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Preoperative Factors Predicting Admission to the Intensive Care Unit After Kidney Transplantation

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Abstract

Objective: To identify preoperative factors predicting early admission (within 30 days) of adult kidney transplant recipients to the intensive care unit (ICU).

Patients and Methods: This is a single-center retrospective study of consecutive kidney transplant recipients between January 1, 2007, and December 31, 2016. Children (aged <18 years) and patients who underwent simultaneous multiorgan transplantation were excluded from the analysis. Associations between demographic, transplant-related, and comorbidity variables with ICU admission within 30 days of transplantation were analyzed using univariate and multivariate logistic regression models.

Results: Of the 1527 eligible patients, 305 (20%) required early ICU admission. In univariate analysis, older age, higher body mass index (BMI), previous transplantation, myocardial infarction, congestive heart failure, obstructive pulmonary disease, longer ischemia time, pretransplant dialysis, and transplantation from a deceased donor were associated with increased odds of ICU admission. After multivariate adjustment, every 10-year increase in recipient age (odds ratio [OR], 1.26; 95% CI, 1.12-1.42; $P<.001$), 5-unit increase in BMI (OR, 1.11; 95% CI, 1.00-1.22; $P=.049$), pretransplant dialysis (OR, 1.57; 95% CI, 1.19-2.08; $P=.002$), and deceased donor transplantation (OR, 1.82; 95% CI, 1.29-2.55; $P<.001$) were associated with the increased risk of ICU admission. Preemptive transplantation (OR, 0.64; 95% CI, 0.48-0.84; $P=.002$) and living donor kidney transplantation (OR, 0.55; 95% CI, 0.39-0.77; $P<.001$) were associated with lower odds of ICU admission after transplantation.

Conclusion: Recipient age, BMI, and the need for pretransplant dialysis are associated with a higher risk of early ICU admission after kidney transplantation, whereas living donor kidney transplantation and preemptive transplantation decrease these odds. Early referral of patients with end-stage renal disease for preemptive transplantation and living donor kidney transplantation can significantly reduce transplant-related ICU admissions.

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Kidney transplantation is the treatment of choice for patients with end-stage renal disease (ESRD).[1] In comparison to patients maintained on dialysis, life expectancy and quality improve significantly in transplant recipients.[1-4] However, the relative risk of death within the first month of transplantation is approximately 3 times higher than that in patients undergoing dialysis.[1] Patients with ESRD are at least American Society of Anesthesiologists (ASA) class III per the ASA physical status classification system,[5,6] which is associated with higher postsurgical mortality.[6,7] Therefore, many of these patients require high acuity care in the intensive care unit (ICU) early after transplantation. Intensive care unit admission rates after kidney transplantation range between 3% and 42% in historical observations, although these rates likely do not reflect the more recent changes in the demographic and clinical characteristics of kidney transplant recipients.[8-13] In addition, little is known about the preoperative factors that predict early ICU admission after kidney transplantation.

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Transplant trends have changed in the past 2 decades.[14-17] Because of the increasing incidence of ESRD and a limited supply of organs, the number of wait-listed candidates continues to increase.[15,17] At the same time, listing criteria have expanded significantly over the same time period. For example, the percentage of elderly patients (aged >64 years) on the United Network for Organ Sharing waiting list increased from 15.3% to 22.5% and diabetic nephropathy as the cause of ESRD increased from 39.4% to 46% from 2006 to 2016.[15,18] Given these changes in the risk profile of kidney transplant recipients, we attempted to identify preoperative factors that predict early admission of adult kidney transplant recipients to the ICU over a 10-year period.

PATIENTS AND METHODS

The study was carried out at Mayo Clinic in Rochester, Minnesota, and was approved by the Mayo Clinic Institutional Review Board. All adult patients (aged ≥18 years) who received a kidney transplant between January 1, 2007, and December 31, 2016, were selected for the study. Patients younger than 18 years of age at the time of transplantation, individuals who did not give previous research authorization for chart review, or individuals who received combined organ transplantation (liver, heart, or pancreas with a kidney) were excluded from the study. The *ICU cohort* was defined as patients who required ICU admission within 30 days of their kidney transplantation surgery. Patients who did not require ICU admission within 30 days of transplant surgery were included in the non-ICU cohort (Figure).

Data on recipient-related characteristics including age; sex; body mass index (BMI; calculated as the weight in kilograms divided by the height in meters squared); comorbidities; dialysis before transplantation; previous solid organ transplant; retransplant; donor-related information including age, deceased vs living, and sex; and finally surgery-related data including warm ischemia time (WIT), total ischemia time, and induction immunosuppression were abstracted from the Mayo Clinic Transplant Center database. *Warm ischemia time* was defined as the time between taking the kidney allograft out of the cold preservation solution and reperfusion. The ICU-related data were collected from a previously validated electronic data mart.[19] Associations between these variables with ICU admission within 30 days of transplant surgery were analyzed using univariate and multivariate logistic regression models.

Data were descriptively summarized by ICU admission within 30 days using frequencies and percentages for categorical variables (male sex; retransplant; any previous solid organ transplant; history of myocardial ischemia [MI], congestive heart failure [CHF], peripheral vascular disease [PVD], cerebrovascular accident, dementia, chronic obstructive pulmonary

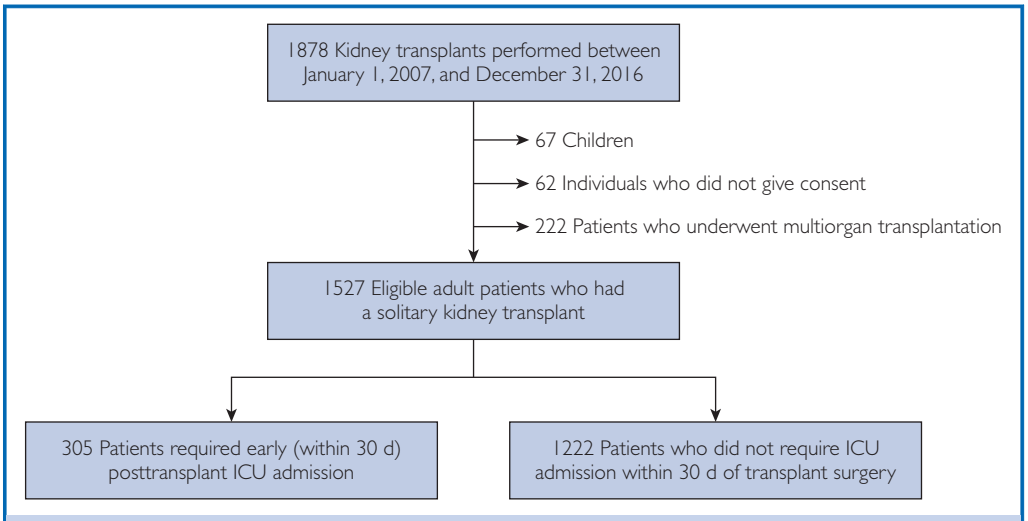

FIGURE. Flowchart showing the inclusion of study participants. ICU = intensive care unit.

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disease [COPD], asthma, interstitial lung disease [ILD], diabetes mellitus [DM], cirrhosis, and hemi- or paraplegia; donor type; donor male sex; preoperative dialysis; and type of induction immunosuppression used) and medians and interquartile ranges (IQRs) for continuous variables (age of recipient, BMI, donor age, WIT, and total ischemia time). Data distributions across ICU admission within 30 days were compared using chi-square and Fisher exact tests (where appropriate) for categorical data and Wilcoxon rank-sum tests for continuous data.

Logistic regression models were used to analyze associations with ICU admission within 30 days of transplant after multivariate adjustment. To control for all variables, a 2-step regression model was used. In the first step, variables that were found significant ($P<.05$) in the unadjusted models were entered into a minimally adjusted model. Variables considered for the unadjusted model included age, BMI, sex, previous solid organ transplantation, medical history (MI, DM, CHF, PVD, COPD, ILD, cerebrovascular accident, and asthma), deceased donor transplantation, WIT, pretransplant dialysis, induction immunosuppression (alemtuzumab, basiliximab, or anti-thymocyte globulin), and donor age and sex. To be fully inclusive, our final multivariate model included all covariates with $P<.40$ in the minimally adjusted models (age, BMI, organ transplant, MI, CHF, PVD, COPD, ILD, CTD, donor age, donor deceased, WIT, pretransplant dialysis, alemtuzumab, basiliximab, and thymocyte). To ensure that the model fit was reasonable on the fully adjusted model, model diagnostics were performed, and there was no evidence for lack of fit using the Hosmer-Lemeshow test and when examining the model residuals.

All analyses were performed using SAS version 9.4 (SAS Institute Inc.). A 2-sided *P*-value of less than .05 was considered significant.

RESULTS

Study Population

A total of 1878 kidney transplants were performed between January 1, 2007, and December 31, 2016, at Mayo Clinic, Rochester, MN. The eligible cohort comprised 1527 adult patients who had a solitary kidney transplant. The demographic and clinical characteristics of the cohort are summarized in Table 1. The median age was 54.2 years (IQR, 43.4-63.6 years), and the median BMI was 28.9 kg/m^2 (IQR, 24.9-33.5 kg/m^2). Most recipients were male (58.9%) and received a living donor allograft (82.8%). A significant number of patients had undergone previous solid organ transplantation (n=273 [17.9%]), most of whom have had a previous kidney transplant (n=256 [16.8%]). Approximately half (n=813 [53.2%]) of the patients were undergoing dialysis at the time of transplant (Table 1).

Comparison Between ICU and Non-ICU Cohorts

A total of 305 patients (20.0%) who required an ICU admission within the first 30 days of transplant surgery comprised the ICU cohort. The median Sequential Organ Failure Assessment score on day 1 of ICU admission was 5 (IQR, 3-7). Recipient sex and donor sex and age were similar in the 2 cohorts (Table 1). Patients in the ICU cohort were older (55.9 years [IQR, 45.5-64.6 years] vs 53.6 years [IQR, 42.7-63.1 years]; $P=.01$), had higher BMI (29.9 kg/m^2 [IQR, 25.5-34.5 kg/m^2] vs 28.8 kg/m^2 [IQR, 24.8-33.3 kg/m^2]; $P=.04$), and were more likely to have had a previous solid organ transplant (22.0% vs 16.9%; $P=.04$). Patients requiring ICU admission had a higher incidence of MI (9.2% vs 5.6%; $P=.02$), CHF (9.8% vs 4.9%; $P=.001$), PVD (5.2% vs 2.7%; $P=.02$), and COPD (5.6% vs 3.0%; $P=.03$), but not DM (37.3% vs 32.1%; $P=.16$). They were also more likely to have received a kidney allograft from a deceased donor (29.5% vs 14.2%; $P<.001$) while undergoing dialysis (65.9% vs 50.1%; $P<.001$). The overall total ischemia time was longer in the ICU cohort (138 minutes [IQR, 84-721 minutes] vs 94 minutes [IQR, 69-184 minutes]; $P<.001$) (Table 1).

Unadjusted Model for Factors Associated With Early ICU Admission

In unadjusted logistic regression models, older recipient age (odds ratio [OR], 1.13; 95% CI, 1.03-1.24); higher BMI (OR, 1.11; 95% CI, 1.01-1.22); previous solid organ transplantation (OR, 1.39; 95% CI, 1.02-1.89); history of MI (OR, 1.69; 95% CI, 1.07-2.67), CHF (OR, 2.11; 95% CI, 1.34-3.34), PVD (OR,

TABLE 1. Patient Demographic and Clinical Characteristics By ICU Admission Within 30 d[a,b]

Characteristic	Non-ICU cohort (n=1222)	ICU cohort (n=305)	Total (N=1527)	*P* value
Baseline characteristics				
Age (y)	53.6 (42.7, 63.1)	55.9 (45.5, 64.6)	54.2 (43.4, 63.6)	.01[c]
Sex: male	723 (59.2)	176 (57.7)	899 (58.9)	.64[d]
BMI (kg/m^2)	28.8 (24.8, 33.3)	29.9 (25.5, 34.5)	28.9 (24.9, 33.5)	.04[c]
Retransplant	195 (16.0)	61 (20.0)	256 (16.8)	.09[d]
Previous solid organ transplant	206 (16.9)	67 (22.0)	273 (17.9)	.04[d]
Comorbid conditions				
MI	69 (5.6)	28 (9.2)	97 (6.4)	.02[d]
CHF	60 (4.9)	30 (9.8)	90 (5.9)	.001[d]
PVD	33 (2.7)	16 (5.2)	49 (3.2)	.02[d]
CVA	69 (5.6)	24 (7.9)	93 (6.1)	.15[d]
Dementia	4 (0.3)	0 (0.0)	4 (0.3)	.59[e]
COPD	37 (3.0)	17 (5.6)	54 (3.5)	.03[d]
Asthma	75 (6.1)	19 (6.2)	94 (6.2)	.95[d]
ILD	24 (2.0)	10 (3.3)	34 (2.2)	.16[d]
Chronic pulmonary disease	126 (10.3)	42 (13.8)	168 (11.0)	.08[d]
Connective tissue disease	50 (4.1)	18 (5.9)	68 (4.5)	.17[d]
Diabetes				.16[d]
None	830 (67.9)	190 (62.3)	1020 (66.8)	
Diabetes, no complications	204 (16.7)	57 (18.7)	261 (17.1)	
Diabetes, with complications	188 (15.4)	58 (19.0)	246 (16.1)	
Cirrhosis/mild liver disease	76 (6.2)	14 (4.6)	90 (5.9)	.28[d]
Hemi/paraplegia	4 (0.3)	1 (0.3)	5 (0.3)	1.00[e]
Donor-related variables				
Donor age	45 (35, 55)	46 (34, 55)	46 (35, 55)	.93[c]
Donor type				<.001[d]
Living	1049 (85.8)	215 (70.5)	1264 (82.8)	
Deceased	173 (14.2)	90 (29.5)	263 (17.2)	
Donor sex: male	529 (43.3)	144 (47.2)	673 (44.1)	.22[d]
Surgery-related variables				
Warm ischemia time (min)	42 (36, 48)	43 (37, 51)	42 (36, 49)	.01[c]
Total ischemia time (min)	94 (69, 184)	138 (84, 721)	100 (72, 206)	<.001[c]
Preoperative dialysis	612 (50.1)	201 (65.9)	813 (53.2)	<.001[d]
Induction type				<.001[d]
Anti-thymocyte globulin	585 (47.9)	188 (61.6)	773 (50.6)	
Alemtuzumab	281 (23.0)	56 (18.4)	337 (22.1)	
Basiliximab	356 (29.1)	61 (20.0)	417 (27.3)	

[a]BMI = body mass index; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; CVA = cerebrovascular accident; ICU = intensive care unit; ILD = interstitial lung disease; MI = myocardial ischemia; PVD = peripheral vascular disease; Q1 = quartile 1; Q3 = quartile 3.
[b]Data are presented as median (Q1, Q3) and as No. (percentage).
[c]Wilcoxon rank-sum test.
[d]Chi-square test.
[e]Fisher exact test.

1.99; 95% CI, 1.08-3.67), and COPD (OR, 1.89; 95% CI, 1.05-3.41); deceased donor transplantation (OR, 2.54; 95% CI, 1.89-3.41); prolonged WIT (OR, 1.57; 95% CI, 1.22-2.01); and need for pretransplant dialysis (OR, 1.93; 95% CI, 1.48-2.50) were associated with increased odds of ICU admission within the first 30 days of transplant ($P<.05$ for all) (Table 2). Induction with the T cell–depleting anti-thymocyte globulin, compared with induction with the interleukin-2 receptor antagonist basiliximab, was also associated with increased odds of ICU admission (OR, 1.88; 95% CI,

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1.37-2.58; $P<.01$). Conversely, preemptive transplantation (OR, 0.52; 95% CI, 0.40-0.67; $P<.001$) and living donor kidney transplantation (OR, 0.39; 95% CI, 0.29-0.53; $P<.001$) were associated with lower odds of ICU admission after kidney transplantation.

Multivariate Model for Factors Associated With Early ICU Admission

In the minimally adjusted model, several variables including recipient age; BMI; previous solid organ transplantation; history of MI, CHF, PVD, COPD, and ILD; donor age; deceased donor transplantation; WIT; pretransplant dialysis; and induction immunosuppression with either anti-thymocyte globulin or alemtuzumab were all associated with altered odds of ICU admission, with a P value of less than 0.4. These were then chosen for the final fully adjusted model (Table 2). In the fully adjusted multivariate model, advanced recipient age (OR per every

TABLE 2. Associations Between Patient Characteristics and Clinical Characteristics With ICU Admissions Using Unadjusted, Minimally Adjusted, and Fully Adjusted Logistic Regression Models[a]

Characteristic	Unadjusted[b]		Minimally adjusted[c]		Fully adjusted[d]	
	Odds ratio (95% CI)	*P* value	Odds ratio (95% CI)	*P* value	Odds ratio (95% CI)	*P* value
Recipient age (per 10 y)	1.13 (1.03-1.24)	.009	1.27 (1.13-1.43)	<.001	1.26 (1.12-1.42)	<.001
BMI (per 5 kg/m^2)	1.11 (1.01-1.22)	.03	1.11 (1.00-1.22)	.049	1.11 (1.00-1.22)	.049
Any previous solid organ transplant	1.39 (1.02-1.89)	.04	1.25 (0.89-1.75)	.20	1.24 (0.88-1.75)	.21
History of MI	1.69 (1.07-2.67)	.03	1.33 (0.80-2.19)	.27	1.33 (0.80-2.20)	.27
History of CHF	2.11 (1.34-3.34)	.001	1.48 (0.90-2.41)	.12	1.48 (0.90-2.43)	.12
History of PVD	1.99 (1.08-3.67)	.03	1.38 (0.71-2.70)	.35	1.37 (0.70-2.69)	.36
History of COPD	1.89 (1.05-3.41)	.03	1.50 (0.80-2.81)	.20	1.48 (0.79-2.77)	.22
History of ILD	1.69 (0.80-3.58)	.17	1.57 (0.71-3.44)	.26	1.55 (0.71-3.41)	.27
History of connective tissue disease	1.47 (0.85-2.56)	.17	1.52 (0.85-2.71)	.16	1.47 (0.82-2.64)	.19
Donor age (per 10 y)	1.00 (0.91-1.10)	.97	1.05 (0.95-1.17)	.34	1.05 (0.94-1.17)	.35
Donor, deceased (reference = living)	2.54 (1.89-3.41)	<.001	1.89 (0.96-3.73)	.07	1.82 (1.29-2.55)	<.001
Warm ischemia time (per 30 min)	1.57 (1.22-2.01)	<.001	1.28 (0.98-1.68)	.07	1.28 (0.98-1.68)	.07
Pretransplant dialysis	1.93 (1.48-2.50)	<.001	1.57 (1.18-2.07)	.002	1.57 (1.19-2.08)	.002
Alemtuzumab (reference = anti-thymocyte globulin)	0.62 (0.45-0.86)	.005	0.73 (0.51-1.03)	.07	0.75 (0.52-1.06)	.11
Basiliximab (reference = anti-thymocyte globulin)	0.53 (0.39-0.73)	<.001	0.38 (0.27-0.56)	<.001	0.38 (0.26-0.55)	<.001
Total ischemia time (per 30 min)	1.02 (1.02-1.03)	<.001	1.00 (0.98-1.02)	.81		
Recipient male (reference = female)	0.94 (0.73-1.21)	.64	0.94 (0.72-1.23)	.67		
Retransplant	1.32 (0.96-1.81)	.09	0.80 (0.41-1.53)	.49		
History of CVA	1.43 (0.88-2.31)	.15	1.01 (0.60-1.73)	.96		
History of asthma	1.02 (0.60-1.71)	.95	0.85 (0.49-1.48)	.57		
Chronic pulmonary disease	1.39 (0.96-2.02)	.09	1.00 (0.61-1.64)	1.00		
DM, no complications (reference = no DM)	1.22 (0.87-1.70)	.24	1.19 (0.83-1.70)	.35		
DM w/ complications (reference = no DM)	1.35 (0.97-1.88)	.08	1.07 (0.74-1.54)	.74		
History cirrhosis/mild liver disease	0.73 (0.40-1.30)	.28	0.79 (0.43-1.44)	.44		
Donor male (reference = female)	1.17 (0.91-1.50)	.22	1.02 (0.781.33)	.88		

[a]BMI = body mass index; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; CVA = cerebrovascular accident; DM = diabetes mellitus; ICU = intensive care unit; ILD = interstitial lung disease; MI = myocardial ischemia; PVD = peripheral vascular disease.
[b]Odds ratios and *P* values are adjusted only for the row covariate.
[c]Odds ratios and *P* values are additionally adjusted for variables significant ($P<.05$) in unadjusted analyses (age, BMI, previous transplant, history of MI, history of CHF, history of PVD, history of COPD, donor deceased, warm ischemia time, pretransplant dialysis, thymoglobulin, and total ischemia time).
[d]Odds ratios and *P* values are additionally adjusted for variables with $P<.40$ in the minimally adjusted models.

10 years, 1.26; 95% CI, 1.12-1.42; $P<.001$), higher BMI (OR per every 5 kg/m^2, 1.11; 95% CI, 1.00-1.22; $P=.049$), deceased donor transplantation (OR, 1.82; 95% CI, 1.29-2.55; $P<.001$), need for pretransplant dialysis (OR, 1.57; 95% CI, 1.19-2.08; $P=.002$), induction immunosuppression with anti-thymocyte globulin (OR, 2.63; 95% CI, 1.82-3.81; $P<.001$), or alemtuzumab (OR, 1.97; 95% CI, 1.26-3.07; $P=.003$) were associated with increased odds of ICU admission within the first 30 days. The association of medical history, ischemia time, and previous solid organ transplantation with ICU admission was lost in this fully adjusted model. However, preemptive transplantation (OR, 0.64; 95% CI, 0.48-0.84; $P=.002$) and living donor kidney transplantation (OR, 0.55; 95% CI, 0.39-0.77; $P<.001$) continued to be associated with lower odds of ICU admission.

Indications for ICU Admission

The indications for early ICU admission are listed in Table 3. Most ICU admissions (n=170 [55.7%]) were for cardiac and/or vital sign monitoring in patients who had relative asymptomatic hypotension (systolic blood pressure reduction >20% of baseline) or who were at high risk because of comorbidities. Cardiac causes were the next most common reason for ICU admission (n=62 [20.3%]). Rhythm disorders were the most common cardiac cause (n=41), followed by acute myocardial infarction (n=18). Only 1 patient required ICU admission for the management of sepsis.

TABLE 3. Indications for ICU Admission[a]

Indication	n	Percentage
Cardiac monitoring	170	55.7
Hypotension, asymptomatic	82	
Cardiopulmonary monitoring (high risk)	69	
Tachycardia	13	
Chest pain	2	
Hypertension, asymptomatic	2	
Delayed anesthesia recovery	1	
ST changes in ECG	1	
Cardiac causes	62	20.3
Rhythm disorder	41	
NSTEMI or MI	18	
Cardiogenic pulmonary edema	2	
Cardiac arrest	1	
Electrolyte and pH imbalance	28	9.2
Hyperkalemia	17	
Acidosis	8	
Hyponatremia	1	
Hypocalcemia	1	
Hypercalcemia	1	
Blood pressure changes	21	6.9
Hypertension, symptomatic	16	
Hypotension, symptomatic	5	
Pulmonary	14	4.6
Neurological	4	1.3
Sepsis	1	0.3
Others	5	1.6
Total	305	100

[a]ECG = electrocardiography; MI = acute myocardial infarction; NSTEMI = non–ST-segment elevation myocardial infarction.

Thirty-Day Mortality

Overall, mortality within 30 days of transplant surgery was low at 0.34% (n=5). The characteristics of 5 mortality cases are summarized in Table 4. All deaths occurred in the ICU cohort (1.64%).

DISCUSSION

Patients with ESRD are at a higher surgical and anesthesia risk than patients with ASA physical status class 1,[6] and many require high acuity care immediately after kidney transplantation. To date, there have been no analyses of factors predicting early ICU admission after kidney transplantation in North America. The present study provides insights into these factors. Our results suggest that most kidney transplant recipients do not require high acuity care in the ICU after transplant surgery. The odds of ICU admission increase with advanced age and higher BMI of the recipient at the time of transplant surgery. Similarly, patients who are undergoing dialysis before kidney transplantation and those who receive kidney allografts from deceased donors are more likely to require ICU admissions within 30 days of transplantation, whereas none of the comorbid conditions used in the Charlson index[20] appear to be associated with early ICU admission.

In the present study, standardized institutional criteria for ICU admission were used during the entire length of the study period.

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TABLE 4. Characteristics of Mortality Cases

Patient no.	Age (y)	Sex	Pretransplant dialysis	Donor type	Charlson index	BMI (kg/m^2)	ICU admission indication	Cause of death
1	60	M	Y	D	6	25.5	Cardiac arrest	Cardiac arrest
2	62	M	N	L	8	26.8	NSTEMI	Septic shock
3	61	M	N	L	7	27	Hyperkalemia	Cardiac arrest
4	41	M	N	L	4	27	Acute cerebellar bleed	Cerebellar bleed
5	35	M	Y	D	2	33.4	Hypertensive urgency	Acute cardiopulmonary failure

BMI = body mass index; D = deceased; F = female; ICU = intensive care unit; L = living; M = male; N = no; NSTEMI = non–ST-segment elevation myocardial infarction; Y = yes.

These criteria include (1) systolic blood pressure less than 90 mm Hg in 2 consecutive measurements that does not respond to fluid resuscitation, (2) a posttransplant reduction in systolic blood pressure of more than 20% as compared with the pretransplant measurement, and (3) new-onset cardiac arrhythmia associated with hemodynamic instability. In addition, 69 patients with a significant medical history who had intraoperative hypotension that was corrected by the end of operation were admitted to the ICU after kidney transplantation. With strict adherence to these criteria, the ICU admission rate within the first 30 days of kidney transplantation was 20%. Unlike earlier studies,[9,12] we excluded patients who underwent multiorgan transplantation; therefore, we believe that this incidence reflects an accurate assessment of the risk profile of contemporary kidney transplant recipients.

Selection of candidates for kidney transplantation has evolved over the past 2 decades because of both the changes in transplant candidate demographic characteristics and the liberalization of selection criteria.[14-17] For example, between 2007 and 2017, the percentage of patients on the waiting list older than 50 years increased from 58.7% to 67.2%, with those older than 65 years accounting for the most significant increase (from 16.2% to 23.1%).[18] Similarly, the ratio of obese (BMI $\geq$30 kg/m^2) patients waiting for a kidney transplant increased from 10.1% in 1995 to 34.5% in 2011.[21,22] Assuming that these 2 trends are unlikely to change in the near future, our results suggest that a minority of transplant patients will continue to require unplanned ICU admission and high acuity care within the first month of transplantation. To define patients at risk in more detail, we used the components of the Charlson Comorbidity Index in our logistic regression analyses. Although the effect of medical comorbidities on patient survival, rejection episodes, cardiovascular events, and graft survival has been studied in the past,[23-25] to our knowledge, the present study is the first one to assess their effect on the ICU admission. Although a higher percentage of patients in our ICU cohort had a history of MI, CHF, PVD, or COPD, these factors were not found to have a substantial effect on early ICU admission in multivariate analysis, likely because of the complete evaluation, careful selection, and medical optimization of the transplant candidates.

After controlling for confounding factors, 2 variables appeared to independently predict lower odds of ICU admission: preemptive kidney transplantation and living donor kidney transplantation. Several large studies using registry data over the past decade reported that preemptive kidney transplantation is associated with improved graft and patient survival as compared with transplantation after the initiation of dialysis.[26-28] In fact, on the basis of extensive literature review, the Descartes Working Group and the European Renal Best Practice Advisory Board released a position statement to stimulate programs for preemptive kidney transplantation with living donor kidneys.[29] Our present analysis complements the growing body of knowledge supporting the superiority of preemptive kidney transplantation, by revealing another important difference, this time in the early posttransplant surgery outcome. We have previously found that non-preemptive kidney

transplantation resulted in a significantly higher pretransplant health care resource utilization and cost.[30] Although the aim of the present study was not to investigate the posttransplant health care resource utilization and cost, the results suggest that these are higher in non-preemptive or deceased donor kidney transplantation. Living donor kidney transplantation remains the most cost-effective option for patients with ESRD as compared with dialysis and deceased donor kidney transplantation.[31]

This study has several limitations inherent to retrospective analyses and represents the outcomes of a single center. In addition, the center referral bias may have a role in patient cohort selections. However, the protocolized patient selection coupled with standardized ICU admission criteria and ICU management provides a homogeneous cohort with reduced bias. Analyzing ICU resource utilization and ICU outcomes was not the aim of the present study. However, preliminary data on these variables have previously been presented.[32]

CONCLUSION

In a contemporary cohort of kidney transplant patients, we report that patients with advanced age and higher BMI and those who are transplanted while undergoing dialysis or with a deceased donor kidney are more likely to be admitted to the ICU after transplantation. Preemptive transplantation and living donor kidney transplantation decrease the odds of early ICU admission, whereas baseline comorbidities do not have a substantial effect on posttransplant early ICU admissions. In all, these results suggest that early referral of patients with ESRD for preemptive transplantation and living donor kidney transplantation can significantly reduce transplant-related early ICU admissions.

Abbreviations and Acronyms: **ASA** = American Society of Anesthesiologists; **BMI** = body mass index; **CHF** = congestive heart failure; **COPD** = chronic obstructive pulmonary disease; **DM** = diabetes mellitus; **ESRD** = end-stage renal disease; **ICU** = intensive care unit; **ILD** = interstitial lung disease; **IQR** = interquartile range; **MI** = myocardial ischemia; **OR** = odds ratio; **PVD** = peripheral vascular disease; **WIT** = warm ischemia time

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