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Postkidney Transplant Delayed Graft Function Outcomes Are Not Worsened by Deceased Donor Type

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ABSTRACT

Introduction: Kidney-delayed graft function (DGF) is more common in donation after circulatory death (DCD) donors in comparison to donatation after brain death (DBD). We analyzed deceased kidney transplant recipients (DDKTR) at our center between 2005 and 2019, stratified by donor type (DBD vs. DCD).

Methods: We assessed risk factors for DGF, acute rejection (AR), graft failure (GF), along with the death with functioning graft (DWFG), and the interaction between types of donors for those complications.

Results: Among 2543 DDKTRs, 804 (32%) were from DCD donors. Older donor age, higher recipient body mass index, and receipt of a depleting induction agent were associated with increased risk for DGF in both DBD and DCD. In contrast, preemptive transplant and female recipient gender were associated with reduced risk. Additional risk factors in DBD, but not in DCD recipients, included higher donor terminal serum creatinine, higher kidney donor profile index, right donor kidney, and prolonged cold ischemia time. Female donors were associated with a reduced risk of DGF only among DCD donors. DGF was associated with higher AR and GF, with no significant differences across donor types, DBD vs. DCD (AR: adjusted hazard ratio [aHR] 2.22 vs. 2.37, p-interaction = 0.65; GF: 3.04 vs. 2.56; p-interaction = 0.47). DGF was associated with a higher risk for DWFG among DBD (aHR: 3.43, 95% CI: 1.96–6.00, $p < 0.001$) but not with DCD (aHR: 1.90, 95% CI: 0.78–4.61, $p = 0.16$), with p-interaction of 0.15

Conclusion: Despite higher DGF rates in DCD, early adverse outcomes after DGF were similar between deceased donor types and should not deter the utilization of DCD kidneys.

1 | Background

Delayed graft function (DGF) occurs in a significant proportion of deceased donor kidney transplants (DDKTs) and may impact graft function and survival [1, 2]. The incidence rate of DGF among DDKTs has risen from 14.7% between 1985 and 1992 to 29% between 2010 and 2018, largely due to increased expansion of donor acceptability criteria, including donation after circulatory

Abbreviations: aHR, adjusted hazard ratio; AR, acute rejection; BMI, body mass index; CIT, cold ischemia time; DBD, donatation after brain death; DCD, donation after circulatory death; DCGF, death-censored graft failure; DDKT, deceased donor kidney transplant; DGF, delayed graft function; DSA, donor-specific antibodies; GF, graft failure; HR, hazard ratio; IRI, ischemia-reperfusion injury; IVIG, intravenous immunoglobulin; KDPI, kidney donor profile index; TCMR, T-cell mediated rejection.

death (DCD), and major allocation changes which have led to broader sharing and significant increase in organ travel and subsequent cold ischemia time (CIT) [3–5].

Previous studies have shown that DGF is associated with older donor age, elevated terminal serum creatinine, greater body mass index (BMI), donor cardiac arrest or hypotension, long CIT, and DCD donor type. Jushinskis et al. additionally reported an increased risk of DGF with recipients of older age and female gender [6–8]. Due to significant growth in these donor and recipient risk factors, it's no surprise that DGF rates have increased over time. While these practices have allowed increased access to deceased donor transplantation, it is important to note that DGF has been associated with inferior graft function, increased risk of acute rejection (AR), and shorter graft survival, although these findings are controversial [9, 10]. Additionally, it is unclear how DGF affects posttransplant outcomes across various donor types.

Given the increase in DCD kidney transplantation and its associated increased risk of DGF, we sought to explore the downstream effects of postkidney transplant DGF stratified by deceased donor type. To better understand the benefits and consequences of using donatation after brain death (DBD) vs. DCD kidneys, we compared the risk factors and outcomes of postkidney transplant DGF at our center. We also sought to determine if donor type modified the impact of postkidney transplant DGF on short-term outcomes.

2 | Methods

This is a single-center observational study conducted at the University of Wisconsin, focusing on all adult DDKT recipients. The study includes recipients of either DBD or DCD kidney transplants performed between January 2005 and December 2019. We excluded recipients of multiorgan transplants. Also, recipients who had early graft failure (GF) within 2 weeks posttransplant ($n = 16$) were excluded; of these, 8 had DGF. Additionally, living donor kidney transplant recipients were excluded due to the uncommon occurrence and different mechanisms and risk factors of DGF compared to deceased donor recipients.

DGF was defined as the need for dialysis within 7 days posttransplant, regardless of the number of dialyses. We determined the percentage of recipients that had DGF and then determined the association between various donor, immunologic, and recipient factors and DGF. We further determined the association between DGF and the following outcomes of interest: AR, GF, and death-censored graft failure (DCGF) within 12 months posttransplant. Outcomes were limited to the first 12 months posttransplant to better correlate DGF with early posttransplant results. All graft rejections were confirmed by biopsy. GF included all causes of GF, including death. DCGF was defined as a requirement for chronic dialysis or retransplantation.

This study was approved by the University of Wisconsin Health Sciences Institutional Review Board (IRB protocol number: 2014-1072) and adhered to the Declaration of Helsinki. The clinical and research activities reported were consistent with the Principles of the Declaration of Istanbul on Organ Trafficking and Transplant Tourism. Due to the nature of this study, informed consent specific to this research was not obtained from patients.

2.1 | Immunosuppressive Protocols

The standard protocol for most kidney transplant recipients at our institution involves induction therapy using either a depleting agent (antithymocyte globulin or alemtuzumab) or a nondepleting agent (basiliximab). This is followed by a maintenance immunosuppressive regimen of tacrolimus and mycophenolic acid, with or without prednisone. The choice between depleting and nondepleting agents was based on immunological risk factors. Depleting agents were preferred for patients with pretransplant donor-specific antibodies (DSA), glomerulonephritis as the cause of kidney disease, and those who will undergo early steroid withdrawal [11]. Though not formalized in a protocol, patients at risk for DGF generally received a depleting agent, as decided by the transplant surgeon.

2.2 | Kidney Allograft Biopsy

Biopsies were performed mainly for causes, such as an unexplained increase in serum creatinine or proteinuria. Protocol biopsies were performed at 3 and 12 months for patients with pretransplant DSA or those who developed de novo DSA [12]. An additional reason for allograft biopsy was poor graft function without improvement within 7–14 days posttransplant, among recipients with DGF.

2.3 | Rejection Protocols

The treatment for allograft rejection varied based on the severity and timing of antibody-mediated rejection (AMR) and acute T-cell-mediated rejection (TCMR), as previously described [13]. Briefly, TCMR was managed with a steroid pulse for borderline and Banff stage I rejection, while Banff stages II and III were treated with a steroid pulse plus antithymocyte globulin. AMR within 3 months posttransplant was treated with dexamethasone bolus, plasmapheresis, and intravenous immunoglobulin (IVIG). The treatment regimen for episodes occurring more than 3 months posttransplant included a dexamethasone bolus with taper, IVIG, plus/minus rituximab, depending on the severity of the rejection.

2.4 | DGF Management

Prior to 2011, patients with DGF were managed as inpatients until their graft function was sufficient to avoid dialysis. After 2011, patients with DGF have been followed as outpatients in a dedicated DGF clinic, as previously described [14]. They were either discharged to their homes or a nearby hotel with a support person and were required to attend a clinic visit within 1–3 days

TABLE 1 | Baseline characteristics.

Variables		DBD ($n = 1739$)	DCD ($n = 804$)	p
Delayed graft function		364 (20.9%)	375 (46.6%)	**< 0.001**
Donor factors	Mean age (years)	44.9 (13.4)	41.7 (16.7)	**< 0.001**
	Female (%)	33.0	39.4	**0.002**
	Non-White (%)	5.1	10.0	**< 0.001**
	Mean body mass index (Kg/m^2)	29.7 (7.7)	28.5 (7.4)	**0.003**
	Cause of death: Cardiovascular (%)	19.7	34.0	**< 0.001**
	Terminal serum creatinine (mg/dL)	0.84 (0.44)	1.03 (0.81)	**< 0.001**
	Mean kidney donor profile index (%)	51.1 (20.1)	46.6 (21.6)	**< 0.001**
	Right kidney (%)	50.6	54.1	0.10
	Cold ischemia time (hrs)	14.3 (5.9)	16.1 (6.0)	**< 0.001**
Immunology factors	cPRA > 20% (%)	23.3	30.4	**< 0.001**
	Mean HLA mismatch (of 6)	4.2 (1.3)	3.9 (1.6)	**< 0.001**
	Previous transplant (%)	15.7	22.5	0.18
Recipients Factors	Mean age (years)	53.6 (12.0)	52.6 (12.8)	0.06
	Female (%)	37.1	39.0	0.34
	Non-White (%)	32.1	27.5	**0.02**
	Mean body mass index (Kg/m^2)	28.3 (5.2)	28.1 (5.2)	0.24
	Causes of ESRD (%)			0.20
	Diabetes	30.2	26.1	
	Hypertension	14.4	14.6	
	Glomerulonephritis	11.3	12.0	
	Polycystic kidney disease	22.6	25.9	
	Other	21.4	21.6	
	Induction immunosuppression (%)			0.24
	Alemtuzumab	12.1	11.7	
	Antithymocyte globulin	34.7	31.6	
	Basiliximab	53.2	56.7	
	Early steroid withdrawal (%)	6.5	5.5	0.31
	Preemptive transplant (%)	10.9	13.1	0.13
	CMV high risk (D+/R−) (%)	18.5	17.9	0.69

Bold values siginifies statistical significant with $p < 0.05$.
Abbreviation: DBD, donatation after brain death.

postdischarge. Dialysis was scheduled as needed on the same day in our inpatient dialysis unit.

2.5 | Statistical Analysis

Continuous data were compared using Student's *t*-test or the Wilcoxon rank-sum test, as appropriate, while categorical data were analyzed using Fisher's exact test or chi-square test. p values ≤ 0.05 were considered statistically significant. Factors associated with DGF for each risk factor were computed using both univariate and multivariate analyses. Kaplan–Meier analyses were performed for AR, GF, and DCGF categorized by DBD vs. DCD. An interaction analysis was performed to determine if effect modification was present in our outcomes of interest across donor types. The reported p value here reflects the p value for the interaction between the donor types.

3 | Results

A total of 2543 DDKTs were included; 1739 (68%) were DBD and 804 (32%) were DCD transplant recipients (Table 1). A total of 739 (29.1%) recipients had DGF. DGF was more common in DCD (375 recipients, 46.6%) compared to DBD transplant recipients (364 recipients, 20.9%) ($p < 0.001$). A total of 134 (18.1 %) recipients with DGF needed only one session of dialysis. 33 of 375 (8.8%) were in DCD, and 101 of 364 (27.7%) were in DBD kidney transplant recipients. DBD donors were older, had greater BMI and mean kidney profile index (KDPI), were less

TABLE 2 | Risk factors for DGF in donation after brain death donors.

		DBD					
		Univariate			Multivariate		
		HR	95% CI	*p*	HR	95% CI	*p*
Donor factors	Age (per year)	1.02	1.02–1.03	**< 0.001**	1.02	1.00, 1.03	**0.01**
	Female	0.98	0.77–1.24	0.86	0.95	0.73, 1.24	0.73
	Non-White	0.83	0.56–1.24	0.37	0.82	0.52, 1.29	0.39
	Body mass index	1.02	1.00–1.03	**0.01**	1.01	0.99, 1.02	0.54
	Cause of death: Cardiovascular	1.50	1.19–1.91	**0.001**	1.08	0.80–1.45	0.62
	Terminal serum Creatinine	1.43	1.18–1.74	**< 0.001**	1.63	1.29–2.05	**< 0.001**
	Kidney donor profile index	1.01	1.01–1.02	**< 0.001**	1.01	1.00–1.02	**0.01**
	Right kidney	1.17	0.93–1.47	0.19	1.44	1.12–1.87	**0.005**
	Cold ischemia time	1.01	0.99–1.03	0.16	1.03	1.00–1.05	**0.04**
Immunologic factors	cPRA > 20%	1.23	0.97–1.58	0.09	1.38	1.00–1.90	0.05
	HLA mismatch	1.06	0.98–1.14	0.14	1.06	0.97–1.15	0.22
	Previous transplant	0.98	0.74–1.29		0.92	0.64–1.31	0.64
Recipients factors	Age	1.01	1.00–1.02	0.07	1.00	0.99–1.01	0.95
	Female	0.68	0.53–0.86	**0.002**	0.68	0.51–0.89	**0.005**
	Non-White	1.19	0.92–1.53	0.19	1.03	0.77–1.37	0.86
	Body mass index	1.08	1.05–1.10	**< 0.001**	1.08	1.05–1.10	**< 0.001**
	Cause of ESRD: Diabetes vs. other	1.57	1.22–2.01	**< 0.001**	1.17	0.88–1.55	0.29
	Depleting induction	2.21	1.74–2.81	**< 0.001**	2.10	1.60–2.76	**< 0.001**
	Early steroid withdrawal	1.30	0.80–2.09	0.29	0.89	0.52–1.54	0.68
	Preemptive transplant	0.12	0.06–0.24	**< 0.001**	0.13	0.06–0.27	**< 0.001**
	CMV high risk (D+/R−)	1.02	0.75–1.37	0.91	0.98	0.70–1.36	0.89

Bold values siginifies statistical significant with $p < 0.05$.

likely to be female, nonwhite, have a cardiovascular cause of death, and had lower terminal serum creatinine and shorter CIT compared to DCD donors. DBD transplant recipients had a greater HLA mismatch and were less likely to have a cPRA>20%. Additionally, a greater proportion of DBD transplant recipients were non-White.

3.1 | Risk Factors for DGF

Older donor age, higher recipient BMI, and depleting induction were associated with increased risk for DGF in both DBD and DCD kidney transplant recipients (Tables 2 and 3). Unique independent risk factors for DGF among DBD recipients included higher donor terminal serum creatinine (adjusted hazard ratio [aHR] 1.63, $p < 0.001$), higher KDPI (aHR 1.01, $p = 0.01$), right kidney graft (aHR 1.44, $p = 0.005$), and prolonged CIT (aHR 1.03, $p = 0.04$). On the contrary, female recipients and preemptive transplants were associated with lower incidence of DGF in both DBD (aHR 0.68, $p = 0.005$; aHR 0.13, $p < 0.001$) and DCD (HR 0.59, $p = 0.002$; HR 0.11, $p < 0.001$) recipients. Female donors were also associated with a lower risk of DGF among DCD kidney transplants (HR 0.68, $p = 0.03$).

3.2 | Outcomes

AR was more common in recipients with DGF among both DBD (HR: 2.51, 95% CI: 1.97–3.21, $p < 0.001$) and DCD donors (HR: 2.09, 95% CI: 1.47–2.95, $p < 0.001$). However, risk of AR after DGF when comparing DBD and DCD was not significantly different, with a p-interaction of 0.40 (Table 4). This was further confirmed by an unadjusted Kaplan–Meier (KM) survival analysis (Figure 1A). Similar outcomes were observed even after adjustment for multiple baseline characteristics for both DBD (aHR: 2.22, 95% CI: 1.70–2.90, $p < 0.001$) and DCD (aHR: 2.37, 95% CI: 1.62–3.48, $p < 0.001$) with p-interaction 0.65.

The risk for GF was also greater after DGF in both DBD (HR: 3.61, 95% CI: 2.40–5.44, $p < 0.001$) and DCD (HR: 2.63, 95% CI: 1.33–5.18, $p = 0.005$). However, the risk of GF after DGF when comparing DBD and DCD was not significantly different, with a p-interaction of 0.44 (Table 4). This was further confirmed by unadjusted KM survival analysis (Figure 1B). Adjustment for baseline characteristics yielded similar outcomes in both DBD (aHR: 3.04, 95% CI: 1.94–4.76, $p < 0.001$) and DCD (aHR: 2.56, 95% CI: 1.22–5.39, $p = 0.01$) with p-interaction 0.47.

TABLE 3 | Risk factors for DGF in donation after circulatory death donors.

		DCD					
		Univariate			Multivariate		
		HR	95% CI	*p*	HR	95% CI	*p*
Donor factors	Age (per year)	1.02	1.01–1.03	**< 0.001**	1.03	1.01–1.05	**< 0.001**
	Female	0.72	0.53–0.97	**0.03**	0.68	0.48–0.95	**0.03**
	Non-White	0.51	0.26–1.01	0.05	0.54	0.26–1.13	0.10
	Body mass index	1.03	1.01	1.05	1.02	1.00–1.04	0.06
	Cause of death: Cardiovascular	1.34	0.95–1.90	0.10	1.28	0.85–1.93	0.23
	Terminal serum Creatinine	1.23	0.89–1.68	0.20	1.29	0.89–1.85	0.18
	Kidney donor profile index	1.01	1.00–1.01	**0.04**	0.99	0.98–1.00	0.13
	Right kidney	0.85	0.65–1.13	0.27	0.95	0.69–1.29	0.73
	Cold ischemia time	1.02	0.99–1.04	0.15	1.02	0.99–1.05	0.17
Immunologic factors	cPRA > 20%	1.02	0.74–1.42	0.90	1.14	0.73–1.76	0.57
	HLA mismatch (per 6)	1.04	0.93–1.15	0.52	1.03	0.91–1.16	0.65
	Previous transplant	1.26	0.86–1.85	0.23	1.32	0.81–2.14	0.26
Recipients factors	Age	1.00	0.99–1.01	0.70	1.00	0.98–1.01	0.63
	Female	0.57	0.42–0.76	**< 0.001**	0.59	0.42–0.83	**0.002**
	Non-White	1.28	0.95–1.72	0.11	1.27	0.89–1.80	0.18
	Body mass index	1.04	1.02–1.07	**0.001**	1.04	1.01–1.08	**0.01**
	Cause of ESRD: Diabetes vs. other	1.52	1.12–2.06	**0.007**	1.15	0.81–1.64	0.43
	Depleting induction	1.88	1.42–2.48	**< 0.001**	1.77	1.28–2.46	**0.001**
	Early steroid withdrawal	1.48	0.54–2.61	0.18	1.14	0.59–2.20	0.69
	Preemptive transplant	0.10	0.05–0.20	**< 0.001**	0.11	0.05–0.24	**< 0.001**
	CMV high risk (D+/R−)	0.92	0.64–1.32	0.65	1.00	0.66–1.49	0.99

Bold values siginifies statistical significant with $p < 0.05$.

Unadjusted DCGF risk was similarly elevated in recipients who experienced DGF among both DBD (HR: 3.47, 95% CI: 1.73–6.95, $p < 0.001$) and DCD (HR: 6.39, 95% CI: 1.42–28.8, $p = 0.02$). However, DCGF risk after DGF when comparing DBD and DCD was not significantly different, with a p-interaction of 0.47 (Table 4). This was further confirmed by unadjusted KM survival analysis (Figure 1C). Sample sizes were too small (DBD $n = 32$ and DCD $n = 13$) to adjust for baseline characteristics in DCGF.

Additionally, the risk of death in recipients with a functioning graft was found to be increased after DGF in DBD only (HR: 3.69, 95% CI: 2.22–6.12, $p < 0.001$) and not in DCD (HR: 1.87, 95% CI: 0.85–4.13, $p = 0.12$), with p-interaction of 0.16 between groups. Similar outcomes were obtained after adjusting for baseline characteristics in DBD (aHR: 3.43, 95% CI: 1.96–6.00, $p < 0.001$) and DCD (aHR: 1.90, 95% CI: 0.78–4.61, $p = 0.16$) with p-interaction of 0.15 (Table 4).

4 | Discussion

In this large cohort of 2543 DDKT recipients stratified by DBD and DCD donors, we observed that kidney transplants from both groups were at an increased risk of developing DGF when the donor was older, the recipient had a higher BMI, or depleting induction was utilized. Additional risk factors for DGF identified among DBD recipients include higher donor terminal creatinine, greater KDPI, right kidney graft, and prolonged CIT. Although DCD recipients unsurprisingly had higher rates of DGF [15], risks of post-DGF AR, GF, and patient death were, while increased, not significantly different between DBD and DCD kidney recipients.

Risk factors for DGF identified in this study for both DBD and DCD kidneys are consistent with those for deceased kidney transplants overall [6–8]. Older donor age also carries known risk for DGF [16]. Obesity measured by BMI in recipients is associated with a proinflammatory state and higher postoperative complication rates, further elevating the risk of DGF [17–19]. The quality of the donor kidney, represented by donor terminal serum creatinine and KDPI, also influences the odds of DGF [15, 20, 21]. Prolonged CIT induces metabolic damage at the cellular level, impairing critical enzyme functions, leading to cell injury that may not recover after reperfusion [22, 23]. CIT is especially prolonged in right renal transplants due to the shorter right renal vein requiring extended back-table preparation, possibly explaining the observed higher risks of delayed function. [24] Additional anatomical complexities may also contribute, such as the proximity of the right renal artery to the super mesenteric

TABLE 4 | Association of DGF with outcomes during first year posttransplant.

		DBD		DCD		p-interaction
		HR (95% CI)	*p*	HR (95% CI)	*p*	
Acute rejection	***n*/N**	277/1739	—	136/804	—	—
	Unadjusted	2.51 (1.97, 3.21)	**<0.001**	2.09 (1.47, 2.95)	<0.001	0.40
	Adjusted[a]	2.22 (1.70, 2.90)	**<0.001**	2.37 (1.62, 3.48)	<0.001	0.65
Graft failure	***n*/N**	92/1739	—	39/804	—	—
	Unadjusted	3.61 (2.40–5.44)	**<0.001**	2.63 (1.33–5.18)	0.005	0.44
	Adjusted[a]	3.04 (1.94–4.76)	**<0.001**	2.56 (1.22–5.39)	0.01	0.47
Death-censored graft failure	***n*/N**	32/1739	—	13/804	—	—
	Unadjusted	3.47 (1.73, 6.95)	**<0.001**	6.39 (1.42, 28.8)	0.02	0.47
	Adjusted	x	x	x	x	x
Death with a functioning graft	***n*/N**	60/1739		26/804		
	Unadjusted	3.69 (2.22, 6.12)	<0.001	1.87 (0.85, 4.13)	0.12	0.16
	Adjusted	3.43 (1.96, 6.00)	<0.001	1.90 (0.78, 4.61)	0.16	0.15

[a]Adjusted for all baseline characteristics from Table 1.

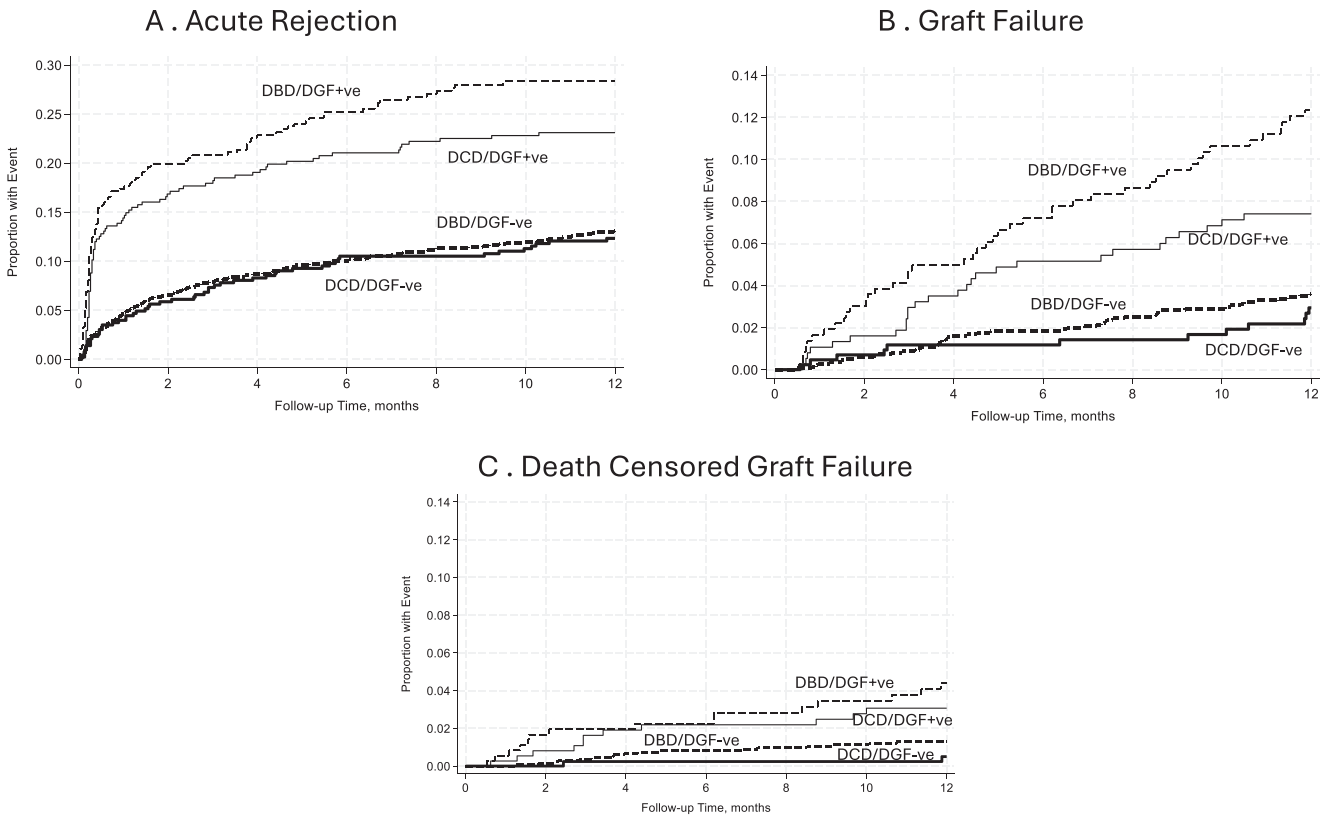

FIGURE 1 | Outcomes comparing types of deceased donors with and without delayed graft function.

artery, often resulting in a limited aortic cuff that may cause prolonged anastomosis time, arterial kinking, and vascular mispositioning. Our data also reported depleting induction as a risk factor for DGF in both groups; however, this association is likely attributable to our center protocol to administer lymphocyte-depleting induction therapy to patients anticipated to develop DGF as a preventative measure against DGF, AR, and early GF [25].

Protective factors identified include female donor, female recipient, and preemptive transplantation. Studies suggest that females exhibit a less androgenic hormonal milieu and higher expression of endothelial nitric oxide synthase and superoxide dismutase, leading to better recovery from renal ischemia-reperfusion injury (IRI) [26, 27]. However, in one recent study, sex discordance between donor and recipient was not significantly associated with AR or GF [28]. Preemptive transplants reduce waiting time on dialysis, mitigating the associated risks of cardiovascular disease, renal allograft vascular dysfunction, poor nutrition, altered immune function, and chronic inflammation [29].

Development of DGF is known to significantly raise the risk of early AR, potentially explained by the withholding of calcineurin inhibitors in patients with DGF, creating an under-immunosuppressed environment that is weaker in preventing native T-cells from attacking the allograft [9, 30–32]. DGF is subsequently associated with GF since the hyperinflammatory state of AR increases the risk of GF [33, 34]. The impact of DGF on graft survival in the absence of AR is unclear [35–37]. Further studies have examined the impact of DGF in conjunction with other variables, such as cold ischemia time. Ahlmark et al. found similarly poor graft survival in kidney transplants with DGF, regardless of whether CIT was short or prolonged [38]. Also, recently, Cashion et al. analyzed the interaction between CIT and KDPI among 69 490 kidney transplant recipients to assess various outcomes [39]. Interestingly, a statistically significant interaction between CIT and KDPI was found for the risk of DGF; however, this interaction of increasing values of CIT was less pronounced for grafts with increasing KDPI values (coefficient = −0.102; $p < 0.001$) [39].

Our study suggests that the occurrence of DGF impacts the risk of AR and GF within 1-year posttransplant equally between DBD and DCD kidney transplants. This indicates that there is no clinical benefit in waiting for one type of deceased donor over the other based on concerns about DGF-related early graft outcomes alone. There is a contradiction in the existing literature where Li et al. report in a 2023 meta-analysis that DBD kidney recipients experiencing DGF face increased odds of GF at 1-year posttransplant, while no such increased risk is observed among DGF-positive DCD KT recipients [33]. However, this review compares data across multiple studies and may not account for center-specific differences that can impact the reported findings. Hoogland et al. found that the function of DGF-positive DCD kidney grafts that do overcome the initial postoperative period is comparable to DGF-negative DBD kidneys 10 years posttransplant, suggesting differing mechanisms of GF after DGF between the two groups [10]. Therefore, further research, particularly on the risk factors and mechanisms causing DGF in DBD kidneys, is necessary to fully understand the discrepancies between the findings of this study and others.

Of note, many existing single-center studies on this topic include analysis of cohorts of less than 1000 patients. When extracting data from a much larger pool such as the Organ Procurement and Transplant Network database, the list of significant risk factors decreases drastically to include only those widely reported such as recipient age and prolonged CIT (> 30 h), indicating that many findings of single-center studies may be attributable to center-specific protocols [23]. This study still faces the expected limitations of a single-center observational study, including center-specific practices, which should be factored into interpretation. Also, we were not able to provide WIT among DCD donors, however, our practice has been to wait for up to 2 h of the agonal phase. Also, the second WIT with time to perfusion was not reliably collected in our database, and we could not provide that data. Further, subgroup analysis among patients with AR or other risk factors was not assessed. Due to the nature of the retrospective observational study design, not all confounding variables may have been accounted for; however, we attempted to minimize the effects of those most influential to our outcomes of interest by adjusting multiple baseline characteristics.

5 | Conclusion

While DCD grafts were more likely to develop DGF when compared to DBD grafts, DBD kidney transplants were found to have more unique risk factors for DGF than DCD kidney transplants, including higher terminal creatinine, higher KDPI, right renal graft, and prolonged CIT. Further research is needed to elucidate a method that mitigates these factors. DGF worsened outcomes within the first year for both DBD and DCD kidney recipients. However, there was no significant difference in the risk of AR and GF between DGF-positive DBD and DGF-positive DCD transplant recipients within the first year. As organ shortage is becoming a more prominent issue in transplants and the relative proportion of DCD kidneys is rising, the results of this study suggest that DCD grafts remain a viable option and should not be discouraged from use based on DGF concerns alone.

Author Contributions

Angela L. Zhou: manuscript preparation, design, and writing. Suseela Raj, Ekaterina Fedorova, Jacqueline Garonzik-Wang and Didier Mandelbrot: editing. Brad C. Astor: statistical analysis and editing. Sandesh Parajuli: original idea, writing, and editing.

Disclosure

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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