



Article

Perioperative Factors Associated with Delayed Graft Function in Adults Undergoing Deceased Donor Kidney Transplantation

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Abstract

Introduction: In adult patients undergoing deceased donor kidney transplantation, anesthesia management impacts graft function and survival and is influenced by various donor and recipient clinical factors. The aim of this study was to describe the perioperative factors and to evaluate their association with delayed graft function (DGF) during the first seven days after transplantation. **Materials and Methods:** This cross-sectional study of adult patients who underwent deceased donor kidney transplantation at a tertiary care hospital from 2022–2023 was performed to evaluate pre-, trans- and postoperative patient's characteristics. Comparisons or association tests were implemented between patient characteristics grouped by the absence or presence of DGF. In the case of the variables with clinical relevance, univariate and multivariate logistic models were constructed to evaluate the predictive capacity of these variables to predict delayed graft function. Crude and adjusted odds ratio (ORs) with 95% confidence intervals were calculated for each variable. **Results:** DGF was present in 25/69 (36.23%) patients. The anesthesia time was significantly longer (310.28 vs. 273.55 min; $p = 0.043$) and the post-transplantation stay was significantly longer (11.04 vs. 8.11 days; $p < 0.001$) in patients with delayed graft function. In univariable analyses, male sex ($p = 0.018$), platelet count ($p = 0.025$), and surgical time ($p = 0.062$) showed significant or borderline associations with DGF. In the multivariable model, male sex remained independently associated with DGF (adjusted OR 10.64; 95% CI 1.23–92.1; $p = 0.031$). Platelet count (per $50 \times 10^3 \mu\text{L}$ increase) demonstrated a borderline inverse association (adjusted OR 0.57; 95% CI 0.32–1.02; $p = 0.057$). **Conclusions:** Our results suggest that male sex was independently associated with delayed graft function after deceased donor kidney transplantation, while platelet count showed a borderline association.

Keywords: deceased donor; delayed graft function; kidney transplantation; logistic regression; perioperative factors



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1. Introduction

Chronic kidney disease (CKD) is defined as structural or functional abnormalities in the kidney that lead to a glomerular filtration rate (GFR) < 60 mL/min/1.73 m² or albuminuria > 30 mg per 24 h persisting for more than 3 months [1]. CKD has emerged as a priority health problem worldwide [2], affecting an alarming number of 843.6 million people in CKD stages 1 to 5 worldwide [3]. CKD has increased in incidence and prevalence rates over the last three decades [4].

End-stage kidney disease, which can necessitate dialysis or kidney transplantation, is the most serious form of CKD and is fatal if renal replacement therapy is not implemented [2]. Studies carried out in the Mexican population have revealed that the prevalence of CKD in Mexico is comparable to that reported in industrialized countries. However, the fact that only 1 in 4 Mexican patients who require renal replacement therapy have access to this treatment is worrisome [5]. Analysis of data from the transplant observatory for the year 2022 revealed that, in Mexico, 2713 transplantations were recorded; 725 were from deceased donors, and 1988 were from living donors [6].

Most CKD patients have cardiopulmonary, respiratory and metabolic problems secondary to CKD, and when they undergo kidney transplantation, they are exposed to hemodynamic changes, mechanical ventilation, and anesthetics; therefore, their condition can be affected by adverse effects or major complications throughout the perioperative period [7]. This situation increases the complexity of the anesthesiologist's care, especially for the maintenance of intraoperative hemodynamics, in addition to the fact that drug pharmacokinetics and pharmacodynamics are also affected [8]. Patient monitoring and the use of an adequate anesthesia regimen that ensures hemodynamic stability in kidney transplantation is important to prevent delayed graft function and reduce the risk of post-operative dialysis [9]. In this study, delayed graft function was defined as the recipient needing dialysis during the first 7 days post-transplant [10].

The use of drugs with decreased metabolism, short half-lives and extrarenal clearance should be an option to allow rapid emergence, with early recovery of cognitive and psychomotor function. General anesthesia with an inhaled, intravenous or combined agent is an anesthesia technique commonly used in kidney transplantation.

Certainly, transanesthesia management impacts graft function and survival and is influenced by various clinical factors of the donor and recipient, such as sex, age, body mass index (BMI), creatinine levels, the presence/absence of hypertension and/or diabetes, and smoking [11]. It is important to determine which transanesthesia management strategy leads to the best results in terms of graft function. Anesthesia management during the pre-, trans- and postoperative periods can impact graft function. Particularly during the transanesthesia period, there is controversy about the optimal management, including the choice of induction drugs, neuromuscular relaxants, anesthetic gases, analgesic techniques, immunosuppressants, vasopressors and inotropics, and/or diuretics. Although there is evidence for the safety of several approaches, the superiority of one approach in particular has not been determined. The objective of this study was to describe the perioperative factors and to evaluate their association with delayed graft function during the first seven days after transplantation in adult patients undergoing deceased donor kidney transplantation to identify predictive factors of delayed graft function.

2. Materials and Methods

A cross-sectional study was conducted in which 82 patients of Mexican ethnicity who underwent deceased donor kidney transplantation in the transplantation department of a tertiary care hospital from 1 January 2022 to 31 December 2023 were eligible. Only 69 adult patients (women and men between 18 and 73 years of age) met the inclusion criteria and

were considered in the analysis. Patient selection was carried out retrospectively using a consecutive sampling strategy based on availability. The exclusion criteria were previous kidney transplantation, vascular complications or death.

2.1. Preanesthesia Characteristics of Recipients and Donors

The data on the preanesthesia characteristics of the recipients (age, sex, diabetes status, hypertension status, alcoholism status, smoking status, weight, height, BMI, nutritional status based on BMI, waiting time on the National Transplant Registry list, time on renal replacement therapy, American Society of Anesthesiologists (ASA) classification, revised cardiovascular risk index (RCRI), metabolic equivalents of a task (METs), Duke Activity Status Index (DASI), left ventricular ejection fraction, recipient blood group, hemoglobin, hematocrit, platelet count, thrombin time, total thromboplastin time, international normalized ratio, residual uresis, creatinine level, GFR, sodium level, potassium level and calcium level were obtained from the HRAEB clinical records. The characteristics of the donors (age, blood group, HLA-DR and cause of death) were obtained from the clinical records of the hospitals where organ procurement was performed.

2.2. Characteristics of Transanesthesia Management

Data on transanesthesia management were obtained from the HRAEB clinical records and included medications and interventions used during induction, neuromuscular relaxation, maintenance, analgesia, immunosuppression, hemodynamic monitoring, blood pressure optimization, diuretics, and blood management.

Induction agents included fentanyl and propofol [8], while neuromuscular relaxation was achieved primarily with rocuronium, with cisatracurium used selectively. Reversal agents such as sugammadex and neostigmine were used as indicated [12]. Maintenance anesthesia consisted of either inhaled agents (sevoflurane or desflurane) [8,9], with adjunctive infusions of fentanyl, lidocaine or dexmedetomidine [13] when clinically indicated. Analgesia included nonsteroidal anti-inflammatory drugs (NSAIDs), and in select cases, regional blocks [14], while immunosuppressive therapy included thymoglobulin + methylprednisolone or basiliximab + methylprednisolone [15]. Hemodynamic monitoring involved arterial line placement, central venous pressure monitoring, and pulse pressure variability measurements [16]; however, continuous or time-weighted hemodynamic variables were not available for quantitative analysis. Blood pressure was optimized with norepinephrine [17] or dobutamine [18] infusions as needed, and diuretics such as mannitol [19] or furosemide [20] were administered according to institutional protocols. Blood component transfusions were given in rare cases. Most interventions followed standardized institutional protocols, with adjustments based on patient characteristics or intraoperative conditions.

2.3. Time Parameters and Postanesthesia Follow-Up

Data on daily postanesthesia follow-up during the first seven days after transplantation and time parameters (cold ischemia time of the organ, surgery time, anesthesia time, postoperative hospital stay, and time to graft function during the first seven days after transplantation) were obtained from HRAEB clinical records.

2.4. Statistical Analysis

All the data were analyzed using the R programming language (version 3.6.0, R Core Team, Vienna, Austria) [21]. Descriptive statistics were calculated for the preanesthesia characteristics, transanesthesia management details, time parameters and daily postanesthesia follow-up data during the first seven days after transplantation. Additionally, recipients were divided into two groups according to the presence or absence of delayed graft func-

tion, the presence of delayed graft function and each of the characteristics was associated or compared by implementing the Chi square or Mann–Whitney U test.

In the case of the variables with clinical relevance, univariate logistic models were constructed to evaluate the predictive capacity of these variables to predict delayed graft function. A crude odds ratio (OR) value with 95% confidence interval was thus calculated for each variable. A multivariable logistic regression model was also constructed to adjust for potential confounders and identify independent predictors of delayed graft function. Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were estimated. In all tests, $\alpha = 0.05$ was the threshold used.

3. Results

A total of 82 patients who underwent deceased donor kidney transplantation during the study period were eligible. Thirteen patients were excluded: nine patients who were under 18 years of age, two patients who had previously undergone transplantation, one patient who died one day after transplantation and one patient who had graft renal artery malformation and required nephrectomy. Only 69 adult patients (men and women between 18 and 73 years of age) who underwent deceased donor kidney transplantation met the inclusion criteria were included in the analysis. The average age of the donors was 35.80 ± 15.39 years; in descending order, the causes of death of the donors were severe traumatic brain injury (47/69; 68.12%) and non-traumatic hemorrhagic cerebrovascular events (22/69; 31.88%). In all cases, the HLA-DR crossmatches were negative.

Of the 69 patients, 16 (23.19%) were women and 53 (76.81%) were men. The mean ($\pm$ standard deviation (SD)) age of the patients was $38.39 (\pm 14.25)$ years. Highlighting that delayed graft function was absent in 44/69 (63.77%) patients and present in 25/69 (36.23%) patients.

The clinical characteristics of patients overall and grouped according to the absence or presence of delayed graft function are presented in Table 1. The Mann–Whitney U test was used to perform comparative analysis, revealing that height was significantly greater (1.67 vs. 1.61 m) in those patients with delayed graft function ($p = 0.007$). Additionally, the chi-square test identified an association between the variable presence or absence of delayed graft function and the variable sex ($p = 0.006$).

Table 1. Clinical characteristics of patients undergoing deceased donor kidney transplantation, grouped by the absence or presence of delayed graft function.

Variable	Overall $n = 69$	Delayed Graft Function		Comparison
		Absent $n = 44$	Present $n = 25$	
Age (years)	38.39 (14.25)	37.42 (13.32)	40.11 (15.89)	$p = 0.699^a$
Age group				$p = 0.756^b$
$18 \leq \text{Age} < 30, n (\%)$	25 (36.23%)	16 (36.36%)	9 (36.00%)	
$30 \leq \text{Age} < 60, n (\%)$	38 (55.07%)	25 (56.82%)	13 (52.00%)	
$\text{Age} \geq 60, n (\%)$	6 (8.70%)	3 (6.82%)	3 (12.00%)	
Sex				$p = 0.006^{b,*}$
Female, $n (\%)$	16 (23.19%)	15 (34.09%)	1 (4.00%)	
Male, $n (\%)$	53 (76.81%)	29 (65.91%)	24 (96.00%)	
Weight (kg)	62.79 (12.74)	61.00 (13.48)	65.93 (10.88)	$p = 0.106^a$
Height (m)	1.63 (0.09)	1.61 (0.09)	1.67 (0.06)	$p = 0.007^{a,*}$
BMI (kg/m^2)	23.47 (3.47)	23.36 (3.68)	23.67 (3.12)	$p = 0.520^a$
Nutritional status				$p = 0.650^b$
Malnutrition ($\text{BMI} < 18.5, n (\%)$)	3 (4.35%)	2 (4.55%)	1 (4.00%)	
Normal weight ($18.5 \leq \text{BMI} < 25, n (\%)$)	43 (62.32%)	29 (65.91%)	14 (56.00%)	
Overweight ($25 \leq \text{BMI} < 30, n (\%)$)	22 (31.88%)	12 (27.27%)	10 (40.00%)	
Obesity ($\text{BMI} \geq 30, n (\%)$)	1 (1.45%)	1 (2.27%)	0 (0.00%)	

Table 1. Cont.

Variable	Overall <i>n</i> = 69	Delayed Graft Function		Comparison
		Absent <i>n</i> = 44	Present <i>n</i> = 25	
Diabetes, <i>n</i> (%)	11 (15.94%)	6 (13.64%)	5 (20.00%)	<i>p</i> = 0.511 ^b
Hypertension, <i>n</i> (%)	66 (95.65%)	43 (97.73%)	23 (92.00%)	<i>p</i> = 0.296 ^b
Alcoholism, <i>n</i> (%)	19 (27.54%)	10 (22.73%)	9 (36.00%)	<i>p</i> = 0.271 ^b
Smoking, <i>n</i> (%)	24 (34.78%)	15 (34.09%)	9 (36.00%)	<i>p</i> = 0.999 ^b
Time on renal replacement therapy (years)	4.87 (2.15)	5.07 (2.32)	4.51 (1.81)	<i>p</i> = 0.261 ^a
Waiting time on the NTR until transplantation (years)	3.34 (1.81)	3.50 (1.92)	3.07 (1.58)	<i>p</i> = 0.259 ^a

Unless otherwise indicated, all values are presented as the mean (standard deviation). ^a Mann–Whitney U test.

^b Chi-square test. * *p*-significant value. BMI, body mass index; NTR, National Transplantation Registry.

Furthermore, preanesthesia characteristics and transanesthesia management details are presented in Tables 2 and 3, respectively. The Mann–Whitney U test was used to perform comparative analysis, revealing that the platelet count was significantly lower (150.8 vs. 182.64 $\mu\text{L} \times 10^3$) (*p* = 0.035), the anesthesia time was significantly longer (310.28 vs. 273.55 min) (*p* = 0.043) and the post-transplantation stay was significantly longer (11.04 vs. 8.11 days) (*p* < 0.001) in patients with delayed graft function.

Table 2. Preanesthesia characteristics of patients undergoing deceased donor kidney transplantation, grouped by the absence or presence of delayed graft function.

Variable	Overall <i>n</i> = 69	Delayed Graft Function		Comparison
		Absent <i>n</i> = 44	Present <i>n</i> = 25	
ASA classification				<i>p</i> = 0.992 ^b
III, <i>n</i> (%)	58 (84.06%)	37 (84.09%)	21 (84.00%)	
IV, <i>n</i> (%)	11 (15.94%)	7 (15.91%)	4 (16.00%)	
RCRI	2.25 (0.53)	2.18 (0.54)	2.36 (0.49)	<i>p</i> = 0.126 ^a
METs	6.12 (1.21)	6.03 (1.15)	6.26 (1.30)	<i>p</i> = 0.416 ^a
DASI	27.60 (9.99)	26.96 (9.34)	28.73 (11.14)	<i>p</i> = 0.446 ^a
LVEF	54.76 (8.04)	53.90 (7.46)	56.25 (8.94)	<i>p</i> = 0.285 ^a
Blood group				<i>p</i> = 0.622 ^b
O−, <i>n</i> (%)	1 (1.45%)	0 (0.00%)	1 (4.00%)	
A−, <i>n</i> (%)	1 (1.45%)	1 (2.27%)	0 (0.00%)	
B−, <i>n</i> (%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	
AB−, <i>n</i> (%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	
O+, <i>n</i> (%)	46 (66.67%)	29 (65.91%)	17 (68.00%)	
A+, <i>n</i> (%)	14 (20.29%)	9 (20.45%)	5 (20.00%)	
B+, <i>n</i> (%)	5 (7.25%)	3 (6.82%)	2 (8.00%)	
AB+, <i>n</i> (%)	2 (2.90%)	2 (4.55%)	0 (0.00%)	
Hemoglobin (g/dL)	11.36 (1.80)	11.34 (1.86)	11.41 (1.73)	<i>p</i> = 0.965 ^a
Hematocrit (%)	34.18 (5.44)	34.21 (5.78)	34.12 (4.88)	<i>p</i> = 0.822 ^a
Platelet count ($\mu\text{L} \times 10^3$)	171.10 (54.85)	182.64 (57.55)	150.80 (43.79)	<i>p</i> = 0.035 ^{a,*}
Prothrombin time (s)	11.67 (1.14)	11.65 (1.17)	11.72 (1.12)	<i>p</i> = 0.736 ^a
Partial thromboplastin time (s)	29.43 (4.15)	28.61 (2.79)	30.88 (5.60)	<i>p</i> = 0.051 ^a
International normalized ratio	1.04 (0.15)	1.05 (0.17)	1.03 (0.10)	<i>p</i> = 0.910 ^a
Residual uresis, <i>n</i> (%)	27 (39.13%)	17 (38.64%)	10 (40.00%)	<i>p</i> = 0.911 ^b
Creatinine	12.71 (4.38)	12.29 (4.39)	13.47 (4.37)	<i>p</i> = 0.151 ^a
Glomerular filtration rate	5.21 (2.55)	5.14 (1.93)	5.33 (3.42)	<i>p</i> = 0.470 ^a
Sodium level	139.90 (4.02)	139.45 (3.24)	140.68 (5.10)	<i>p</i> = 0.164 ^a
Potassium level	5.06 (0.80)	4.96 (0.72)	5.23 (0.92)	<i>p</i> = 0.195 ^a
Calcium level	8.33 (1.32)	8.48 (1.24)	8.08 (1.44)	<i>p</i> = 0.274 ^a

Unless otherwise indicated, all values are presented as the mean (standard deviation). ^a Mann–Whitney U test.

^b Chi-square test. * *p*-significant value. ASA, American Society of Anesthesiologists; RCRI, revised cardiovascular risk index; METs, metabolic equivalents of a task; DASI, Duke Activity Status Index; LVEF, left ventricular ejection fraction.

Table 3. Transanesthesia management details of patients undergoing deceased donor kidney transplantation, grouped by the absence or presence of delayed graft function.

Variable	Total <i>n</i> = 69	Delayed Graft Function				Comparison
		Absent <i>n</i> = 44		Present <i>n</i> = 25		
Induction						
Fentanyl for induction (μg)	254.35 (46.76)		252.27 (46.95)		258.00 (47.17)	<i>p</i> = 0.541 ^a
Propofol for induction (mg)	133.19 (43.64)		135.00 (45.47)		130.00 (40.93)	<i>p</i> = 0.705 ^a
Neuromuscular relaxation						
Rocuronium, <i>n</i> (%)	9 (13.04%)	<i>n</i> = 9	8 (18.18%)	<i>n</i> = 8	1 (4.00%)	<i>p</i> = 0.093 ^b
Rocuronium (mg)	45.56 (11.30)		46.25 (11.88)		40 (0.00)	<i>p</i> = 0.286 ^a
Cisatracurium, <i>n</i> (%)	62 (89.86%)		38 (86.36%)		24 (96.00%)	<i>p</i> = 0.203 ^b
Cisatracurium (mg)	8.69 (1.90)	<i>n</i> = 62	8.67 (2.10)	<i>n</i> = 38	8.71 (1.57)	<i>p</i> = 0.920 ^a
Sugammadex, <i>n</i> (%)	4 (5.80%)		4 (9.09%)		0 (0.00%)	<i>p</i> = 0.120 ^b
Neostigmine, <i>n</i> (%)	3 (4.35%)		3 (6.82%)		0 (0.00%)	<i>p</i> = 0.182 ^b
Maintenance						
Sevoflurane, <i>n</i> (%)	31 (44.93%)		23 (52.27%)		8 (32.00%)	<i>p</i> = 0.104 ^b
Desflurane, <i>n</i> (%)	38 (55.07%)		21 (47.73%)		17 (68.00%)	<i>p</i> = 0.104 ^b
Fentanyl infusion, <i>n</i> (%)	64 (92.75%)		40 (90.91%)		24 (96.00%)	<i>p</i> = 0.433 ^b
Lidocaine infusion, <i>n</i> (%)	14 (20.29%)		7 (15.91%)		7 (28.00%)	<i>p</i> = 0.230 ^b
Dexmedetomidine infusion, <i>n</i> (%)	4 (5.80%)		1 (2.27%)		3 (12.00%)	<i>p</i> = 0.097 ^b
Analgesia						
NSAIDs, <i>n</i> (%)	24 (34.78%)		14 (31.82%)		10 (40.00%)	<i>p</i> = 0.493 ^b
Paracetamol, <i>n</i> (%)	65 (94.20%)		41 (93.18%)		24 (96.00%)	<i>p</i> = 0.630 ^b
Regional block, <i>n</i> (%)	5 (7.25%)		3 (6.82%)		2 (8.00%)	<i>p</i> = 0.856 ^b
Immunosuppression						
Thymoglobulin, <i>n</i> (%)	67 (97.10%)		43 (97.73%)		24 (96.00%)	<i>p</i> = 0.681 ^b
Basiliximab, <i>n</i> (%)	2 (2.90%)		1 (2.27%)		1 (4.00%)	<i>p</i> = 0.681 ^b
Methylprednisolone, <i>n</i> (%)	60 (86.96%)		35 (79.55%)		25 (100.00%)	<i>p</i> = 0.015 ^{b,*}
Hemodynamic monitoring						
Arterial line, <i>n</i> (%)	65 (94.20%)		40 (90.91%)		25 (100.00%)	<i>p</i> = 0.120 ^b
Central venous catheter, <i>n</i> (%)	40 (57.97%)		23 (52.27%)		17 (68.00%)	<i>p</i> = 0.203 ^b
Pulse pressure variability monitoring and systolic pressure variability, <i>n</i> (%)	65 (94.20%)		40 (90.91%)		25 (100.00%)	<i>p</i> = 0.120 ^b
Central venous pressure monitoring, <i>n</i> (%)	4 (5.80%)		4 (9.09%)		0 (0.00%)	<i>p</i> = 0.120 ^b
Blood pressure optimization						
Norepinephrine in infusion, <i>n</i> (%)	26 (37.68%)		16 (36.36%)		10 (40.00%)	<i>p</i> = 0.764 ^b
Dobutamine in infusion, <i>n</i> (%)	10 (14.49%)		4 (9.09%)		6 (24.00%)	<i>p</i> = 0.091 ^b
Diuretics						
Mannitol, <i>n</i> (%)	55 (79.71%)		34 (77.27%)		21 (84.00%)	<i>p</i> = 0.504 ^b
Furosemide, <i>n</i> (%)	49 (71.01%)		30 (68.18%)		19 (76.00%)	<i>p</i> = 0.491 ^b
Blood management						
Blood component transfusion, <i>n</i> (%)	1 (1.45%)		0 (0.00%)		1 (4.00%)	<i>p</i> = 0.181 ^b
Times						
Cold ischemia time (hours)	13.96 (5.90)		13.93 (5.97)		14.03 (5.88)	<i>p</i> = 0.960 ^a
Surgery time (minutes)	221.77 (49.59)		212.50 (35.10)		238.08 (65.77)	<i>p</i> = 0.264 ^a
Anesthesia time (minutes)	286.86 (53.97)		273.55 (42.07)		310.28 (64.71)	<i>p</i> = 0.043 ^{a,*}
Post-transplantation stay (days)	9.17 (3.09)		8.11 (2.21)		11.04 (3.54)	<i>p</i> < 0.001 ^{a,*}

Unless otherwise indicated, all values are presented as the mean (standard deviation). ^a Mann–Whitney U test.

^b Chi-square test. * significant *p* value. NSAIDs, nonsteroidal anti-inflammatory drugs.

Table 4 shows the crude odds ratios for each of the predictive variables with clinical relevance (age, sex, platelet count, surgical time, and cold ischemia time) for delayed graft

function according to the results of univariable logistic models, as well as the adjusted odds ratios derived from a multivariable logistic model.

Table 4. Results of logistic regression models for predicting delayed graft function ($n = 69$).

Variable	Univariable			Multivariable		
	Crude OR	CI 95%	<i>p</i> Value	Adjusted OR	CI 95%	<i>p</i> Value
Age (per 10-year increase)	1.14	0.82–1.59	$p = 0.449$	1.15	0.75–1.75	$p = 0.522$
Sex (male vs. female)	12.41	1.60–96.10	$p = 0.018 *$	10.64	1.23–92.1	$p = 0.031 *$
Platelet count (per $50 \times 10^3 \mu\text{L}$ increase)	0.54	0.31–0.93	$p = 0.025 *$	0.57	0.32–1.02	$p = 0.057$
Surgical time (per 60 min increase)	1.98	0.97–4.05	$p = 0.062$	1.69	0.79–3.59	$p = 0.176$
Cold ischemia time (per 60 min increase)	1.00	0.92–1.08	$p = 0.946$	1.00	0.91–1.10	$p = 0.999$

OR: odds ratio. CI: confidence interval. * *p* value indicates statistical significance. Continuous variables were rescaled to clinically meaningful units (age per 10 years, platelet count per $50 \times 10^3 / \mu\text{L}$, surgical time per 60 min).

In univariable analyses, male sex ($p = 0.018$), platelet count ($p = 0.025$), and surgical time ($p = 0.062$) showed significant or borderline associations with DGF. In the multivariable model, male sex remained independently associated with DGF (adjusted OR 10.64; 95% CI 1.23–92.1; $p = 0.031$). Platelet count (per $50 \times 10^3 \mu\text{L}$ increase) demonstrated a borderline inverse association (adjusted OR 0.57; 95% CI 0.32–1.02; $p = 0.057$). Age, surgical time, and cold ischemia time were not independently associated after adjustment.

4. Discussion

In the context of patients undergoing deceased donor kidney transplantation, anesthesia management during the pre-, trans-, and postoperative periods is critical since transanesthesia management impacts the function and survival of the graft and is influenced by various clinical factors of the donor and the recipient, such as sex, age, BMI, creatinine levels, the presence/absence of hypertension and/or diabetes, and smoking [11]. Patient monitoring and the use of an adequate anesthesia regimen that ensures hemodynamic stability in kidney transplantation are important to prevent delayed graft function. The aim of this study was to describe the perioperative factors and to evaluate their association with delayed graft function during the first seven days after transplantation in adult patients who underwent deceased donor kidney transplantation to identify predictive factors of this delay.

In our study of 69 patients who underwent deceased donor transplantation, 36.23% of the patients experienced delayed graft function, a percentage similar to that reported by Meliha et al. [22], who reported a 45.3% prevalence of delayed graft function in a cohort of 62 patients who underwent deceased donor kidney transplantation.

In addition, 76.81% of the patients in this study were men, similar to the percentage reported by Kang Woong Jun et al. [23] (59.94% men) in a cohort study of 367 transplantation patients. In their study, they did not find an association between sex and the presence of delayed graft function ($p = 0.570$), but in our study, we identified an association between sex and the presence of delayed graft function ($p = 0.006$).

Although univariable analysis identified male sex and lower platelet count as potentially associated with delayed graft function, only male sex remained independently associated with delayed graft function. Platelet count showed a borderline inverse association. Higher platelet counts may reflect better baseline physiological reserve, potentially

explaining the observed inverse association with delayed graft function. Therefore, while these findings are noteworthy, they should be interpreted with caution.

Additionally, we identified a mean anesthesia time of 286.86 ± 53.97 min, similar to that reported by Rajmohan et al. [24] of 268.00 ± 81.80 min in a cohort of deceased donor transplantation patients. Patients with delayed graft function exhibited significantly longer anesthesia times. Prolonged anesthesia duration could reflect hemodynamic instability, respiratory complications, surgical complexity, delayed emergence, or other perioperative challenges that are themselves associated with delayed graft function. Therefore, while anesthesia time should not be interpreted as a causal factor per se, it can be considered a practical summary indicator of the overall complexity of the perioperative course, which is relevant to the risk of DGF.

In addition, international studies highlight that anesthesia techniques and perioperative hemodynamic management vary across centers and can influence graft outcomes. Differences in anesthesia approaches, including balanced general anesthesia versus combined general–epidural techniques, may also impact hemodynamic stability and early graft recovery [25,26]. Strategies such as goal-directed fluid therapy and invasive arterial monitoring have been associated with reduced rates of delayed graft function [27,28]. Our findings, although limited by the lack of detailed intraoperative hemodynamic data, align with this global evidence. Moreover, the post-transplantation stay was significantly longer (11.04 vs. 8.11 days; $p < 0.001$) in patients with delayed graft function, similar to the findings of Rajmohan et al. [24], who reported a longer post-transplantation stay (12.60 vs. 9.70 days; $p = 0.001$) in patients with delayed graft function.

This study has certain limitations. First, as a cross-sectional, single-center study with a small sample ($n = 69$), the results may not be generalizable to other centers with different institutional practices, which could affect anesthesia management and graft outcomes, and the small sample size may limit the precision of some estimates and the ability to detect smaller effects. Second, the retrospective design and inclusion based on available records introduce potential selection bias. Third, there is no detailed characterization of the donors due to heterogeneity and/or limited access to the medical records of their units of origin, which would allow us to explore the possible associations between the detailed characteristics of the donors—such as donor kidney function, vascular anatomy, and other clinical parameters—and delayed graft function. This limited donor information may have introduced residual confounding, as some donor-related factors could influence the risk of delayed graft function. Fourth, the retrospective nature of our study did not allow the evaluation of some variables in which an association with the delayed graft function has been identified, such as baseline intraoperative mean arterial pressure [29]; which could not be analyzed as a continuous or time-weighted variable, the transanesthesia use of intravenous solutions [30] and some emerging biomarkers that can be measured in urine and have been identified as predictors of delayed graft function, such as neutrophil gelatinase-associated lipocalin (NGAL) [31] and clusterin (CLU) [32]. Nevertheless, the observed associations provide useful insights into perioperative factors related to delayed graft function and can guide future larger studies.

However, the strengths of the study include the evaluation of various donor and recipient characteristics, scales and anesthesia techniques that have been identified in other populations as potential predictors of delayed graft function to evaluate a Mexican cohort of patients. Finally, this study and the proposed methodology can be the basis for a multicenter and/or longitudinal study with a large sample size that allows us to identify the characteristics that best predict delayed graft function in the Mexican population.

Given the limitations of our study, we believe that multicenter and/or longitudinal studies could be carried out with a large sample size that would allow us to identify the characteristics

that can best predict delayed graft function in the Mexican population. These studies should include the precise doses of all drugs and/or intravenous solutions used during transanesthesia management and incorporate emerging urinary biomarkers such as NGAL and clusterin, measured preoperatively and at reperfusion or early postoperatively, to guide early detection of delayed graft function. Such data could then be used to construct and evaluate the performance of a multivariate model (logistic regression) for the prediction of delayed graft function considering a wide variety of pre-, trans- and postanesthesia characteristics.

5. Conclusions

The findings of this study expand the knowledge base of deceased donor kidney transplantation and associated preanesthesia, transanesthesia and postanesthesia factors in the Mexican population with the delayed graft function that may occur after transplantation. Our results suggest that male sex was independently associated with delayed graft function after deceased donor kidney transplantation, while platelet count showed a borderline association. It is necessary to conduct multicenter and/or longitudinal studies with large sample sizes that validate the results of this study and favor the prediction of delayed graft function.

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Informed Consent Statement: The ethics committee/institutional review board waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin given the retrospective nature of the study. The confidentiality of the data was meticulously maintained, and all procedures adhered to the pertinent guidelines and regulations governing this research.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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