl and <1.5 mg/dl. In addition, estimated glomerular filtration rate (eGFR) was calculated according to the 2021 Chronic Kidney Disease Epidemiology Collaboration equation.

Statistical analysis

Continuous variables were expressed as mean (standard deviation) for normally distributed data and median (interquartile range [IQR]) for non-normally distributed data, while categorical variables were expressed as frequencies and percentages. Differences between continuous variables were analyzed using the Kruskal–Wallis test, and categorical variables were analyzed using the chi-square or Fisher's exact tests if the assumptions were not met.

Binary logistic regression was performed to obtain the odds ratio (OR) for the relationships between MAP, SBP, DBP, and primary outcomes, including mortality, DGF, and acute rejection. Potential confounding variables were included in the multivariate analyses: age, sex, BMI, history of hypertension, biological relationship with the donor, and sex mismatch. The intraoperative variables WIT and CIT were also included in the analyses. The performance of the logistic regression model was assessed using the Hosmer–Lemeshow chi-square statistic, and discrimination was evaluated using the area under the receiver operating characteristic curve.

To determine the relationship between intraoperative BP and kidney function, multivariate linear regressions were performed with serum creatinine levels at different time points and time to diuresis as the dependent variables and MAP as the main independent variable. Statistical significance was set at $p<0.05$. Statistical analyses were performed using SPSS software version 27.0 (IBM Corp., USA).

RESULTS

A total of 79 renal transplant recipients were included in this study. The recruitment of the study participants is shown in Figure 1. The median (IQR) age of the patients was 32 (27–44) years, and the majority were male (59%). The incidence of mortality at 3 months was 6.3%, the incidence of DGF was 7.6%, and that of acute rejection was 3.8%. The general characteristics of the patients are outlined in Table 1.

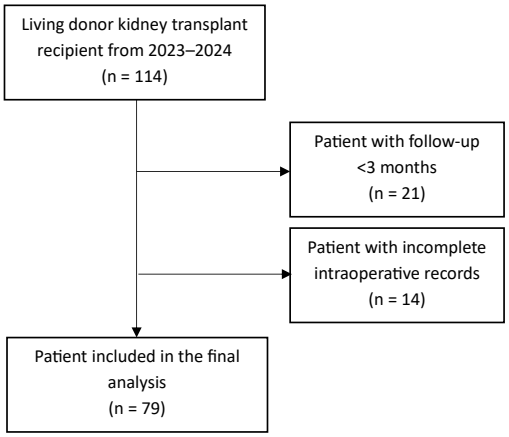


Figure 1. Flowchart of study participant recruitment

Table 1. Patient characteristics

Variables	N = 79
Recipient factors	
Age, median (IQR)	32 (27–44)
Male gender, n (%)	47 (59)
BMI (kg/m^2)	21.58 (20.16–24.86)
Hypertension, n (%)	49 (62)
Baseline eGFR, mean (SD)	10.62 (12.28)
Baseline SBP (mmHg), median (IQR)	141 (131–160)
Baseline DBP (mmHg), median (IQR)	94 (82–102)
Donor factors	
Biological relationship with donor, n (%)	
Related	44 (56)
Unrelated	35 (44)
Gender mismatch, n (%)	44 (56)
Intraoperative factors	
Average intraoperative SBP (mmHg), mean (SD)	140 (17.97)
Average intraoperative DBP (mmHg), mean (SD)	84.92 (13.92)
Average intraoperative MAP (mmHg), mean (SD)	97.28 (12.53)
WIT 1 (min), median (IQR)	3.27 (2.77–4.17)
WIT 2 (min), median (IQR)	38.2 (22.75–41.83)
CIT (min), median (IQR)	41.85 (34.35–52.8)

BMI=body mass index; CIT=cold ischemic time; DBP=diastolic blood pressure; eGFR=estimated glomerular filtration rate; IQR=interquartile range; MAP=mean arterial pressure; SBP=systolic blood pressure; SD=standard deviation; WIT=warm ischemic time

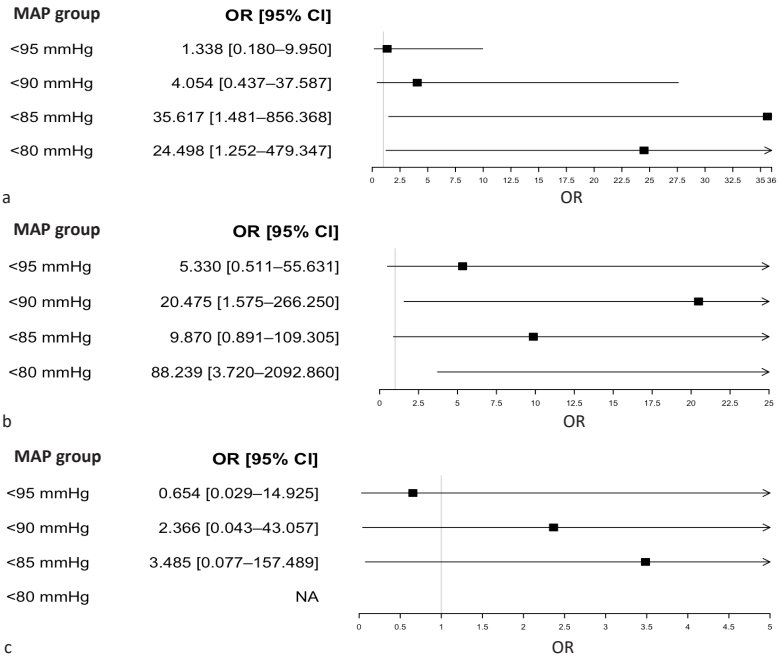


Figure 2. Adjusted OR for mortality (a), DGF (b), and acute rejection (c) outcomes by MAP metrics. Models were adjusted for age, sex, BMI, history of hypertension, biological relationship with the donor, sex mismatch, WIT, and CIT. BMI=body mass index; CI=confidence interval; CIT=cold ischemic time; DGF=delayed graft function; MAP=mean arterial pressure; NA=not available; OR=odds ratio; WIT=warm ischemic time

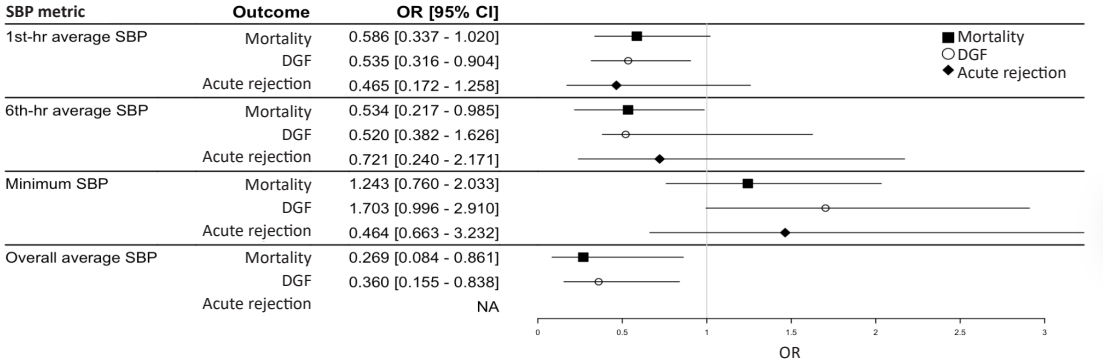


Figure 3. Effect of intraoperative SBP on post-transplant outcomes. Adjusted OR for mortality, DGF, and acute rejection outcomes by SBP metrics, per 10-mmHg increment. Models are adjusted for age, sex, BMI, history of hypertension, biological relationship with donor, gender mismatch, WIT, and CIT. BMI=body mass index; CI=confidence interval; CIT=cold ischemic time; DGF=delayed graft function; NA=not available; OR=odds ratio; SBP=systolic blood pressure; WIT=warm ischemic time

Intraoperative MAP and transplant outcomes

Five (6%), 14 (18%), 24 (30%), and 38 (48%) patients had an average MAP of <80, 85, 90, and 95 mmHg, respectively. After adjusting for covariates, a trend towards an increased risk of mortality, DGF, and acute rejection was observed with a lower MAP threshold, although only MAP <80 mmHg was consistently significant for mortality (OR: 24.498 ;95% CI: 1.252–479.347) and DGF (OR: 88.239; 95% CI: 2.720–2,092.86), as shown in Figure 2. Due to sparse data, the OR for acute rejection with MAP <80 mmHg was not calculated.

Categorization of BP at different time points

Logistic regression analysis was performed to examine the association between intraoperative SBP metrics and outcomes. In the adjusted model (Figure 3), each 10-mmHg increase in the overall average SBP was associated with reduced odds of mortality (OR: 0.269; 95% CI: 0.084–0.861) and DGF (OR: 0.360; 95% CI: 0.155–0.838). The association between acute rejection and overall average SBP yielded an implausibly low OR, likely due to sparse data; thus, it was not calculated. The first-hour average SBP showed a borderline association with mortality (OR: 0.586; 95% CI: 0.337–1.020) and was similarly protective against DGF (OR: 0.535; 95% CI: 0.316–0.904). In contrast, no association was observed between the sixth-hour average SBP and minimum SBP with mortality and DGF. None of the SBP metrics were significantly associated with acute rejection.

Table 2. Multivariable linear regression between MAP and secondary outcomes

Variables	β	95% CI	*p*
Serum creatinine			
2 days	0.054	0.115 to 0.007	0.083
1 week	0.030	0.066 to 0.006	0.106
1 month	0.013	–0.010 to 0.036	0.271
3 months	0.048	0.130 to 0.034	0.249
eGFR			
2 days	0.389	0.145 to 0.924	0.151
1 week	0.302	0.314 to 0.919	0.331
1 month	0.060	0.514 to 0.393	0.791
3 months	0.113	0.516 to 0.290	0.578

BMI=body mass index; CI=confidence interval; CIT=cold ischemic time; eGFR=estimated glomerular filtration rate; MAP=mean arterial pressure; WIT=warm ischemic time
Models are adjusted for age, sex, BMI, history of hypertension, biological relationship with donor, gender mismatch, WIT, and CIT

Table 3. Statistical analyses of mean arterial pressure (MAP) values between patients with elevated serum creatinine and non-elevated serum creatinine at 2 days, 1 week, 1 month, and 3 months post-transplant

Variables	Serum creatinine <1.5 mg/dl	Serum creatinine ≥1.5 mg/dl	*p*
MAP			
2 days	99.30 (14.05)	96.77 (12.18)	0.474
1 week	99.21 (12.98)	95.26 (11.58)	0.167
1 month	97.42 (12.68)	99.56 (10.71)	0.499
3 months	97.28 (12.38)	99.31 (11.77)	0.493

Intraoperative MAP and early graft function

Serum creatinine levels were evaluated at 2 days, 1 week, 1 month, and 3 months post-transplant. Five patients who died within the 3-month period were excluded from the analysis (n = 74). Multivariate linear regression analysis was performed to analyze the association between MAP and serum creatinine levels. Following adjustment for covariates, no statistically significant association was observed between MAP and serum creatinine levels across all time points. Similarly, no statistically significant association was observed between the calculated eGFR at any time point (Table 2). The serum creatinine levels were further categorized into elevated (≥1.5 mg/dl) and non-elevated (<1.5 mg/dl) groups at different time points. There were no significant differences in the overall MAP values between the patients with elevated serum creatinine levels and those with non-elevated serum creatinine levels at any time point (Table 3).

DISCUSSION

Intraoperative BP control is important for good postoperative outcomes after kidney transplantation. This study showed a significant association between a lower overall average MAP and both 3-month mortality and DGF, suggesting that sustained intraoperative hypotension negatively affects early graft function and patient survival. An increase in the overall average SBP was significantly associated with lower odds of mortality and DGF. Moreover, the first-hour average SBP was significantly associated with DGF, indicating that early intraoperative hemodynamics are critical for graft perfusion and function.

Several studies have shown that patients undergoing kidney transplantation are at a risk of developing DGF, primarily due to AKI. Following reperfusion, the transplanted kidney requires approximately 10–12% of the total cardiac output in adult recipients.[13] Aulakh et al[14] suggested that maintaining a MAP above 95 mmHg during reperfusion was associated with immediate graft function; however, a MAP below 70 mmHg may increase the risk of DGF. A meta-analysis by Gu et al[15] found that low MAP was associated with a higher risk of 30-day mortality and AKI.

Due to the lack of autonomic innervation in the transplanted kidney, renal perfusion is entirely dependent on systemic arterial pressure, which may compromise the ability of the kidney to autoregulate blood flow. This is particularly critical during the first hour of surgery, as general anesthesia can induce hypotension, thereby reducing MAP. A reduction in MAP may lead to diminished blood flow to the newly implanted donor kidney and potentially worsen ischemic injury to the graft.[6]

Hemodynamic stability is also important following reperfusion, as this period is the phase that is most susceptible to ischemia-reperfusion injury (IRI).[16] Sudden restoration of blood flow during reperfusion can cause a cascade of harmful processes, such as the formation of reactive oxygen species. Beyond this initial phase, renal perfusion generally stabilizes and transient BP fluctuations are less likely to cause significant injury.

In this study, we found no significant association between any intraoperative SBP parameter and the occurrence of acute rejection. This finding differs from that of Calixto Fernandes et al,[10] who suggested that intraoperative BP may contribute to the development of acute rejection, especially during the early phase of reperfusion, owing to the amplification of graft inflammation and injury, although not through a direct causal pathway. The inconsistency between these results may be due to the complex and multifactorial nature of acute rejection, which is influenced by both immunological and non-immunological factors. Immunological risk factors include human leukocyte antigen (HLA) mismatches, the presence of preformed donor-specific antibodies, and suboptimal immunosuppression. Non-immunological factors include DGF, prolonged cold ischemia time, advanced donor age, and recipient-related factors.[17]

In this study, no significant association was observed among intraoperative MAP, serum creatinine levels, and eGFR at any postoperative time point. This finding can be attributed to several factors. The intraoperative MAP in the cohort was likely maintained within a clinically acceptable range; this may limit the variability necessary to detect an association. Moreover, transient fluctuations in SBP during surgery may not cause lasting graft injury, especially if other perioperative parameters such as cold ischemia time, perfusion quality, and fluid balance were adequately managed.[18] According to Hiramitsu et al,[19] the period of 3 weeks after kidney transplantation is an early phase for optimizing immunosuppression, treating comorbidities, and detecting and treating surgical complications. Furthermore, allograft function is influenced by multiple post-transplant factors, such as donor characteristics, immunologic events, nephrotoxic medications, and postoperative BP control, which may have a stronger impact on renal function than intraoperative SBP alone.[20] These findings suggest that intraoperative SBP, although important for overall hemodynamic stability, may not be associated with post-transplant renal function, as measured by serum creatinine and eGFR.

This study is the first to examine the influence of intraoperative BP on a recipient's serum creatinine levels and eGFR at multiple postoperative time points. However, this study has a few limitations that must be acknowledged. First, BP measurements were only recorded based on the average SBP during the first and sixth hours, the minimum SBP, and the overall average SBP. However, SBP was not specifically recorded during the reperfusion phase, a critical window of revascularization when the transplanted kidney is particularly susceptible to IRI. Second, owing to institutional constraints, only cross-matching was conducted; HLA testing, an important factor in predicting acute rejection, was not performed. Third, the sample size was relatively small, as several cases were excluded owing to incomplete data. This limitation may have contributed to the low incidence of the primary outcomes and may have influenced the statistical power of our findings.

In conclusion, intraoperative BP management is crucial for improving the postoperative outcomes of kidney transplantation. This study identified a significant association between SBP, particularly during the first hour after surgery, and both 3-month mortality and DGF. No significant association was observed between MAP and incidence of acute rejection, likely because of its multifactorial pathogenesis. MAP was also not associated with post-transplant kidney function at any time point. These findings suggest that maintaining an adequate BP during surgery may help protect kidney function and improve patient outcomes.

Conflict of Interest

The authors affirm no conflict of interest in this study.

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