Duration of Dialysis in Acute Kidney Injury Donors and Transplant Outcomes

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BACKGROUND: Acute kidney injury (AKI) kidneys, including those from donors on dialysis, are often underutilized, although there is increasing data available demonstrating good transplant outcomes. To date, data on the duration of donor dialysis and transplant outcomes are limited.

STUDY DESIGN: This was a single-center study of deceased donor kidney transplants from 2010 to 2022. The study cohort consisted of recipients of deceased donor kidney transplants from donors with AKI and on dialysis. Three groups were identified based on the predetermined interquartile range of donor dialysis duration: 1 to 2 dialysis days, 3 to 4 dialysis days, and 5 or more dialysis days.

RESULTS: During this period, 765 AKI deceased donor transplants were performed, of which 230 were from donors on dialysis. The median dialysis duration was 2 days with a maximum of 13 days. Across the 3 groups, there were no differences in recipient age (p = 0.23) or dialysis vintage (p = 0.70). Donor age (p = 0.86) and kidney donor profile index (p = 0.57) were comparable between the groups. Recipients of deceased donor kidney transplants from donors on dialysis 5 or more days had lower terminal creatinine levels (p = 0.003) and longer cold ischemia times (p = 0.04). Posttransplant, the median length of hospital stay was 3 days for all groups (p = 0.75). There were no differences in delayed graft function occurrence (94.4% vs 86.8% vs 92.1%, p = 0.19), duration of delayed graft function (p = 0.56), or readmissions (p = 0.99). At 1 year posttransplant, the estimated glomerular filtration rate (p = 0.76), patient survival (p = 0.82), or death-censored graft survival (p = 0.28) were comparable.

CONCLUSIONS: Excellent outcomes have been observed in AKI deceased donor kidney transplants, including those coming from donors on dialysis. In this small cohort, the duration of donor dialysis did not adversely affect outcomes. Cautious expansion of the donor pool, including donors on dialysis, should be considered given the ongoing organ shortage. (J Am Coll Surg 2024;238:61–69. © 2023 by the American College of Surgeons. Published by Wolters Kluwer Health, Inc. All rights reserved.)

The increasing gap between the number of patients awaiting a kidney transplant and the number of available donors has led transplant centers to expand their organ acceptance criteria.[1,2] Donors previously considered marginal are now increasingly used with success, with 1 such group being donors with acute kidney injury (AKI).[3]

To date, several single- and multi-center cohort studies have demonstrated good outcomes using kidneys from deceased donors with AKI; however, variability exists within this cohort, and factors such as the degree of tubular injury have been found to influence outcomes.[2-6] Our center previously reported outcomes specific to donors with severe AKI undergoing renal replacement therapy.[7] Although the risk of delayed graft function (DGF) is higher in these kidneys, all other outcomes, including acute rejection, graft survival, and renal allograft function, are favorable.[5,7] To date, the duration of donor dialysis prior to organ donation has not been investigated. Given

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Abbreviations

AKI	=	acute kidney injury
DCD	=	donation after circulatory death
DGF	=	delayed graft function
IQR	=	interquartile range
KDPI	=	kidney donor profile index
PNF	=	primary non function

our center's experience with using AKI kidneys from donors undergoing temporary dialysis, we sought to assess the relationship between the duration of donor dialysis and kidney transplant outcomes.

METHODS

This was a retrospective review of patients who received a deceased donor kidney transplant at the Mayo Clinic Arizona between 2010 and 2022. The study cohort consisted of recipients who received deceased donor kidneys from donors with AKI and on dialysis. Three groups were identified based on the predetermined interquartile range of donor dialysis duration: 1 to 2 dialysis days, 3 to 4 dialysis days, and 5 or more dialysis days. Recipients who received deceased donor kidneys from donors who did not meet these criteria were excluded. Living donor kidneys and multivisceral transplant recipients were also excluded. This study was approved by the Mayo Clinic Institutional Review Board (IRB 22-009347).

We provide education on donor options during the transplant evaluation process to all patients, including information about AKI kidneys and their outcomes. At the time of organ offer, our nurse-led procurement team provides information to the recipient about the potential kidney offer. This information includes if the donor has AKI. Verbal consent is documented in the electronic medical record.

AKI was defined using the Acute Kidney Injury Network criteria, as previously published, with stage 3 applied to donors on dialysis.[3,7] DGF was defined as the requirement for dialysis within 7 days of kidney transplantation. Donor admission creatinine was defined as the first recorded creatinine level at the time of donor hospitalization; peak creatine was defined as the highest recorded creatinine level during donor hospitalization; terminal creatinine was defined as the last recorded creatinine level prior to donation. Early acute cellular rejection was defined as biopsy-proven rejection occurring within 6 weeks of transplantation.

Donor dialysis duration data were extracted from DonorNet. Donors for whom dialysis duration could not be verified were excluded (n = 24). According to our center's protocol, a preimplantation (procurement) frozen section wedge biopsy was performed on AKI kidneys before transplantation.[5,7] Kidneys with >10% cortical necrosis were not transplanted.[4] Postreperfusion (time-zero) formalin-fixed core needle biopsies were performed for most allografts.

All patients received protocolized induction and maintenance immunosuppression. Patients aged less than 65 years received depleting induction (alemtuzumab or thymoglobulin). Patients 65 years of age or older received basiliximab induction and continued maintenance corticosteroids. Steroids were discontinued on postoperative day 5 in patients receiving depleting induction. Maintenance immunosuppression consisted of tacrolimus and mycophenolate mofetil. Tacrolimus was started on posttransplant day 1 or 2, regardless of DGF status. Tacrolimus levels were maintained at 8 to 10 ng/mL for the first month and between 6 to 8 ng/mL thereafter. Recipients were discharged on postoperative day 2 or 3 regardless of DGF status. Recipients with ongoing DGF were managed on an outpatient basis with non-hospital-based dialysis, laboratory studies, and nephrology clinic visits. Per our transplant center's clinical protocol, patients were advised to undergo a 1-year surveillance biopsy.[2]

Outcomes

The primary outcomes included the incidence of DGF, primary nonfunction events (PNF), 1-year renal function, and patient and death-censored graft survival.

Statistical methods

Categorical variables were analyzed using chi-square analysis; 1-way ANOVA was used for quantitative variables. Kaplan-Meier survival analysis was used to assess graft and patient survival. Statistical significance was set at a p value < 0.05. Data are reported as the mean ± SD and median plus interquartile range (IQR). Categorical variables were reported as counts and percentages. Data were analyzed using GraphPad Prism 9.3.1 (2021 GraphPad Software, Inc).

RESULTS

During the study period, 3,103 deceased donor kidney transplants were performed at our center; 254 recipients (8.2%) received kidneys from donors on dialysis. Of these 254 recipients, the duration of dialysis was extracted from DonorNet for 230 donors (90.6%). Among these 230 donors, 124 donors required dialysis for 1 to 2 days

(53.9%), and 68 donors required dialysis for 3 to 4 days (29.6%), 38 donors required dialysis for 5 or more days (16.5%). The median duration of donor dialysis was 2 days. The longest duration of donor dialysis was 13 days (Figure 1).

Recipient and donor characteristics

Recipient characteristics are shown in Table 1. In comparing the 3 groups, there were no differences in recipient age (p = 0.23), sex (p = 0.52), race (p = 0.22), or presence of diabetes (p = 0.09). A small percentage of recipients were preemptive to dialysis at the time of transplantation (5.6% vs 11.7% vs 7.9%, p = 0.32). Dialysis vintage was similar between the 3 groups (mean 3.4 vs 3.6 vs 3.2 years, p = 0.47).

Donor characteristics are shown in Table 1. Donor age (p = 0.86), number of days hospitalized before donation (median, 7 vs 7 vs 8 days, p = 0.37), and kidney donor profile index (KDPI, p = 0.57) were similar between the groups. Admission creatinine was highest for donors with 3 to 4 days of dialysis (mean 2.8 mg/dL, p = 0.03) while peak creatinine was highest for donors with 1 to 2 days of dialysis (mean 7.9 mg/dL, p = 0.02). Terminal creatinine was lowest for donors with 5 or more days of dialysis (mean 2.8 mg/dL, p = 0.003). In the 3 cohorts, anoxia was the most common cause of donor death (82.3% vs 76.5% vs 81.6%, p = 0.06), and drug intoxication followed by cardiovascular events were the most common mechanisms of injury (p = 0.02). Cold ischemia times were longer for kidney allografts from donors on dialysis 5 or more days (mean 28.9 hours, p = 0.04). Donation after circulatory death (DCD) donor utilization was uncommon and similar across the 3 groups (p = 0.18). There were no differences in allocation patterns (p = 0.19).

Posttransplant outcomes

The hospital length of stay (LOS) was similar among the 3 groups (median 3 days, p = 0.75) (Table 2). For donors with 1 to 2, 3 to 4, and 5 or more dialysis days, DGF was observed in 94.4%, 86.8%, and 92.1% of recipients, respectively (p = 0.19). The duration of DGF did not vary among the 3 groups (median, 12 vs 11 vs 10 days, p = 0.46). Most patients did not require any readmissions within 30 days of transplant (62.1% vs 61.8% vs 63.2%, p = 0.99). For those who required readmission, there were no differences between the 3 groups (37.9% vs 38.2% vs 36.8%, p = 0.99) and the majority of patients only required a single readmission (70.2% vs 80.8% vs 64.3%, p = 0.48). There were also no differences in the number of outpatient clinic visits (p = 0.70). PNF (p = 0.25) and acute cellular rejection (p = 0.31) events were uncommon and similar among the 3 groups. At 1 year postoperative, there were no differences in the estimated glomerular filtration rate (mean 60.8 vs 62.7 vs 58.7 mL/min, p = 0.76).

Two PNF events were observed (n = 1, 3 to 4 dialysis days; n = 1, 5 or more dialysis days). Recipient-related infectious factors contributed to these PNF events. The mate kidneys of both PNF cases were also transplanted at our center. Both mate kidneys have good function.

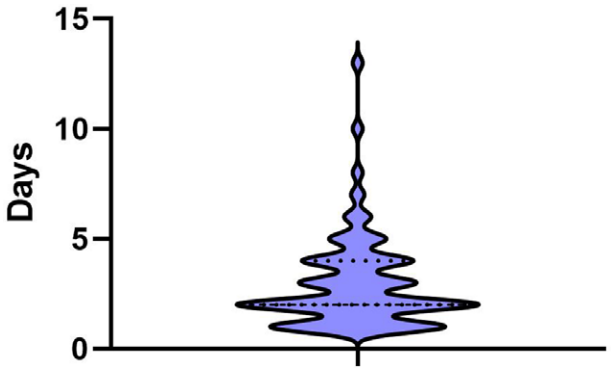

Figure 1. Donor dialysis days.

Survival

The median follow-up period were 3 years (IQR 1.0 to 5.6), 2.7 years (IQR 2.1 to 4.2), and 2.5 years (IQR 0.9 to 4.3) for recipients receiving allografts from donors with 1 to 2, 3 to 4, and 5 or more dialysis days, respectively. Patient (p = 0.82) and death-censored graft (p = 0.28) survival rates were similar among the 3 groups (Figure 2). For donors with 1 to 2, 3 to 4, and 5 or more dialysis days, 1-year patient survival rates were 99.2%, 100%, and 97.4%; 1-year death-censored graft survival rates were 96.8%, 98.5%, and 89.5% respectively.

Biopsy data

Time-zero postreperfusion biopsies were performed in 194 recipients (84.3%) (Table 3). Cortical necrosis was more commonly observed in kidney allografts from donors with 3 to 4 dialysis days (30.5%, p = 0.04). Most of the time-zero biopsies showed mild tubular injury (p = 0.40). Severe tubular injury (p = 0.4) and fibrin thrombi (p = 0.30) were similar among dialysis days 1 to 2, 3 to 4, and 5 or more. Of the 8 allografts that had fibrin thrombi (Table 3), 5 (n = 5, 62.5%) had diffuse glomerular fibrin thrombi (>50% of glomeruli involved) and 3 (n = 3, 37.5%) had focal involvement. A total of 75% of biopsies with diffuse fibrin thrombi had glomerular ischemia, 62.5% (n = 5) had endothelial swelling, and 37.5% (n = 3) had arteriolar involvement. Two of 3 grafts that had arteriolar involvement also had cortical necrosis ranging from 15% to 20%. There were no differences among the 3 groups with regard to glomerulosclerosis (mean 2.6%

Table 1. Recipient and Donor Characteristics

Variable	1–2 donor dialysis days (n = 124)	3–4 donor dialysis days (n = 68)	≥5 donor dialysis days (n = 38)	p Value
Recipient				
Age, y, mean ± SD	56.0 ± 13.0	52.6 ± 13.5	55.2 ± 11.6	0.23
Sex, m, n (%)	78 (62.9)	40 (58.8)	21 (55.3)	0.52
Race, n (%)				0.22
White	49 (39.5)	23 (33.8)	17 (44.7)	—
Hispanic	19 (15.3)	13 (19.2)	6 (15.8)	—
Black	31 (25.0)	15 (22.1)	7 (18.4)	—
Asian	7 (5.6)	12 (17.6)	5 (13.2)	—
AI/AN	18 (14.5)	5 (7.4)	3 (7.9)	
Preemptive, n (%)	7 (5.6)	8 (11.7)	3 (7.9)	0.32
Dialysis time, y, mean ± SD	3.4 ± 2.1	3.6 ± 2.3	3.2 ± 2.0	0.70
Diabetes, n (%)	64 (51.6)	24 (35.3)	16 (42.1)	0.09
Prior kidney transplant, n (%)	5 (4.0)	5 (7.4)	1 (2.6)	0.47
Donor				
Age, y, mean ± SD	31.0 ± 10.3	31.9 ± 9.8	31.6 ± 12.7	0.86
Days hospitalized, median (range)	7 (5, 8)	7 (5, 7)	8 (5, 14)	0.37
Creatinine, mg/dL, mean ± SD				
Admission	1.9 ± 1.0	2.8 ± 3.3	2.2 ± 1.3	0.03
Peak	7.9 ± 3.2	6.7 ± 3.1	6.5 ± 4.0	0.02
Terminal	4.6 ± 2.7	3.7 ± 2.2	2.8 ± 1.8	0.003
KDPI, %, mean ± SD	38.6 ± 18.8	36.6 ± 21.2	35.0 ± 21.0	0.57
Cause of death, n (%)				0.06
Anoxia	102 (82.3)	52 (76.5)	31 (81.6)	—
Head trauma	15 (12.1)	14 (20.6)	2 (5.3)	—
CV/stroke	3 (2.4)	1 (1.5)	4 (10.5)	—
Other	4 (3.2)	1 (1.5)	1 (2.6)	—
Mechanism of injury, n (%)				0.02
Cardiovascular	32 (25.8)	17 (25.0)	6 (15.8)	—
Blunt trauma	10 (8.1)	6 (8.8)	2 (5.3)	—
Drowning	4 (3.2)	0 (0.0)	1 (2.6)	—
Drug intoxication	53 (42.7)	35 (51.5)	22 (57.9)	—
Asphyxiation	5 (4.0)	0 (0.0)	0 (0.0)	—
Gunshot wound	5 (4.0)	8 (11.8)	2 (5.3)	—
Intracranial bleed	3 (2.4)	1 (1.5)	4 (10.5)	—
Other	12 (9.7)	1 (1.5)	1 (2.6)	—
DCD, n (%)	10 (8.1)	6 (8.8)	0 (0.0)	0.18
Allocation, n (%)				0.19
Local	31 (25.0)	28 (41.2)	11 (28.9)	—
Regional	37 (29.8)	17 (25.0)	13 (34.2)	—
National	56 (45.2)	23 (33.8)	14 (36.8)	—
CIT, h, mean ± SD	23.8 ± 5.9	21.5 ± 5.6	28.9 ± 6.5	0.04
Induction, n (%)				0.37
Alemtuzumab	78 (62.9)	45 (66.2)	28 (73.7)	—
Basiliximab	41 (33.1)	17 (25.0)	8 (21.1)	—
Thymoglobulin	5 (4.0)	6 (8.8)	2 (5.3)	—

AI/AN, American Indian or Alaska native; CIT, cold ischemia time; CV, cardiovascular; DCD, donation after circulatory death; KDPI, kidney donor profile index.

Table 2. Posttransplant Outcomes

Variable	1–2 donor dialysis days	3–4 donor dialysis days	≥5 donor dialysis days	p Value
Hospital LOS, d, median (range)	3 (2–4)	3 (2–4)	3 (2–4)	0.75
DGF, n (%)	117 (94.4)	59 (86.8)	35 (92.1)	0.19
DGF duration, d, median (range)	12 (8, 17)	11 (7, 13)	10 (6, 18)	0.46
30-days readmission, n (%)	47 (37.9)	26 (38.2)	14 (36.8)	0.99
Readmission frequency, n (%)				0.48
Single readmission	33 (70.2)	26 (80.8)	9 (64.3)	—
≥2 readmissions	14 (29.8)	5 (19.2)	5 (35.7)	—
Number of outpatient visits, mean ± SD	11.1 ± 7.7	12.2 ± 10.0	12.0 ± 13.1	0.70
PNF, n (%)	0 (0.0)	1 (1.5)	1 (2.6)	0.25
Early ACR event, n (%)	5 (4.0)	1 (1.5)	0 (0.0)	0.31
1-year eGFR, mL/min, mean ± SD	60.8 ± 20.7	62.7 ± 23.4	58.7 ± 19.2	0.76
eGFR <30 mL/min, n (%)	6 (5.0)	2 (5.4)	1 (2.9)	0.75

ACR, acute cellular rejection; DGF, delayed graft function; eGFR, estimated glomerular filtration rate; LOS, length of stay; PNF, primary nonfunction.

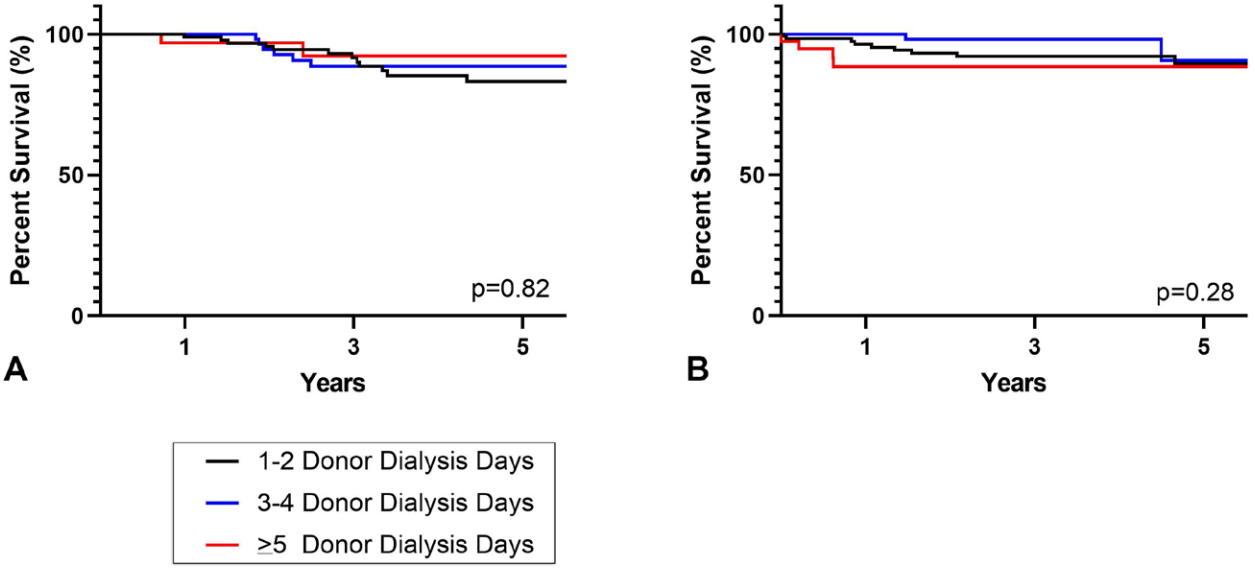

Figure 2. Outcomes for (A) patient survival and (B) death-censored graft survival.

vs 1.6% vs 1.5%, p = 0.58), fibrosis (ci, p = 0.44), tubular atrophy (ct, p = 0.53), vascular intimal thickening (cv, p = 0.96) and arteriolar hyalinosis (ah, p = 0.51).

One-year protocol biopsies were performed in 114 recipients (51.6%) (Table 4). There were no differences among the 3 groups with regard to glomerulosclerosis (mean 4.7% vs 3.7% vs 5.6%, p = 0.80), fibrosis (ci, p = 0.96), tubular atrophy (ct, p = 0.90), vascular intimal thickening (cv, p = 0.27) and arteriolar hyalinosis (ah, p = 0.47).

DISCUSSION

With increasing experience, transplant centers have cautiously begun to expand their criteria for kidney acceptance. These changes have resulted in a slow but incremental increase in the number of kidney transplants from donors with AKI donors. With this experience, excellent outcomes have been increasingly reported in AKI kidneys, including those from donors on dialysis.[1-4,7-9] Despite growing data supporting favorable outcomes for AKI kidneys, the nonprocurement and discard rates remains high and are even higher for AKI kidneys from donors undergoing renal replacement therapy.[4,10-12] Kidney allografts from donors undergoing dialysis account for a small percentage of kidney transplants, and data on their outcomes remains limited.[7] Our center has previously reported outcomes specific to donors with severe AKI undergoing renal replacement therapy; however, the

Table 3. Time-Zero Biopsy Findings

Variable	1–2 donor dialysis days	3–4 donor dialysis days	≥5 donor dialysis days	p Value
Tubular injury, n (%)				0.40
Mild	58 (56.3)	31 (52.5)	17 (56.7)	—
Moderate	32 (31.1)	25 (42.4)	11 (36.7)	—
Severe	13 (12.6)	3 (5.1)	2 (6.7)	—
Cortical necrosis, n (%)	16 (15.5)	18 (30.5)	4 (13.3)	0.04
Fibrin thrombi, n (%)	5 (4.9)	1 (1.7)	2 (6.5)	0.49
Glomerulosclerosis, %, mean ± SD	2.6 ± 8.1	1.6 ± 3.5	1.5 ± 2.6	0.58
Fibrosis, median (range)	0 (0–0)	0 (0–0)	0 (0–0)	0.44
Tubular atrophy, median (range)	0 (0–0)	0 (0–0)	0 (0–0)	0.53
Vascular intimal thickening, median (range)	0 (0–0)	0 (0–0)	0 (0–1)	0.96
Arteriolar hyalinosis, median (range)	0 (0–0)	0 (0–0)	0 (0–1)	0.51

Table 4. 1-Year Biopsy Findings

1-year biopsy finding	1–2 donor dialysis days	3–4 donor dialysis days	≥5 donor dialysis days	p Value
Glomerulosclerosis, %, mean ± SD	4.7 ± 10.4	3.7 ± 6.2	5.6 ± 14.3	0.80
Fibrosis, median (range)	1 (0–1)	1 (1–1)	1 (0–1)	0.96
Tubular atrophy, median (range)	1 (1–1)	1 (1–1)	1 (1–1)	0.90
Vascular intimal thickening, median (range)	0 (0–1)	0 (0–1)	0 (0–0)	0.27
Arteriolar hyalinosis, median (range)	0 (0–0)	0 (0–0)	0 (0–0)	0.47

association between the duration of donor dialysis and kidney transplant outcomes has not been investigated.[7] In this small cohort of AKI kidneys transplanted from donors on dialysis, the median duration of donor dialysis was 2 days, with the longest donor dialysis duration being 13 days. The overall incidence of DGF was high (>90%), which is similar to our previous observations.[7] Despite variation in donor dialysis duration, there were no differences observed in recipient DGF duration and outcomes at 1 year posttransplant.

Different strategies have been described to assess AKI kidneys, including the use of machine perfusion and biopsy assessment.[2-4,13] At our center, we followed a standard protocol to assess and accept AKI kidneys for transplantation, which includes obtaining and reviewing preimplantation (procurement) biopsies by our transplant center's pathology team prior to utilization.[2-4,7] As noted in the postreperfusion (time zero) biopsy data (Table 3), despite the donor requirement for dialysis, most allografts histologically had mild tubular injury, although severe tubular injury and cortical necrosis were noted in a smaller subset of allografts (Table 3). Despite conflicting data on procurement biopsies and their impact on discard and outcomes, biopsies play an important role in donors with severe AKI, where there is need to assess for irreversible cortical necrosis.[2-4,14]

Although more readily available, donor clinical history, urine output, and serum creatinine are not reliable surrogates for predicting the degree of tubular injury observed on biopsy.[15] As shown in this study cohort, the donor admission creatinine was highest for donors with 3 to 4 days of dialysis, whereas peak and terminal creatinine were highest for donors with 1 to 2 dialysis days and lowest for those with 5 or more dialysis days (Table 1). Additionally, the incidence of cortical necrosis varied from 13% in donors with 5 or more dialysis days to 31% in donors with 3 to 4 days of dialysis. When assessing AKI kidneys for transplantation, we transplant kidneys with cortical necrosis, however, caution is recommended when this finding exceeds 10%. As previously reported, we observed inferior outcomes when combining donor factors, such as AKI and chronic changes observed in kidneys with higher KDPI levels.[5] Most kidney allografts in this cohort had histological changes limited to AKI, with minimal chronic changes (Table 3). In this context, the lack of routine biopsy to guide decision making likely accounts for some of the discrepancies observed in the literature regarding AKI kidney transplant outcomes.[16]

While AKI can be reversible in the nontransplant setting, repeated AKI events increase the risk for chronic kidney disease.[17] Most studies have reported favorable outcomes with AKI kidneys, although there have been reports of inferior outcomes, including a study published by our transplant center where we reported our experience with high KDPI AKI kidneys.[5,16] The role of procurement biopsies remained debated in transplant, however

procurement biopsies allow for the objective identification of irreversible chronic and acute changes, such as fibrosis and cortical necrosis and we have found them to be critical in guiding decision making on AKI kidney utilization. Assessing AKI donors based on terminal creatinine alone can be misleading and cause transplant centers to incorrectly commit to either nonutilization or transplant. Additional caution should be undertaken when assessing for multiple chronic kidney disease (CKD) risk variables such as advanced donor age (high KDPI) and AKI and using clinical data alone is inadequate. Similar to the nontransplant CKD model where sequential AKI events lead to CKD, sequential AKI events along with ischemia reperfusion injury can incrementally reduce the quality of transplanted kidneys. In most studies, AKI donors have more favorable characteristics, including younger age and an absence of chronic biopsy changes, suggesting these donors represent a select subset of AKI donors that have had less exposure to repeated AKI events.[2-4]

Fibrin thrombi were observed in 8 allografts in this cohort. Fibrin thrombi are common in AKI kidneys, particularly when donors die from trauma or head injury. This finding of glomerular fibrin thrombi is generally self-limiting, and we do not routinely modify posttransplant management, although mild thrombocytopenia, increased lactate dehydrogenase, and decreased haptoglobin are frequently observed in the first few days posttransplant.[18] Most of the observed fibrin thrombi were focal, however, as observed even in this small cohort, diffuse thrombi with arteriolar involvement and necrosis did occur. Therefore, additional caution should be exercised when these characteristics are present.

At 1 year posttransplant, excellent estimated glomerular filtration rate was observed across all groups (Table 2). Similar to postreperfusion (time-zero) biopsy findings, 1-year biopsies were favorable and without significant chronic changes (Table 4). In the present study, we did not compare outcomes to non-AKI allografts, although we have previously done so and demonstrated equivalent outcomes.[7] These favorable outcomes reflect careful prescreening at the time of organ offer. Kidney allografts in this cohort were obtained from young donors with an overall low KDPI score and minimal chronic changes on time-zero biopsy. The absence of chronic baseline changes allows for cautious tolerance to severe tubular injury and focal cortical necrosis. Significant cortical necrosis typically results in tubular atrophy and fibrosis, which we did not observe in the 1-year biopsies (Table 4).[19-21] Studies conducted in the general population have raised concerns about patients with AKI, particularly those requiring dialysis, and those with prolonged durations of severe AKI, as they are more likely to develop CKD.[22,23] It is important to note that individuals in these studies often have preexisting CKD and other conditions that influence their recovery and predispose them to CKD progression.

The overall incidence of delayed graft function was very high across all 3 donor dialysis groups, although it was comparable to that previously observed for donors with severe AKI and those on dialysis.[7] Despite differences in donor exposure to dialysis, the recipient duration of DGF was similar. Management of DGF remains challenging for transplant centers and presents a potential barrier to the broader utilization of kidney allografts from donors with AKI.[24] The association of DGF with increased resource utilization, longer hospital lengths of stay, and increased frequency of outpatient visits is difficult for both patients and transplant centers and continues to be a deterrent to transplant centers in accepting kidneys that are at risk for DGF.[25-28] The median length of hospital stay in our study was 3 days for all donor dialysis groups, most patients did not require readmission, and there were no differences in outpatient visits. All of these findings are reflective of our center's experience in managing patients with DGF. Improved sharing of best practices across transplant centers, easier access to outpatient resources, including posttransplant dialysis, optimization of immunosuppression to prevent early rejection, and establishment of DGF consensus guidelines, are potential strategies to further limit these barriers.

Although procurement rates for kidneys with severe AKI have been increasing in recent years, there has also been an increasing trend toward discard.[11] Liu et al. reported that among all discarded kidneys, 50% were from donors with AKI.[8] Similarly, a recent study looking at US data, found that kidneys with a terminal creatinine >2.00 mg/dl were 22 times more likely to not be procured compared to kidneys coming from donors with a terminal creatinine <1.00 mg/dL.[12] Higher KDPI scores driven by higher terminal donor creatinine may be a variable contributing to the discard of viable AKI kidneys.[18] Similar to our AKI experience, our transplant center's DCD utilization has also grown over time, although the overall absolute number of AKI DCD kidneys remains small. We have previously shared our experience with AKI DCD donors, although this experience predominantly included AKI donors not requiring dialysis.[3] In this study, there were no short- or long-term differences in patient or allograft survival between AKI kidneys coming from DCD or donation after brain death donors. In multivariate models, the DCD/donation after brain death status had no significant impact on the estimated GFR, rejection, and progression of interstitial fibrosis/tubular atrophy on protocol biopsy.[3] Within this context, there is a significant opportunity to expand the

utilization of kidneys with severe AKI, including those coming from DCD donors on dialysis.[12] Patient education is also very important in increasing the successful use of AKI kidneys. We provide extensive education on donor options during the transplant evaluation process, including information specific to AKI kidneys and their outcomes. This discussion also includes information on DGF. Ensuring that patients feel comfortable with this information is very important and, as a result, it is very rare that we encounter patients who are unwilling to accept AKI kidneys.

It is important to note that this study included a small cohort of donors on dialysis and that the data reported are reflective of a single-center experience. Although we have provided details specific to our process for assessing and utilizing these donors, we acknowledge that our experience may not be reflective of experiences at other centers. The outcomes described here reflect only of the kidney allografts with AKI used for transplantation. We did not have data specific to AKI kidneys that we assessed but ultimately declined. Notably, the overall number of DCD donors in this cohort was very small. Although have previously found stability when comparing postreperfusion (time-zero) biopsies and 1-year biopsies and have also not observed an association between DGF and fibrosis progression, only 50% of patients in this study had a 1-year protocol biopsy.[2,3,18] While this was a single-center report, to our knowledge, this is the first study to investigate the association between donor dialysis duration and kidney transplant outcomes. Given the overall limited experience with this select group of kidney allografts, these data remain valuable.

CONCLUSIONS

Excellent outcomes have been reported for AKI kidney transplants, including those from donors undergoing dialysis. In this small cohort, we found that the duration of donor dialysis did not adversely impact transplant outcome and that outcomes appear to be similar when comparing shorter and longer durations of donor dialysis. Cautious expansion of the donor pool, including AKI donors with longer durations of dialysis, should be considered given the ongoing organ shortage.

Author Contributions

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