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Characteristics, Trends, and Outcomes of Heart Donation After Circulatory Death: An Early Analysis of the United Network for Organ Sharing Database

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Heart transplantation (HTx) is greatly limited by organ shortage. To address this crisis, donation after circulatory death (DCD) is an emerging alternative to the traditional donation after brain death (DBD). Unfortunately, there is scarce data on HTx outcomes for this donation type, particularly within the United States; our investigation seeks to address this knowledge gap. As part of this study, the UNOS thoracic database was analyzed for first-time, adult, isolated orthotopic HTx recipients between 2019 and 2023. Patients were stratified into 3 groups: DBD, DCD III, and DCD IV. Further subgroup analysis for DCD III donors was conducted based on the procurement method, direct procurement and perfusion (DPP) or normothermic regional perfusion (NRP). After creating the sample cohort, a total of 14,035 HTx recipients were included in our analysis (DBD 86.5%, DCD III 6.9%, DCD IV 6.5%). There was an exponential increase in the number of DCD III cases and HTx centers that offer this donation type during the study period. DCD III recipients had a higher incidence of postoperative dialysis use; otherwise, all 3 groups shared similar rates of postoperative permanent pacemaker placement and stroke, acute rejection, and mortality. Within DCD III recipients, DPP and NRP procurement techniques had similar survival. To conclude, although DCD III was associated with an increased incidence of postoperative dialysis use, both DCD type III and IV had comparable morbidity and survival as the standard of care DBD donors. Overall, our investigation provides encouraging data to support DCD use as a safe option to increase the limited donor pool in the United States.

Heart transplantation (HTx) is significantly limited by an ongoing organ shortage. In 2022 alone, over 7,500 adult patients in the United States were on the HTx waitlist, yet only 3,652 hearts were donated and ultimately transplanted.[1] In addressing this grave donor shortage, many transplant centers have expanded their donor eligibility criteria. In the 21st century, an active area of research and strategy to further expand the donor pool is through donation after circulatory death (DCD). In contrast to donation after brain death (DBD), DCD is highly versatile and includes direct procurement and perfusion (DPP) or normothermic regional perfusion (NRP). However, one unique challenge with DCD is the inevitable warm ischemic time (WIT) period following cardiocirculatory collapse, thereby leading to ischemia and subsequent ischemic-reperfusion injury. Despite this obstacle, with the advent of perfusion technology, DCD utilization has become a practical and safe alternative to DBD. Current results from solid abdominal organ transplant outcomes using DCD, including liver, kidney, and pancreas, describe comparable results to their DBD counterpart.[2] Similarly, preliminary data from international HTx studies suggest that DCD utilization is a safe alternative to DBD.[3,4] In the United Kingdom where DCD procurement was adopted early, this practice allowed for a reported 48% increase in HTx rates; in the United States, it is projected to increase HTx volume by as much as 30%.[5] However, further investigation into potential differences in clinical outcomes between DBD and DCD HTx in the United States is needed. Notably, in this population, the subacute implications of DCD use after 1-year of HTx is unknown. Therefore, we sought to address this gap in knowledge by comparing the national outcomes between DCD and DBD use.

Methodology

Study population

The United Network for Organ Sharing (UNOS) thoracic database was queried for first-time, adult orthotopic HTx recipients in the United States. As the first recorded DCD HTx occurred in 2019, the investigation's review period was limited to patients who were

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transplanted between January 2019 and September 2023. Recipients who received multiorgan transplants were excluded from the analysis.

Classification of donation type and procurement methods

Once the final cohort was established, patients were categorized into groups based on their donor Maastricht classification.[6] Under this system, 4 DCD categories are described: Type I: dead on arrival at the hospital, Type II: dead after unsuccessful resuscitation efforts, Type III: awaiting cardiac arrest, often in a controlled setting following life-support withdrawal, and Type IV: cardiac arrest following brain death.[7] For the current investigation, using the above classifications, recipients were stratified into 3 groups: DBD, DCD Type III (DCD III), and DCD Type IV (DCD IV).

As part of this study, further subgroup analyses were performed in the DCD III group based on their procurement method: DPP or NRP. As the UNOS database does not directly include these modalities as explicit variables, assumptions were made based on methodologies described in previous investigations to indirectly categorize patients into DPP or NRP groups.[8–10] Specifically, the period between donor death to aortic cross-clamping was used to categorize the groups: DPP was considered to be the procurement technique when the interval time was less than 30-minutes, whereas NRP was defined as an interval greater than 30-minutes.[9,10]

Statistical analysis

Continuous variables were reported as mean ± standard deviation if normally distributed, or median (interquartile range) if skewed. Groups were compared using analysis of variance (ANOVA) or Kruskal-Wallis nonparametric testing as appropriate. Categorical variables were presented as a percentage and compared using the Chi-squared test. Kaplan-Meier curves were used to present the survival probabilities of participants separated according to strata of donation type and procurement methods and compared using the log-rank test. Univariable and multivariable Cox proportional hazard methods were utilized to quantify mortality risk for the previous predefined variables. Clinically relevant variables, as listed in the Supplementary Materials, with a univariable p-value of less than or equal to 0.10 in the overall sample were eligible for entry into both multivariable models. The final model for donation type assessment was created using a backward stepwise elimination method that retained covariables with a p-value of less than 0.05. Given the smaller sample size of the DCD III cohort, no further elimination methodology was conducted to obtain the final model for procurement methods mortality assessment.

For the entirety of the study, a p-value less than 0.05 was considered statistically significant. All statistical analyses were performed using JMP Pro 16 software (SAS Institute Inc., Cary, NC). The Institutional Review Board at the University of California Davis deemed that this investigation did not meet the definition of human research, therefore, institutional review was not required.

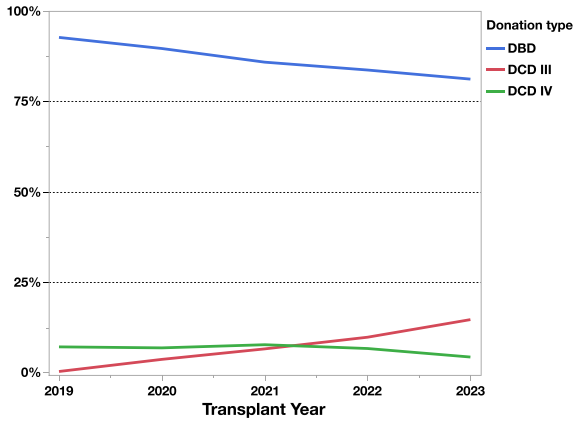

Figure 1. Yearly trends in the incidence of HTx donation type within the United States between 2019 and 2023. DBD = donation after brain death; DCD = donation after circulatory death; HTx = heart transplantation.

Results

A total of 14,035 HTx recipients were included in our study. DBD recipients made up approximately 86.5% of the cohort, DCD III 6.9%, and DCD IV 6.5%. Figure 1 illustrates the temporal trends for each group. There was a clear increase in the proportion of DCD III recipients over the years, culminating in 14.6% of all HTx in the year 2023, while the DCD IV group was mostly stagnant. As shown in Figure 2, the geographic distribution for most DCD III HTx occurred in the New England (Region 1), South-West (Region 5), and South Mid-Atlantic (Region 11) regions. Transplant center practices have also changed significantly during the review period. Figure 3 displays the exponential growth of HTx institutions that offer DCD III transplantation.

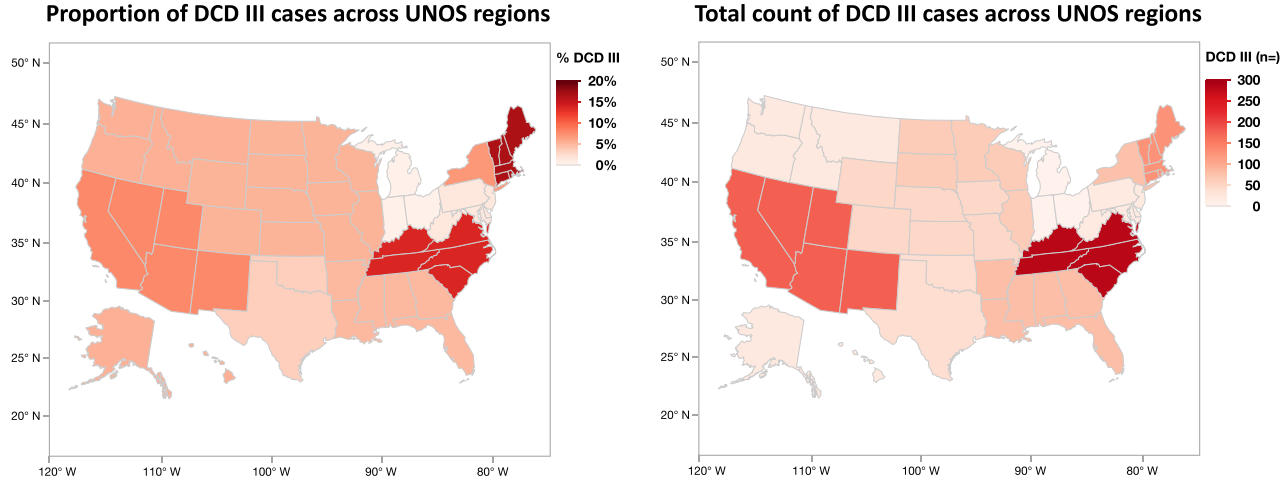

Figure 2. Geographical distribution of DCD III HTx in the United States. DCD = donation after circulatory death; HTx = heart transplantation; UNOS = United Network for Organ Sharing.

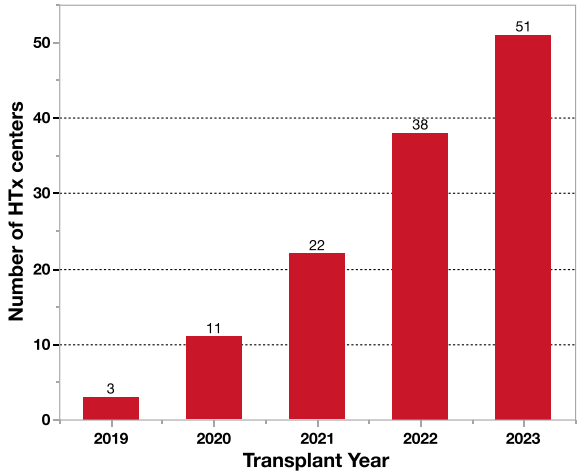

Figure 3. Yearly trends in the number of heart transplant centers that accept DCD III between 2019 and 2023. DCD = donation after circulatory death; HTx = heart transplant.

Similarly, as illustrated in Supplementary Figure S1, the majority of cases come from high-volume centers, although medium-volume HTx institutions showed a similar increase in DCD. Conversely, this donation type has only recently been utilized at low-volume centers, and their contribution to date makes up less than 5% of the yearly DCD III volume.

Patient demographic and medical data is presented in Table 1 across donation types. Those who had DCD III donors were generally White and male, and were least likely to require inotropic, ECMO, IABP, or ventilatory support at the time of listing. However, they had the highest incidence of VAD/TAH use at listing. Ultimately, this group had the greatest proportion of low-acuity status at listing, and similarly the lowest incidence of high-acuity status. All 3 groups had similar rates of diabetes, cigarette use, heart failure etiology, and pulmonary vascular resistance values. Donor and donor-recipient matching data are presented in Table 2. DCD III donors were more likely to be White and male and were also generally lower risk compared to other groups: they were on average younger, and less likely to have a history of hypertension, diabetes, or cigarette use greater than 20 pack years. Apart from DCD III, DCD IV donors were found to have the greatest incidence of CPR use and were most likely to have anoxia as their primary cause of death. Overall, DBD and DCD IV groups were generally found to share similar donor and recipient traits, whereas the DCD III cohort typically had lower risk features.

Specific to DCD III donors, the median agonal time, functional WIT (fWIT), and total WIT was 2 min, 28 min, and 32 min, respectively. Approximately two-thirds of this sample was categorized as utilizing DPP procurement and one-thirds using NRP. The mean ischemic time for DPP and NRP was 5.84 ± 2.16 hours and 3.32 ± 1.14 hours, respectively. Similarly, the median fWIT was 23 minutes (19-28 minutes) for the DPP group and 96 minutes (75-125 minutes) for the NRP category.

Peri- and postoperative data are recorded in Table 3. Just prior to HTx, those with DCD III were more likely to not be hospitalized and had the lowest rates of ICU admission. In the immediate postoperative setting, DCD III recipients had the greatest risk of kidney injury necessitating dialysis. Otherwise, there were no significant differences in the rates of permanent pacemaker placement, stroke, or acute rejection prior to discharge between groups. Similarly, the 1-year incidence of acute rejection requiring treatment was statistically similar across all 3 donation types. For those who had died, the cause of death (COD) between DBD and DCD groups were comparable. Further granular COD etiologies were compared and included in

Table 1
Characteristics of study participants according to donation type

	DBD (n = 12,147)	DCD III (n = 974)	DCD IV (n = 914)	p-value
Age (years)	57 (46-63)	57 (46-64)	57 (46-63)	0.516
Sex (M)	72.6%	79.7%	73.2%	<0.001
Weight (kg)	84.3 ± 18.2	88.8 ± 18.6	84.5 ± 18.4	<0.001
BMI (kg/m^2)	27.8 ± 5.0	28.6 ± 4.9	27.9 ± 4.9	<0.001
Race				<0.001
White	60.0%	68.4%	57.9%	
Black	24.5%	20.0%	24.2%	
Hispanic	10.3%	10.0%	13.0%	
Asian	3.9%	1.5%	3.8%	
History of diabetes	28.4%	29.4%	25.9%	0.200
History of cigarette use	41.3%	44.4%	39.7%	0.093
Primary etiology				0.368
NIDCM	57.4%	55.1%	55.4%	
ICM	27.7%	28.9%	27.8%	
HCM	3.4%	4.5%	3.7%	
RCM	4.4%	4.4%	5.8%	
Hemodynamics				
Mean PAP (mm Hg)	28.1 ± 10.5	27.1 ± 10.4	28.6 ± 10.3	0.004
PCWP (mm Hg)	18.9 ± 9.0	17.7 ± 9.0	19.3 ± 8.7	<0.001
CO (L/min)	4.2 ± 1.3	4.3 ± 1.3	4.2 ± 1.3	0.014
PVR (wood units)	2.5 ± 1.6	2.4 ± 1.5	2.5 ± 1.6	0.071
Highest educational level				0.120
High school or below	41.6%	38.2%	40.9%	
College or above	58.4%	61.8%	59.1%	
Insurance type				0.016
Medicaid or donation	15.2%	14.1%	18.1%	
Medicare or other govt. sponsored	35.2%	38.4%	31.8%	
Private or self-funded	49.6%	47.5%	50.1%	
ECMO*	3.8%	0.7%	5.7%	<0.001
IABP*	16.0%	9.2%	17.4%	<0.001
Inotrope use*	34.7%	27.1%	33.9%	<0.001
VAD/TAH*	28.3%	33.6%	25.0%	<0.001
Ventilator*	1.9%	0.5%	2.3%	<0.001
Acuity status*				<0.001
Low†	19.2%	26.6%	19.0%	
Medium‡	33.6%	40.0%	31.7%	
High§	47.3%	33.4%	49.3%	
Annual HTx center volume				<0.001
Low (<15)	12.5%	2.6%	9.7%	
Medium (15-35)	46.7%	23.7%	42.8%	
High (>35)	40.8%	73.7%	47.5%	
Total days on WL	29 (9-142)	32 (9-154)	30 (9-156)	0.761

BMI = body mass index; ECMO = extracorporeal membrane oxygenation; HCM = hypertrophic cardiomyopathy; IABP = intra-aortic balloon pump; ICM = ischemic cardiomyopathy; NIDCM = nonischemic dilated cardiomyopathy; PVR = pulmonary vascular resistance; RCM = restrictive cardiomyopathy; TAH = total artificial heart; VAD = ventricular assist device; WL = waitlist.

* At listing.

† Allocation status of 2 (1999-2018) and 5 and 6 (2018-Present).

‡ Allocation status of 1B (1999-2018) and 4 (2018-Present).

§ Allocation status of 1A (1999-2018) and 1, 2, and 3 (2018-Present).

Supplementary Table S1; similar to the previous analysis, there was no significant difference in COD between groups (p = 0.593).

Kaplan-Meier survival curves for all 3 donation types are displayed in Figure 4. Survival estimates for 30 days, 6 months, 1 year, and 2 years are as follows for each group, respectively: DBD: 97.1%, 93.0%, 91.2%, and 87.2%; DCD III: 96.4%, 93.2%, 90.9%, and 83.3%; DCD IV: 97.2%, 93.4%, 92.1%, and 87.7%. There were no significant differences in survival between the donation types using the log-rank test (p = 0.303). Mortality risk assessment through Cox regression models is presented in Table 4. For both the univariable and adjusted model, there were no significant differences in mortality risk between the DCD and DBD groups. Additional subgroup analysis was conducted within DCD III recipients to identify the impact of DPP versus NRP

Table 2
Donor characteristics and donor-recipient matching data across donation types

	DBD (n = 12,147)	DCD III (n = 974)	DCD IV (n = 914)	p-value
Age (years)	32.8 ± 10.3	30.5 ± 8.4	32.7 ± 10.2	<0.001
Sex (male)	71.3%	85.9%	70.8%	<0.001
Race				<0.001
White	61.8%	76.9%	62.7%	
Black	17.1%	9.8%	15.9%	
Hispanic	18.0%	11.2%	17.6%	
Asian	1.6%	1.1%	2.7%	
Weight (kg)	84.8 ± 20.0	86.7 ± 20.5	85.9 ± 20.3	0.008
BMI (kg/m^2)	28.1 ± 6.3	27.7 ± 6.5	28.3 ± 6.3	0.102
History of hypertension	15.8%	12.6%	15.1%	0.022
History of cigarette use (>20PY)	12.5%	9.7%	14.4%	0.008
History of diabetes	4.1%	2.3%	3.6%	0.008
History of CAD	0.2%	0.1%	0.3%	0.509
History of MI	1.1%	1.1%	2.6%	0.003
Cause of death				<0.001
Anoxia	45.6%	49.0%	63.8%	
Head trauma	39.1%	40.8%	25.8%	
CVA	12.7%	6.5%	8.8%	
CPR given?	55.1%	56.1%	98.3%	<0.001
CPR duration (min)	20 (10-30)	15 (9-22)	16 (9-30)	<0.001
Ischemic time (hours)	3.5 ± 1.1	5.0 ± 2.2	3.4 ± 1.1	<0.001
Agonal time (min)*	N/A	2 (1-4)	N/A	N/A
Functional warm ischemic time (min)†	N/A	28 (21-81)	N/A	N/A
Total warm ischemic time (min)‡	N/A	32 (24-84)	N/A	N/A
Procurement technique	N/A		N/A	N/A
DPP		66.3%		
NRP		33.8%		
Organs recovered	5 (4-6)	4 (3-4)	4 (4-6)	<0.001
Organs transplanted	4 (4-6)	4 (3-4)	4 (4-6)	<0.001
ABO blood type matching				0.256
Compatible	13.9%	13.1%	15.7%	
Identical	86.1%	86.9%	84.4%	
HLA mismatch				0.371
0-3	14.1%	12.5%	14.8%	
4-6	85.9%	87.5%	85.2%	
PHM ratio	1.04±0.17	1.04±0.18	1.04±0.17	0.746

BMI = body mass index; CVA = cerebrovascular accident; HLA = human leukocyte antigen; PHM = predicted heart mass; PY = pack-year.

* Defined as the interval between the withdrawal of life support to the agonal phase (systolic blood pressure < 80 mmHg or an oxygen saturation of < 80%).

† Defined as the interval between the agonal phase (systolic blood pressure < 80 mmHg or an oxygen saturation of < 80%) to cross clamping of the aorta.

‡ Defined as the interval between the withdrawal of life support to cross clamping of the aorta.

procurement technique and illustrated with Kaplan-Meier survival curves in Supplementary Figure S2. Survival estimates for 30 days, 6 months, 1 year, and 2 years are as follows for each group, respectively: DPP: 95.5%, 90.8%, 89.7%, and 82.4%; NRP: 98.4%, 97.9%, 94.6%, and 83.2%. Using the log-rank test, we demonstrated similar survival between the groups (p = 0.069). This finding was further supported by statistically comparable mortality risk between DPP and NRP in the univariable and multivariable Cox regression models in Table 4.

Discussion

Our investigation shows promising findings for the continued use of DCD donors as a means to expand the HTx donor pool. Since its implementation in the United States, the rate of DCD use and the number of transplant centers that offer this alternative to DBD have increased exponentially between 2019 and 2023. Currently, as of September 2023, nearly 2,000 additional patients have been afforded a heart transplant, with over 50 transplant centers participating in DCD III HTx. Perhaps most importantly, our analysis demonstrated that DCD patients, either Type III or IV, had comparable survival as conventional recipients

Table 3
Clinical characteristics of participants in the peri- and post-transplant period across donation types

	DBD (n = 12,147)	DCD III (n = 974)	DCD IV (n = 914)	p-value
Medical condition at Tx				<0.001
Not hospitalized	29.5%	52.3%	30.5%	
Hospitalized, not in ICU	13.6%	16.0%	14.6%	
ICU	56.9%	31.6%	54.9%	
LOS (days)	17 (12-26)	16 (12-25)	16 (12-24)	0.073
Events prior to discharge				
Dialysis	14.6%	18.2%	15.6%	0.016
PPM	1.8%	1.2%	1.4%	0.381
Stroke	4.1%	4.4%	3.9%	0.868
Acute rejection	17.7%	15.5%	18.0%	0.246
Treated for acute rejection episodes within 1 yr	16.1%	18.6%	16.4%	0.443
Cause of death				0.457
Cardiovascular	16.1%	15.3%	14.9%	
Infection	22.6%	27.1%	31.7%	
Graft failure	9.9%	12.9%	9.9%	
MOF	11.1%	5.9%	8.9%	
Other	40.3%	38.8%	34.7%	

ICU = intensive care unit; LOS = length of stay; MOF = multiple organ failure; PPM = permanent pacemaker; Tx = transplant.

who were paired with DBD donors. Overall, when compared with the existing literature, our findings are consistent with results obtained from both national and international investigations.

Though the first DCD HTx was conducted in South Africa in 1967,[11] the technique was primarily pioneered in Australia and Europe. In an updated report that utilized data from 74 DCD recipients from St. Vincent's Hospital in Sydney, Australia, Joshi et al. discuss their longitudinal experiences and outcomes since 2014.[4] In their analysis, they found that DCD and DBD groups had a similar 1- and 5-year mortality risk. In a subgroup analysis within the DCD group, the authors also compared rates of severe primary graft dysfunction (PGD) between the 2 periods of 2014 to 2018 and 2018 to 2022; they discovered that severe PGD necessitating ECMO use decreased precipitously between these eras, from 35% to 8%, suggesting a protective value of increased experience with the DCD procedure. The Royal Papworth Hospital in Cambridge, United Kingdom similarly found reassuring outcomes between DCD and DBD groups.[3] In their investigation, they report that both groups had comparable postoperative mechanical circulatory support, cardiac function, rejection episodes that required treatment, and survival. Interestingly, the authors describe how they were able to increase their HTx volume by 48% during the study period simply by utilizing DCD donors.

In the United States, the use of DCD donors has only recently been introduced into practice. Similar to outcomes observed internationally, preliminary data suggests that DCD use is a safe and effective way to increase the donor pool. In a single-center investigation at Vanderbilt University Medical Center that examined 122 DCD recipients, the investigators found similar outcomes between DCD and DBD recipients across multiple metrics, including severe PGD at 48-hours, readmission rates, treated rejection events, cardiac allograft vasculopathy (CAV), and survival.[12] Of note, one aspect that was acknowledged was that DCD donors and their recipients were generally healthier with fewer comorbidities than their DBD counterparts, similar to the findings observed in our study. Another investigation using data from Massachusetts General Hospital demonstrated similar survival and graft rejection across donation types; however, an interesting discovery was that the DCD group had transient impairment in right heart function.[13] The investigators attribute this right heart dysfunction to a multitude of factors, including cardiac ischemia and acidosis during the WIT period, sudden brain death at the time of procurement, and stress while on the ex-vivo machine.

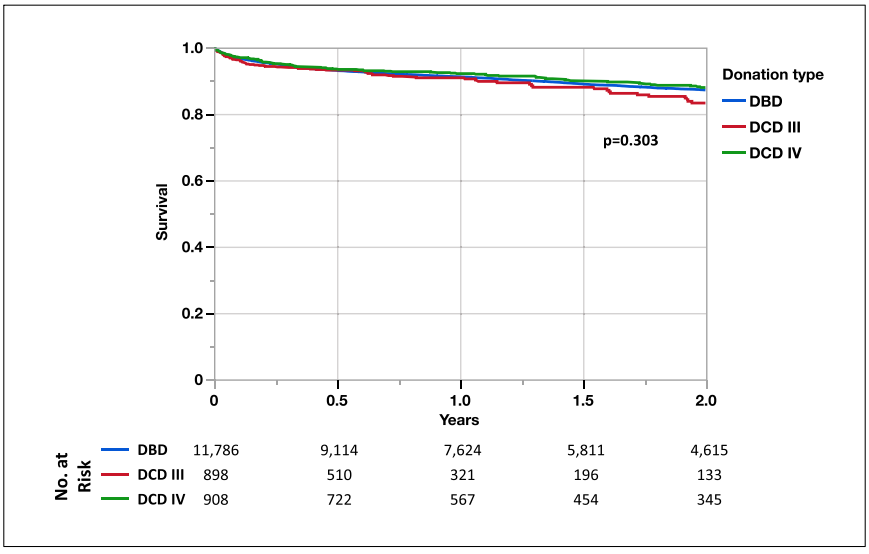

Figure 4. Kaplan-Meier survival curves across heart transplant donation types. DBD = donation after brain death; DCD = donation after circulatory death.

Nonetheless, their right heart function made a full recovery by the third postoperative week. Interestingly, this finding may be indirectly observed within our study; namely, the increased incidence of renal failure necessitating dialysis in the postoperative setting for DCD III recipients may be attributed to a cardiorenal-like syndrome as a result of the associated right-sided heart dysfunction. In addition to single-center investigations, multicenter studies have yielded similar reassuring data on the use of DCD donors for HTx.[9] Notably, there is an ongoing prospective clinical trial involving 15 HTx centers comparing DCD with DBD use; preliminary results after a 6-month follow-up period showed that the DCD arm had noninferior survival compared to the standard of care control group.[14] Remarkably, an ancillary finding to this investigation was that out of the 6 DCD recipients with a WIT greater than 30 minutes, none developed PGD. Given that WIT is conventionally a limiting factor toward DCD organ recovery,[15] such findings may encourage further in-vivo research to determine an appropriate WIT upper limit. This may have particularly significant clinical implications in pediatric DCD HTx, as younger donors have been observed to be less sensitive to the hazard of cold ischemic time,[16] though it is unknown if such a relationship also exists for WIT.

In addition to the survival analysis comparing DBD with DCD groups, our investigation also conducted a subgroup analysis within DCD III recipients based on their procurement technique with either DPP or NRP. Whereas DPP involves the immediate cannulation and excision of the donor heart into an ex-vivo perfusion system, NRP allows for in-vivo perfusion by reanimating the donor heart with a modified ECMO cannulation imposed upon surgically occluding cerebral blood flow. In comparing the advantages of the 2 techniques, though DPP may require less resources, NRP allows for a direct assessment of cardiac function while limiting the WIT period for the heart and other abdominal organs,[3] resulting in less biliary complications and graft failure for liver transplants, as well as early graft function recovery for kidney transplants.[17,18] Nonetheless, the practice of NRP use is controversial, as a patient resuscitated on ECMO is no longer considered "dead" by cardiocirculatory standards. Instead, with blood flow to the brain interrupted, the donor will eventually progress to meeting the full criteria of brain death. The American College of Physicians highlights this ethical dilemma in their positional statement as of 2021,[19] and there remains ongoing debate on this topic.[20] Despite the unique advantages and disadvantages to each procurement technique, there is no clear consensus on which of the 2 modalities is superior. In fact, many investigations have illustrated that survival outcomes between NRP and DPP are comparable.[8,9,21] However, some studies favor NRP as having shorter ischemic time, less time on ventilation, and shorter length of hospitalization, as well as reduced incidence of renal failure necessitating dialysis and rejection requiring treatment.[3] Ultimately, such decisions will likely be dependent on institutional resources and regional policy.

Table 4
Univariable and multivariable mortality risk association of donation type and procurement technique after heart transplantation

	Unadjusted model		Final adjusted model	
	HR (95% CI)	p-value	HR (95% CI)	p-value
Donation type*				
DBD	Ref.	——	Ref.	——
DCD III	1.17 (0.93-1.47)	0.170	1.07 (0.83-1.38)	0.588
DCD IV	0.93 (0.75-1.16)	0.536	0.98 (0.79-1.22)	0.857
Procurement technique‡				
DPP	Ref.	———	Ref.	———
NRP	0.59 (0.33-1.05)	0.072	0.67 (0.33-1.36)	0.272

DBD = donation after brain death; DCD = donation after circulatory death; DPP = direct procurement and perfusion; NRP = normothermic regional perfusion.

* DCD III (ref.) vs DCD IV: unadjusted model: 0.80 (0.59-1.08), p = 0.142; final adjusted model: 0.91 (0.66-1.26); p = 0.587.

‡ Subgroup analysis for DCD III recipients only.

Strengths and Limitations

A major advantage of our study is the use of a national database with a large sample size that is representative of multiple transplant programs of various characteristics. This increases generalizability compared to single-center studies. However, our investigation has limitations inherent to all retrospective studies. One drawback is the potential for missing information or a lack of granularity in collected data. For instance, there is currently no data collected on the procurement method for DCD III donors, whether DPP or NRP. As such, assumptions were made to infer the procurement technique for such donors, which may have its own inherent limitations and biases. Irrespective, the method that we adopted to categorize procurement methods has been widely accepted in prior studies, and our overall results are consistent with the current data in the literature. As DCD use becomes more widespread in the United States, we are hopeful

that further granular data will be collected and incorporated into the UNOS database to allow for nuanced investigation within this evolving topic. Additionally, because DCD use was only recently introduced in the United States, with most of the cases occurring in the past 2 years, our follow-up period had to be selected with great care. As such, in order to better understand the subacute to long-term implications of DCD use while minimizing the potential risk of ascertainment bias from informative censoring, we opted to choose a 2-year follow-up period. Although we adjusted for relevant covariates, there is a possibility of residual confounding from unmeasured risk factors. Further investigations are encouraged in the future to better understand the long-term consequences of DCD use.

Conclusion

The current organ shortage, coupled with the increasing demand for HTx necessitates that we as a transplant community find safe alternatives to the traditional donor eligibility criteria. Our analysis found that DCD use is an increasingly utilized option by a growing number of transplant centers. Though DCD Type III recipients were more likely to have acute kidney injury necessitating dialysis post-HTx, we demonstrated that both DCD type III and IV have comparable permanent pacemaker placement, stroke, and acute rejection prior to discharge, acute rejection requiring treatment within 1-year of transplant, and subacute survival outcomes as the standard of care DBD donors. For those specifically within the DCD III group, we found no significant difference in mortality risk by procurement technique, whether DPP or NRP. Overall, our investigation provides encouraging data to support DCD use as a safe option to increase the limited donor pool in the United States.

Declaration of competing interest

The authors have no competing interests to declare.

CRediT authorship contribution statement

Ahad Firoz: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Imo Ebong:** Writing – review & editing, Validation, Supervision. **Martin Cadeiras:** Writing – review & editing, Validation, Supervision. **Shirin Jimenez:** Writing – review & editing, Validation, Supervision.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amjcard.2025.08.061.

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