Systematic Review

# Cardiac transplantation in controlled donation after circulatory death: a meta-analysis of long-term survival using reconstructed time-to-event data

**Benjamin T. Muston[1,2], Winky Lo[3], Aditya Eranki[4], Massimo Boffini[5], Antonio Loforte[5]**

[1]The Collaborative Research Group (CORE), Sydney, Australia; [2]Department of Cardiothoracic Surgery, Royal Prince Alfred Hospital, Sydney, Australia; [3]School of Medicine and Health, The University of New South Wales, Sydney, Australia; [4]Department of Cardiothoracic Surgery, Austin Hospital, Heidelberg, Melbourne, Australia; [5]Department of Surgical Sciences, City of Health and Science University Hospital, University of Turin, Turin, Italy

*Correspondence to:* Benjamin T. Muston, MD. Department of Cardiothoracic Surgery, Royal Prince Alfred Hospital, 50 Missenden Rd, Sydney, Australia. Email: btmuston@gmail.com.

**Background:** Controlled donation after circulatory death (cDCD) allografts made up a small fraction of donor hearts available for transplant, however it is estimated this could increase to 30% in future years. The purpose of this systematic review and meta-analysis was to describe the largest and most up-to-date short- and long-term survival outcomes for cDCD cardiac transplantation.

**Methods:** Three electronic databases were selected to complete the initial literature search from inception of records until February 2024. Primary outcomes were short-term survival at 12 months, as well as long-term time-to-event survival data. These data were calculated using aggregated Kaplan-Meier curves according to established methods. The secondary outcomes were acute rejection and primary graft dysfunction.

**Results:** Following the PRISMA screening protocol, ten studies were included for analysis, eight of which were published in the last 12 months. A pooled cohort of 1,219 donor/recipient pairs were analyzed, of which all had graphical extraction of individual patient data to reveal an aggregated Kaplan-Meier curve. The survival estimates at 1, 3 and 5 years for the pooled cDCD cohort were 92.4%, 85.3% and 85.3%, respectively. In-hospital mortality rates were low at just 2.5%.

**Conclusions:** While only making up a small percentage of current heart transplant figures, cDCD allografts may not only significantly reduce waitlist times, but could also increase the donor pool, and improve survivability over current procurement techniques. Ultimately, cDCD allografts show promise in offering an effective and favorable procurement source for cardiac transplantation worldwide.

**Keywords:** Controlled donation; circulatory death; heart transplantation; normothermic regional perfusion; direct procurement protocol (DPP)

Submitted Feb 27, 2024. Accepted for publication Nov 04, 2024. Published online Jan 09, 2025.
doi: 10.21037/acs-2024-dcd-20
**View this article at:** https://dx.doi.org/10.21037/acs-2024-dcd-20

## Introduction

Cardiac transplantation has been in existence since the very first successful procedure in December 1967 by South African surgeon Dr. Christiaan Barnard at the Groote Schuur Hospital in Cape Town (1). Controlled donation after circulatory death (cDCD) heart transplants are classified as donors who do not fit the donation by brain death (DBD) criteria but also show no chance of meaningful recovery, likely secondary to a traumatic brain injury or terminal disease. They must then be declared dead due to irreversible cardiopulmonary arrest following the withdrawal of life-sustaining therapies (WLST) (2). The

modified Maastricht classification is perhaps the most widely accepted categorization of the types of asystolic donors, originating in Maastricht, Netherlands and later modified in Madrid in 2011 (3). cDCD is most akin to a Maastricht III score, which is a form of donation in 'controlled asystole', where the patient has undergone WLST after agreement between the family and medical team (4). This differs from Maastricht II as there is no attempt at resuscitation.

The total number of cDCD hearts made up 5.4% of donor hearts available for transplant in the United States (US) in 2021, however it is estimated this could increase to 30% in future years as adoption of the method grows and each procurement technique is popularized (5). There are two primary techniques for transport and perfusion of the explanted allograft, namely direct procurement protocol (DPP) and normothermic regional perfusion (NRP) (6). These two techniques aim to overcome the major challenge of cDCD cardiac transplantation, which is minimizing ischemic time, in both its 'cold' and 'warm' stages. The main differences between the two procurement techniques lie in the order of the cannulation and the nature of the machine perfusion stage. DPP involves removing the heart prior to *ex-vivo* cannulation and machine perfusion, then placing the organ in cold storage before implantation. Thus, cold ischemic time exists before and after the *ex-vivo* machine perfusion stage. Conversely, NRP involves utilization of cardiopulmonary bypass (CPB) and machine perfusion of the *in-vivo* heart before explantation and cold storage prior to implantation (7). Both strategies suffer from an initial 'functional warm ischemic time' whereby once WLST is initiated, there is a state of low perfusion while death is declared and surgical access is accomplished.

The purpose of this systematic review and meta-analysis was to describe the largest and most up-to-date short- and long-term survival outcomes for cDCD cardiac transplantation. Recognition of favorable survival benefit from the 30-day timeframe to 5 years post-operatively may propel the uptake of cDCD hearts and consequently reduce waitlist times for recipients and deaths pre-implantation. We also aimed to graphically depict the estimated survival projection through aggregated Kaplan-Meier curves, utilizing individual patient data extraction.

## Methods

### Literature search

Three electronic databases were screened for the initial literature search, using Medical Subject Headings (MeSH) and focused keywords to adequately cover all possible literature which may be included in the systematic review. The data bases were Embase, PubMed and Scopus, searched from inception until 4th February 2024 with the following search strategy: (heart transplant OR cardiac transplant) AND (circulatory death OR cardiac death) AND controlled donation.

After removal of duplicate records and those published before the year 2000, Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed in accordance with pre-written inclusion and exclusion criteria to screen the remaining records (8). Screening was conducted by two authors independently (W.L. and B.T.M.) with any discrepancies being finalized through team discussion, with ultimate ruling by the leading author (B.T.M.). A PRISMA diagram of the search strategy and list of records at each stage is depicted in *Figure 1*. Once full-text review was completed, the reference lists of all included papers were searched to assess for previously missed publications fitting the inclusion criteria.

### Inclusion and exclusion criteria

Eligibility criteria was established a priori, and focused on inclusion of high-quality prospective studies. Only English language studies were included. Studies were included if they met the following criteria: (I) patients underwent cardiac transplantation, with or without concomitant transplantation of other organs; (II) heart donors were declared dead using circulatory cessation criteria, as opposed to brain death; (III) donation was controlled and non-emergent; (IV) human donors and recipients were used, with survival follow-up documented. Studies were excluded if they: (I) included a pediatric population; (II) had a sample size smaller than ten patients; (III) had overlapping cohorts with larger included studies [including from the United Network for Organ Sharing (UNOS) database]. All conference abstracts, reviews, editorials and animal studies were also excluded.

### Outcome measures

Primary outcomes were short-term survival in-hospital and at 12 months, as well as long-term time-to-event survival data. These data were calculated using aggregated Kaplan-Meier (KM) curves according to established methods. The

 

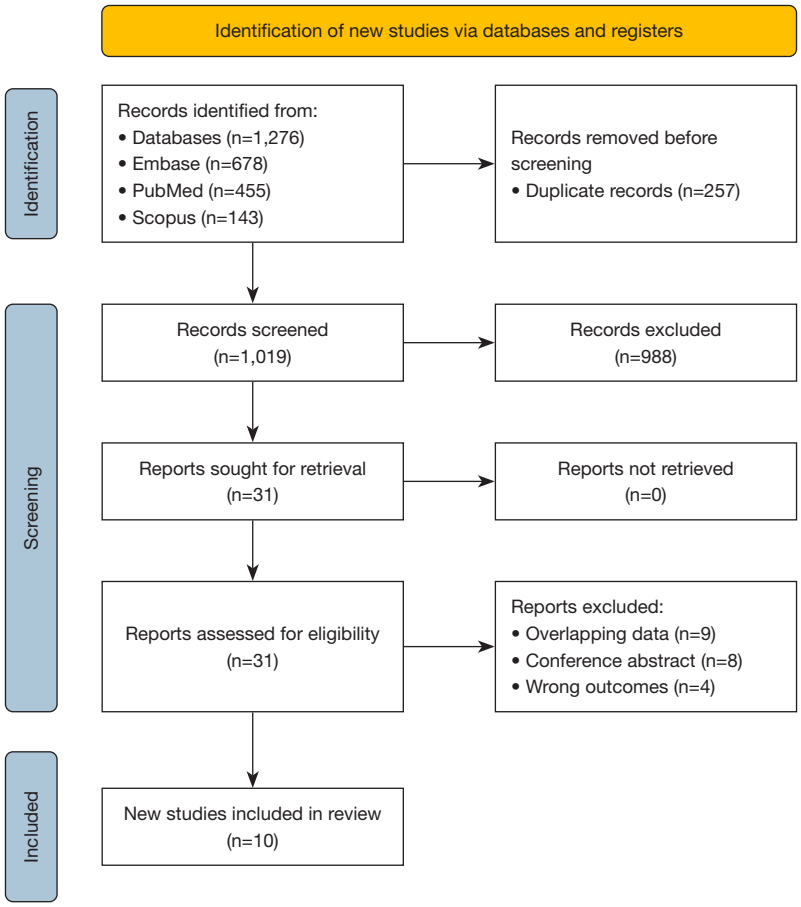


**Figure 1** PRISMA flowchart of included studies.

secondary outcomes were acute rejection and primary graft dysfunction.

### Quality assessment

The quality of each study was assessed using the modified Canadian National Institute of Health Economics (CNIHE) assessment tool for case series (9). Of a possible total of 20 criteria to be met from the CNIHE tool, a study was considered high quality if it scored 17 or higher, moderate quality if it scored between 13 and 16, and low quality if it scored 12 or below. Study quality was independently assessed by two investigators (B.T.M. and W.L.) with review and consensus completed by the senior author (B.T.M.).

### Statistical analysis

Baseline characteristics and operative details were extracted from the text, tables and figures of included papers by two independent authors (B.T.M., W.L.). Discrepancies were discussed then finally reviewed by the senior author (B.T.M.). Statistical analysis was carried out using Stata (version 17.0, StataCorp, Texas, USA) and R (Version 4.1.1. R Core Team, Vienna, Austria) utilizing meta-analysis of proportions and means with a random-effects model where necessary. The 'metafor' package (R) was used for quantitative analysis, while graphical analysis was completed using Stata. Values were considered statistically significant if the reported P value was less than 0.05. For continuous data with central tendency described using median values and interquartile range, the mean and standard deviation were estimated using calculations described by Wan and colleagues (10). Survival data were calculated using aggregated KM curves collected from included studies, where reported, using the methods described by Guyot and colleagues (11). Digitization of source KM curves was

 

**Table 1** Baseline donor cohort characteristics

| Characteristics | Value |
|---|---|
| Patients | 1,219 (100.0) |
| Males | 1,019 (83.6) |
| Age (years) | 30.5±10.5 |
| Co-morbidities | |
| BMI (kg/m$^2$) | 26.8±4.2 |
| Reporting frequency | 75.1% |
| Hypertension | 49 (9.0) |
| Reporting frequency | 44.9% |
| Cause of death | |
| Anoxia | 361 (42.5) |
| Head trauma | 309 (36.4) |
| Stroke/CVA | 130 (15.3) |
| Other | 50 (5.8) |
| Reporting frequency | 69.7% |

Values are n (%) or mean ± SD (weighted average) unless otherwise specified. BMI, body mass index; CVA, cerebrovascular accident; SD, standard deviation.

**Table 2** Baseline recipient cohort characteristics

| Characteristics | Value |
|---|---|
| Patients | 1,219 (100.0) |
| Males | 968 (79.4) |
| Age (years) | 54.8±7.7 |
| Co-morbidities | |
| BMI (kg/m$^2$) | 28.1±6.3 |
| Reporting frequency | 55.9% |
| T2DM | 164 (31.4) |
| Reporting frequency | 42.8% |
| Mechanical circulatory support (bridging) | 469 (50.1) |
| Reporting frequency | 76.8% |
| Creatinine (mg/dL) | 1.2±0.4 |
| Reporting frequency | 24.9% |
| Wait-time (days) | 63.4±27.6 |
| Reporting frequency | 52.8% |

Values are n (%) or mean ± SD (weighted average) unless otherwise specified. BMI, body mass index;T2DM, type 2 diabetes mellitus; SD, standard deviation.

performed using DigitizeIt (version 2.5.9, Braunschweig, Germany) and in the case where multiple cohorts were represented on the same curve, individual KM curves were first generated then subsequently merged with the rest of the data, to be analyzed together. A funnel plot of the primary outcome was used to graphically assess publication bias, paired with the significance of Egger's test. Heterogeneity was measured using $I^2$ values calculated with each outcome undergoing meta-analysis.

## Results

Following independent screening from an initial library of 1,276 studies, 31 were selected for full-text review and finally ten studies were included for analysis (12-21). One of the included studies, written by Messer *et al.* [2023], included two cDCD cohorts distinguished by their enrollment before and after the conception of the Joint Innovation Fund (JIF) (19). They have been referred to as pre-JIF and JIF cohorts, respectively, from here on. There was considerable overlap between patient populations in studies initially included following full text review (notably using the United Network for Organ Sharing (UNOS) database) and therefore nine papers were excluded from analysis prior to inclusion in this review.

Quality analysis using the CNIHE tool found a majority of high-quality studies fitting all inclusion criteria, revealing six publications receiving scores of 17 or more and being classed as high quality. Only four studies were scored as medium quality, whilst zero included studies were low quality (Table S1). Therefore, no further sub-group analysis for outcome data or heterogeneity was required as low quality evidence was not a confounding factor in this meta-analysis.

### Baseline study characteristics

Baseline cohort characteristics are reported in *Table 1* and *Table 2*, along with reporting frequencies for each of the operative methods. A total of 1,219 donor/recipient pairs were followed in this systematic review, of whom 83.6% and 79.4%, respectively, were male. The studies ranged in cohort size from 14 to 425. The mean age of the donor cohort was significantly younger than that of the recipient cohort

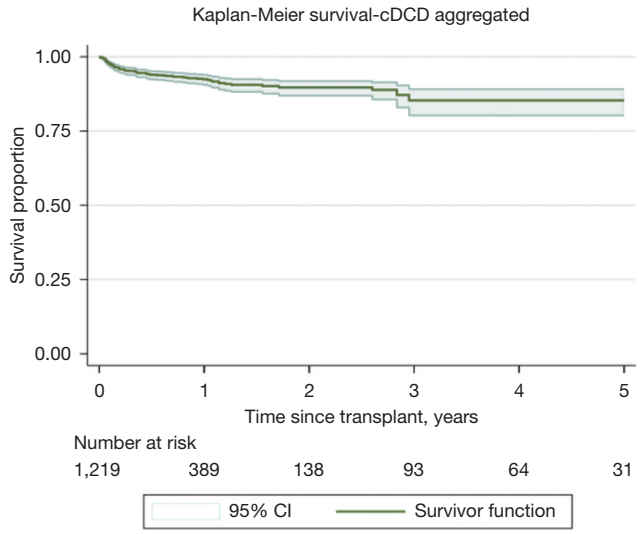


**Figure 2** Aggregated Kaplan-Meier curve for long-term survival after cardiac transplant following cDCD. cDCD, controlled donation after circulatory death; CI, confidence interval.

(30.5±10.5 *vs.* 54.8±7.7 years; P<0.001), however BMI was not significantly different between groups (26.8±4.2 *vs.* 28.1±6.3 kg/m$^2$; P>0.05). There was limited reporting of patient comorbidities as well as intra-operative outcomes between included studies. Half of patients receiving a heart from a cDCD donor underwent mechanical circulatory support (MCS) as bridging therapy to transplantation, which included extra-corporeal membrane oxygenation (ECMO), intra-aortic balloon pump (IABP) and ventricular assist device (VAD) interventions. Study details are shown in Table S1, with the large majority of studies originating in the US and the United Kingdom (UK). One multicenter study was included, as well as the largest cohort published in Australia. All but two of the included studies have been published in the 12 months preceding this report, likely due to the recent rise in acceptance and incorporation of cDCD cardiac transplantation in tertiary centers globally. This also likely reduces heterogeneity between included studies, as similar preservation, surveillance and surgical methods are used. Five of ten included studies report using DPP exclusively, one study reports using NRP exclusively, while three studies report a combination of both, and one does not report their procurement method. Cause of death of the donor group, from most to least prevalent, was: anoxia (42.5%), head trauma (36.4%), stroke (15.3%) and other causes (5.8%).

### Primary outcomes: short-term and long-term post-transplant survival

Short-term survival up to 12 months was evaluated through meta-analysis of proportions, while long-term mortality estimates were reported through aggregated digitized Kaplan-Meier curves, extracted from all included studies, using methods published by Guyot and colleagues.

KM aggregated survival estimates at 1-, 2- and 3-year for the pooled cDCD cohort were 92.4%, 89.9% and 85.3%, respectively (*Figure 2*). Survival through to 5-year remained constant at 85.3%, however there was a precipitous drop in numbers at risk for these time periods (*Table 3)*. Overall pooled 1-year survival was 92.4% (95% CI: 89.7–94.8%; $I^2$=53.4%; *Figure 3*). No significant difference was found when comparing the randomized cohort to the non-randomized studies.

Although acute in-hospital mortality rates were only reported in 59% of the pooled patient population, rates were very low overall, at just 2.5%. This statistic included an aggregation of reported 30-day mortality and in-hospital mortality and was not extrapolated from presented KM curves.

### Secondary outcomes: acute rejection and primary graft dysfunction

Secondary outcomes for this review included both acute allograft rejection rates and primary graft dysfunction over the pooled mean follow-up period of 27 months. The pooled acute rejection rate was 8.6% (95% CI: 4.2–14.2%; $I^2$=86.7%; *Figure 4*), while the rate of primary graft dysfunction was 18.3% (95% CI: 7.6–32%; $I^2$=94.7%; *Figure 5*), both of which showed a high level of heterogeneity. In terms of inclusion for assessment in included studies, acute rejection was an outcome far more prevalent than that of primary graft dysfunction, with reporting frequencies of 91.5% and 65.1%, respectively. It was noted that a source of selection bias may be present in the Ayer *et al.* (13) [2023] study with regards to the primary graft dysfunction outcome, as inclusion criteria for this study required severe primary graft dysfunction for patient selection, which is responsible for the 100% effect size.

### Publication bias

In order to assess for publication bias, analysis using

 

**Table 3** Operative outcomes and survival

| Variable | Value | Reporting frequency |
|---|---|---|
| Patients | 1,219 | 100% |
| 30-day mortality | 18 (2.5) | 59% |
| 1-year survival (%) (95% CI); $I^2$ value (%) | 92.4 (89.7–94.8); 53.7 | 100% |
| Long-term aggregated survival (compare to population death rate) | | |
| 1-year | 92.4% | 31.9%[a] |
| 2-year | 89.9% | 11.3%[a] |
| 3-year | 85.3% | 7.6%[a] |
| 4-year | 85.3% | 5.3%[a] |
| 5-year | 85.3% | 2.5%[a] |
| Hospital LOS (days) | 20.3±10.5 | 92.6% |
| ICU LOS (days) | 7.9±5.9 | 43.6% |
| Acute rejection (%) (95% CI); $I^2$ value (%) | 8.6 (4.2–14.2); 86.7 | 91.5% |
| Primary graft dysfunction (%) (95% CI); $I^2$ value (%) | 18.3 (7.6–32); 94.7 | 65.1% |

Values are n (%) or mean ± SD (weighted average) unless otherwise specified. [a], values represent numbers at risk as a proportion of the entire study population. CI, confidence interval; ICU, intensive care unit; LOS, length of stay; SD, standard deviation.

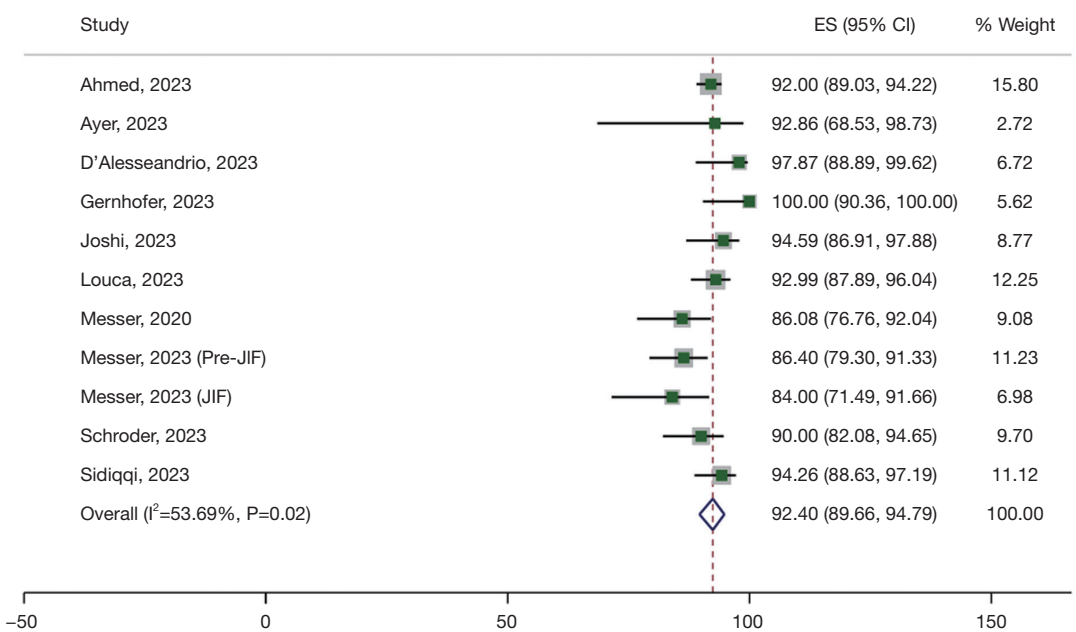


**Figure 3** One-year survival forest plot. ES, effect size; CI, confidence interval; JIF, joint innovation fund.

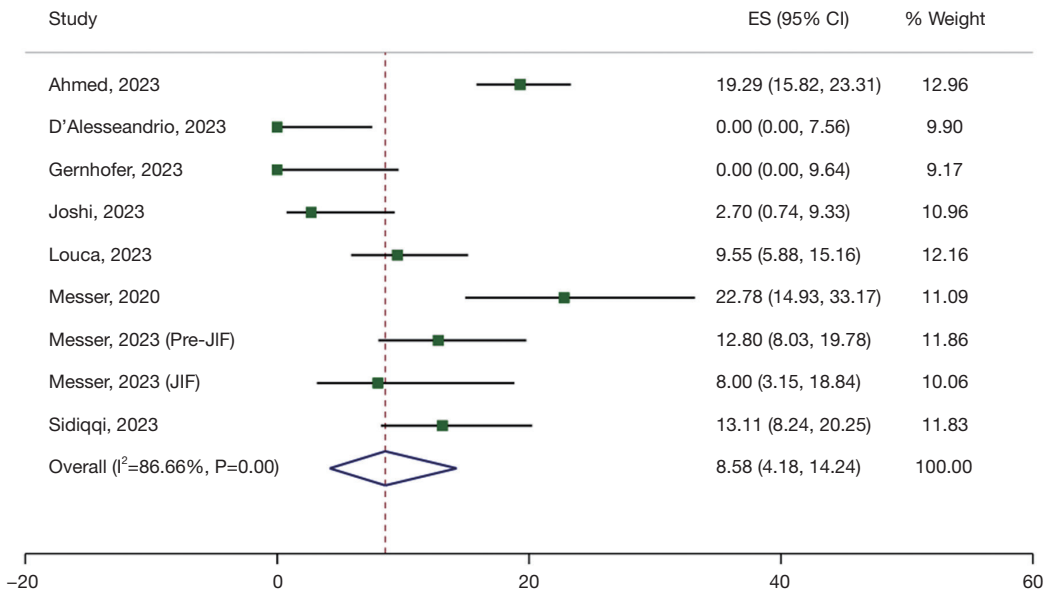


**Figure 4** Acute rejection forest plot. CI, confidence interval. ES, effect size; CI, confidence interval; JIF, joint innovation fund.

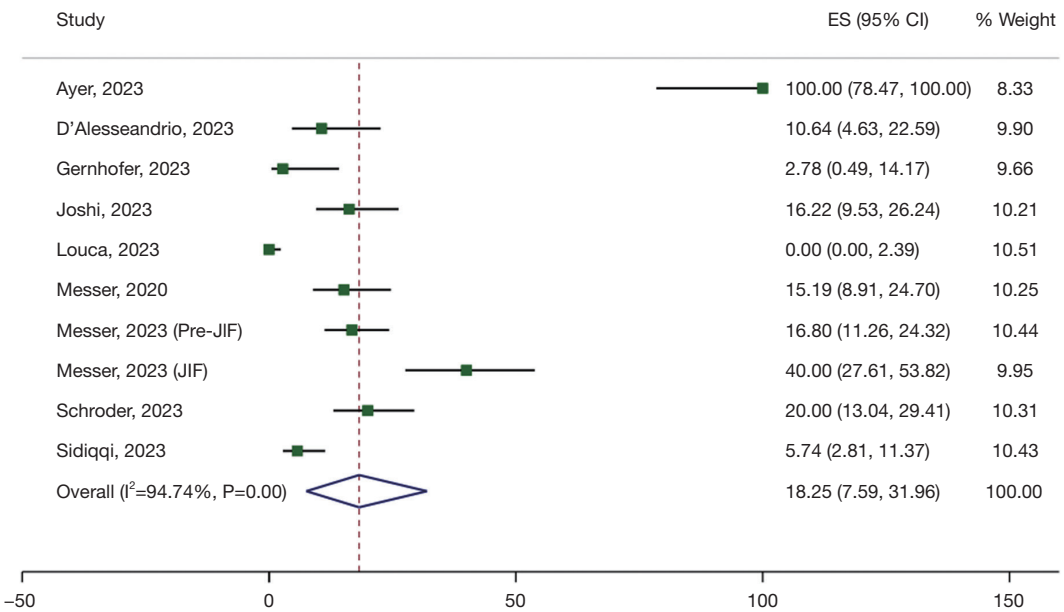


**Figure 5** Primary graft dysfunction forest plot. CI, confidence interval. ES, effect size; CI, confidence interval; JIF, joint innovation fund.

Egger's test and graphical depiction through a funnel plot was necessary. No indication of publication bias was noted in Egger's test following meta-analysis of 1-year survival rates (P=0.95), or in the funnel plot (*Figure 6*). The funnel plot showed central tendency towards the mean effect size without significant deviation by any single study.

## Discussion

### Expanding the donor pool

Recent uptake of cDCD in cardiac transplant centers across the US, Europe and Australia has resulted in a paucity of research analyzing outcomes over a mid-to-long term

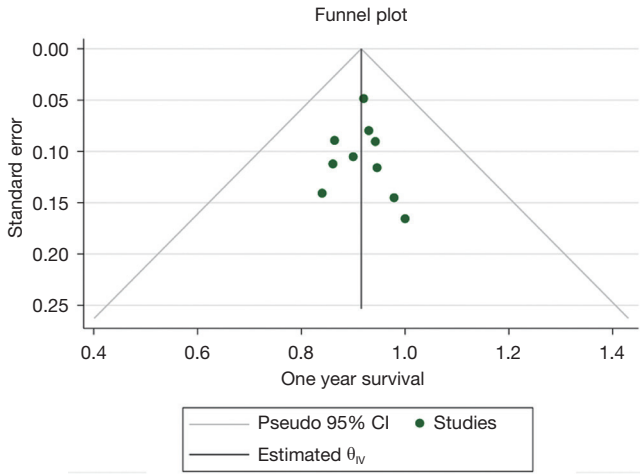


**Figure 6** Funnel plot showing risk of publication bias. CI, confidence interval.

timeframe. Venturing into this new donor pool has sprouted a new opportunity to access healthy hearts for transplant, a benefit that is both difficult to increase and definitively life-saving. However, broadening the donor pool is not without several limitations, ranging from definitional discrepancies, variation in techniques, paucity of research and ethical implications. This study resultantly utilized only the most recent literature, with eight of ten studies being published since 2023, highlighting the contemporary nature of this topic and the scope for future uptake. Until now, the large majority of published research on cDCD for cardiac transplantation has come from large centers in US, UK, Australia and Europe, leaving room for use in other tertiary centers worldwide. In countries such as China, several factors reduce the ability for increased application of cardiac transplants, including: donor heart scarcity, improper facilities at large catchment tertiary hospitals, a lack of a definitive waiting list due to limited communication between transplant hospitals and significant financial expense, due to limited coverage from medical insurance plans (22). DCD hearts, if non-inferiority to DBD hearts can be proven, offer a way to increase available hearts and alleviate waitlists internationally.

## DCD *vs.* DBD

While no comparison was made to DBD hearts in this study, our established long-term survival curve can be compared to those of existing studies examining survival after DBD transplantation. The primary outcome of 12-month aggregated survival in the present study was 92.4%, with a markedly reduced sample size at the 5-year interval suggesting survival of 85.3%. Within the DCD literature, 1-year survival was comparable to the only randomized trial which fit inclusion criteria, written by Schroder *et al.*, who reported 93.3%, which was interestingly greater than that of the 1:1 randomized group of DBD hearts, at just 85.4% (20). While the primary endpoint of this study was adjusted survival at the 6-month time point, where DCD still showed non-significant improved survival over DBD, at the very least non-inferiority could be established with a P value of less than 0.001. In terms of longer follow-up, a large sample size case-control study by Suarez-Pierre *et al.* in 2021 revealed a 5-year survival rate following DBD cardiac transplantation of 72% in 31,892 patients (23). While there were significantly larger numbers-at-risk and less loss to follow-up in their study, the demographic data were similar and represent a similar patient population to that reported in this meta-analysis. Comparisons can also be made to the pediatric population undergoing heart transplant, while recognizing the differences in etiology of heart disease requiring the need for transplant. Kleinmahon *et al.* [2017] reported long-term results from the International Society for Heart and Lung Transplantation Registry for both DBD and DCD cardiac transplants in children up to 18 years old, with a mean of 6 and 3 years of age, respectively (24). The results at 1 and 5 years for 3,856 DBD recipients were 91% and 81%, respectively, comparable to our adult survival data. The study itself also made a comparison to a small cohort of 21 DCD recipients, with a 1-year survival of 61% and a 5-year survival of 56%.

## DPP *vs.* NRP

On review of the literature, we also found variation in procurement strategy between included studies, with six opting for DPP, one using NRP only and three reporting a combination of patients receiving DPP or NRP. No randomized data has yet been published involving direct comparison between these two techniques, which would be needed to outline survival benefit of one technique over the other. However, in a non-randomized comparison of these techniques presented in the included study by Messer *et al.* [2020], recipients of DPP-procured hearts struggled more post-operatively (18). This was demonstrated by longer hospital and intensive care unit (ICU) stay, as well as

 

longer time under ventilator support when compared with the NRP cohort. Of the population groups included in this review, DPP is the more popular choice, likely because it was developed first, can be standardized using the Organ Care System (TransMedics, Andover, MA, USA) and allows for *ex-situ* evaluation of the heart, similar to *ex-vivo* lung perfusion, to determine organ suitability for transplant (25).

### Limitations

Several areas of statistical limitation reduce the generalizability of the results of this study. Firstly, studies included in this review were only published in centers of similar socio-economic standing, arising from 'Western' countries such as the US, UK, Australia and some European nations. This may limit the effect of this data when analyzing cohorts from non-Western countries. Furthermore, mid-to-high heterogeneity ($I^2$>50%) affected all pooled outcome measures and asserts that testing conditions between studies may not provide a reliable result when compared to each other, or pooled for a single result. Finally, only one of the ten included studies utilized prospective randomized data, revealing a dependence of this meta-analysis on retrospective cohort or registry analyses. For future research, more study designs incorporating randomized data or prospective, propensity matched cohorts will allow for more generalizable results.

## Conclusions

This systematic review and meta-analysis of recent literature revealed an updated understanding of current pooled patient data involving immediate and long-term survival, acute rejection and primary graft dysfunction for cDCD allografts. As depicted in the Individual Patient Data (IPD)-sourced aggregated KM curve, cDCD hearts have favorable survival outcomes of 92% to 1 year following transplant. Accompanying this, there were low rates of acute rejection at less than 9%, and rates of primary graft dysfunction at twice this rate, occurring in 18% of reported cDCD recipients. Ultimately, cDCD allografts show promise in offering an effective and favorable procurement source for cardiac transplantation worldwide.

## Acknowledgments

*Funding:* None.

## Footnote

*Conflicts of Interest:* The authors have no conflicts of interest to declare.



## References

1. Barnard CN. The operation. A human cardiac transplant: an interim report of a successful operation performed at Groote Schuur Hospital, Cape Town. S Afr Med J 1967;41:1271-4.
2. Madan S, Saeed O, Forest SJ, et al. Feasibility and Potential Impact of Heart Transplantation From Adult Donors After Circulatory Death. J Am Coll Cardiol 2022;79:148-62.
3. Matesanz Acedos R, Coll Torres E, Domínguez-Gi González B, et al. Donación en asistolia en Espana: situación actual y recomendaciones. Documento de Consenso Nacional 2012 [Monografía en Internet]. Madrid, Espana: Organización Nacional de Trasplantes; 2012 [consultado 6 Jun 2017].
4. González-Méndez MI, López-Rodríguez L. Organ donation after controlled cardiac death under Maastricht category iii: Ethical implications and end of life care. Enferm Clin (Engl Ed) 2019;29:39-46.
5. Jawitz OK, Raman V, DeVore AD, et al. Increasing the United States heart transplant donor pool with donation after circulatory death. J Thorac Cardiovasc Surg 2020;159:e307-9.
6. Adams BL, Brenner L, Levan M, et al. cDCDD-NRP is consistent with US legal standards for determining death. Am J Transplant 2022;22:2302-5.
7. Brann A, Jackson B, White R, et al. Impact of Functional Warm Ischemic Time on Short Term Outcomes in Donation after Circulatory Death Heart Transplantation. Journal of Heart and Lung Transplantation 2023;42:S94.
8. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA

2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71.
9. Moga C, Guo B, Schopflocher D, et al. Development of a quality appraisal tool for case series studies. In: Sons JW, ed. 21st Cochrane Colloquium. (Québec City, Canada, 2013).
10. Wan X, Wang W, Liu J, et al. Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. BMC Med Res Methodol 2014;14:135.
11. Guyot P, Ades AE, Ouwens MJ, et al. Enhanced secondary analysis of survival data: reconstructing the data from published Kaplan-Meier survival curves. BMC Med Res Methodol 2012;12:9.
12. Ahmed HF, Kulshrestha K, Kennedy JT, et al. Donation after circulatory death significantly reduces waitlist times while not changing post-heart transplant outcomes: A United Network for Organ Sharing Analysis. J Heart Lung Transplant 2024;43:461-70.
13. Ayer A, Truby LK, Schroder JN, et al. Improved Outcomes in Severe Primary Graft Dysfunction After Heart Transplantation Following Donation After Circulatory Death Compared With Donation After Brain Death. J Card Fail 2023;29:67-75.
14. D'Alessandro DA, Wolfe SB, Osho AA, et al. Hemodynamic and Clinical Performance of Hearts Donated After Circulatory Death. J Am Coll Cardiol 2022;80:1314-26.
15. Gernhofer YK, Bui QM, Powell JJ, et al. Heart transplantation from donation after circulatory death: Impact on waitlist time and transplant rate. Am J Transplant 2023;23:1241-55.
16. Joshi Y, Scheuer S, Chew H, et al. Heart Transplantation From DCD Donors in Australia: Lessons Learned From the First 74 Cases. Transplantation 2023;107:361-71.
17. Louca J, Öchsner M, Shah A, et al. The international experience of in-situ recovery of the DCD heart: a multicentre retrospective observational study. EClinicalMedicine 2023;58:101887.
18. Messer S, Cernic S, Page A, et al. A 5-year single-center early experience of heart transplantation from donation after circulatory-determined death donors. J Heart Lung Transplant 2020;39:1463-75.
19. Messer S, Rushton S, Simmonds L, et al. A national pilot of donation after circulatory death (DCD) heart transplantation within the United Kingdom. J Heart Lung Transplant 2023;42:1120-30.
20. Schroder JN, Patel CB, DeVore AD, et al. Transplantation Outcomes with Donor Hearts after Circulatory Death. N Engl J Med 2023;388:2121-31.
21. Siddiqi HK, Trahanas J, Xu M, et al. Outcomes of Heart Transplant Donation After Circulatory Death. J Am Coll Cardiol 2023;82:1512-20.
22. Sun YF, Wang ZW, Zhang J, et al. Current Status of and Opinions on Heart Transplantation in China. Curr Med Sci 2021;41:841-6.
23. Suarez-Pierre A, Lui C, Zhou X, et al. Long-term Survival After Heart Transplantation: A Population-based Nested Case-Control Study. Ann Thorac Surg 2021;111:889-98.
24. Kleinmahon JA, Patel SS, Auerbach SR, et al. Hearts transplanted after circulatory death in children: Analysis of the International Society for Heart and Lung Transplantation registry. Pediatr Transplant 2017.
25. Awad MA, Shah A, Griffith BP. Current status and outcomes in heart transplantation: a narrative review. Rev Cardiovasc Med 2022;23:11.

**Cite this article as:** Muston BT, Lo W, Eranki A, Boffini M, Loforte A. Cardiac transplantation in controlled donation after circulatory death: a meta-analysis of long-term survival using reconstructed time-to-event data. Ann Cardiothorac Surg 2025;14(1):1-10. doi: 10.21037/acs-2024-dcd-20

 