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ORIGINAL ARTICLE

Improving the predictability of time to death in controlled donation after circulatory death lung donors

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SUMMARY

Although the use of donation after circulatory death (DCD) donors has increased lung transplant activity, 25–40% of intended DCD donors do not convert to actual donation because of no progression to asystole in the required time frame after withdrawal of cardiorespiratory support (WCRS). No studies have specifically focussed on DCD lung donor progression. This retrospective study reviewed intended DCD lung donors to make a prediction model of the likelihood of progression to death using logistic regression and classification and regression tree (CART). Between 2014 and 2018, 159 of 334 referred DCD donors were accepted, with 100 progressing to transplant, while 59 (37%) did not progress. In logistic regression, a length of ICU stay $\leq$ 5 days, severe infra-tentorial brain damage on imaging and use of vasopressin were related with the progression to actual donation. CART modelling of the likelihood of death within 90-minute post-WCRS provided prediction with a sensitivity of 1.00 and positive predictive value of 0.56 in the validation data set. In the nonprogressed DCD group, 26 died within 6 h post-WCRS. Referral received early after ICU admission, with nonspontaneous ventilatory mode, deep coma and severe infra-tentorial damage were relevant predictors. The CART model is useful to exclude DCD donor candidates with low probability of progression.

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Key words
donation after circulatory death, lung transplant, organ donation, progression within time frame

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Introduction

Lung transplantation (LTx) is an important therapy for end-stage lung disease, with limited application because of a lack of suitable donor lungs. To address this, LTx centres have expanded the donor pool to include the utilization of 'controlled' donation after circulatory death (DCD) donor lungs in addition to the traditional donation after brain death (DBD) lung donors [1].

This has resulted in our program experiencing an increase in availability of transplantable lungs with very acceptable early, intermediate and late transplantation

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outcomes [1–4]. However, we do not always convert potential DCD donor/patient to actual lung donation because of the unpredictability and variability in time of progression to asystole after withdrawal of cardiorespiratory support (WCRS). Typically, a surgical team waits for 90 min after WCRS and approximately 60–75% of donors will progress in that time frame [5,6]. However, with the remaining 25–40% that do not progress to asystole within the time frame and donation, there is the expenditure of donation and transplant healthcare resource.

Previous studies have tried to identify patient characteristics associated with rapid progression to death after WCRS and have developed predictive models [7–11]. Typical measurable parameters shown to be important include the loss of brainstem reflexes [reflected by the Glasgow Coma Scale (GCS)], high ventilatory requirements (reflected by the oxygenation index), high vasopressor doses, and low sedative and analgesic doses [7,9,10]. Interestingly, in turn, Brieva and co-workers showed these predictive measures correlated with the clinical judgement of likelihood of death made by the treating ICU specialist [8]. However, many of these studies included patients who were not universally eligible to become organ donors, for example because of advanced age or infection [7,9,11]. Studies looking at progression to death on true potential DCD donors have focussed on kidney and liver donation within 60 min post-WCRS [7,9,10]. No studies to date have specifically focussed on evaluating DCD lung donation with the typical limit of 90 min post-WCRS. Lung donors basically have good oxygenation at WCRS. Additionally, there is emerging evidence that the arbitrary 90 min commonly practiced may not be the true limit of warm ischaemia for lung donors [6], opening up an opportunity for potential time-extended additional DCD lung donation [12,13].

The current study examined the outcomes of our centre's DCD lung donor referrals. The aim was to characterize the features of DCD lung donor referrals that predict the likelihood of progression to asystole from WCRS. The focus is on the first 90 min after WCRS, but this analysis also considered the factors that influence progression beyond this.

Materials and methods

Study design

We reviewed prospectively collected data on DCD lung donor referrals from DonateLife Victoria to the Alfred Hospital Lung Transplant Service, Melbourne, Victoria, between April 2014 and December 2018. The study was approved by the Alfred Hospital Ethics Committee (Project No: 28/19) and the Australian Red Cross Blood Service Ethics Committee.

Study setting and data sources

De-identified data on lung donor formal referrals were extracted from the DonateLife Victoria Electronic Donor Record and linked with Alfred LTx clinical databases by a unique donor number. The DonateLife Electronic Donor Record has detailed demographic, historical and contemporary data on actual and potential organ donors worked up for donation within the State of Victoria (population 6.2 million). Alfred LTx clinical databases record details of all lung donor referrals to our program and track those accepted and subsequent transplanted patient outcomes.

We collated and analysed donor clinical demographic, physiologic and laboratory data, including computed tomography (CT) or magnetic resonance imaging (MRI) findings, ventilator settings (whether on a spontaneous or mandatory mode) and ICU length of stay (LOS) at donation referral. Patients were classified as having suffered 'severe infra-tentorial damage' if the radiologists report noted one or more of the following in the cerebellum and/or brainstem: massive bleeding, multiple sites of infarction or herniation of brain tissue. GCS values were extracted through linkage to The Australian and New Zealand Intensive Care Society Adult Patient Database, a clinical quality registry to which all ICUs in Victoria contribute. The lowest GCS at the time of or just prior to sedation before ICU admission or during the first 24 h was used.

Recipient and donor management

Recipient selection was based on National and International Guidelines [14]. All recipients were consented regarding the general use of extended donor organs (including the use of older donors) and the concept of DCD lungs, but specific consent for DCD LTx was not mandated. The allocation of DCD and DBD donor lungs are equally locally prioritized on need and logistic considerations. Prospective donor–recipient T- and B-cell lymphocytotoxic cross-matching was performed in all patients.

All donor family discussions, the scheduling and actual management of the WCRS were undertaken according to national and local organ donation

protocols by the ICU team and DonateLife staff in the ICU [15,16]. For DCD lung procurement, the protocol recommends a maximum 90-minute time frame from WCRS to the declaration of death. Heparin administration was not mandated. Donor assessment routinely considers extended-criteria donor lungs up to age 75 for potential DCD LTx [4,17]. DCD donor lung procurement involves reintubation of the donor prior to transfer to theatre table after the locally mandated 3–5 min stand-off time following asystole for death determination, and a rapid sternotomy followed by pulmonary arterial cannulation for instilling preservation fluid [18]. There was no assessment of any lungs using an ex vivo lung perfusion (EVLP) circuit in this cohort.

For LTx recipients, a postoperative fluid management guideline was utilized, encompassing both respiratory and cardiovascular management algorithms, targeting a central venous pressure of less than 7 mmHg, where mean arterial pressure and cardiac index permitted [19].

Study outcomes

The primary outcome is intended DCD donor progression to death within the required time frame and actual lung donation. The study aim is to determine the relevant factors associated with the progression. As secondary aim, we investigated the time from WCRS to asystole and cessation of cardiac output and analysed factors leading to progression to death beyond the 90-minute time frame.

Statistical analyses

Continuous normally distributed variables were compared using Student's t-tests and reported as means (standard deviation), while non-normally distributed data were compared using Wilcoxon rank-sum tests and reported as medians (interquartile range). Categorical data were compared using chi-square tests and reported as n (%).

Multivariate logistic regression analysis was performed to explore the predictors for DCD progression, including all variables with a univariate P value less than 0.05. As analyses for the progression to death beyond 90-minute time frame, multivariate linear regression for a log transformed time from WCRS to death and Cox proportional hazards regression for event of death up to 24 h was performed using the variables based on logistic regression. Classification and regression tree (CART) modelling was used to report the probability of DCD lung donation, which was created with using variables selected by multivariate analyses. The final model was pruned at three levels below the root node for clinical utility. The developed CART model was validated using an additional data set of DCD lung donor referrals between January 2019 and October 2020 to test its performance. The same analyses were performed where a time frame for progression to death was observed out to 6 h selected to reflect a practical period that a surgical team could potentially remain on organ procurement standby at the donor hospital. All analyses were performed using R version 3.6.1 (R Foundation for Statistical Computing, Vienna, Austria). A two-sided $P < 0.05$ was considered statistically significant.

Results

Donor referral and conversion to LTx

There were 708 lung donor referrals (374 DBD and 334 DCD) from DonateLife Victoria, of which 159 DCD donors were accepted for LTx by our centre. Among them, 59 intended DCD donors did not progress to death in the required time frame (Figure 1). Consequently, we compared 100 DCD donors resulting in a transplant in our centre (transplanted DCD) versus 59 DCD donors who did not progress (nonprogressed DCD). An additional five DCD donors were referred to interstate centres as our centre had no suitable recipient, all were accepted and utilized for LTx. Among 100 transplanted DCD lung donors, only 10 donated liver grafts and 77 donated renal grafts successfully.

The characteristics of both groups can be seen in Table 1. The median of time from WCRS to death was 14 min in the transplanted DCD group and 411 min in the nonprogressed DCD group. In the transplanted DCD, warm ischaemic time (systolic blood pressure < 50 mmHg to cold pulmonary artery flush) was 23 (20–26) minutes. The distribution of causes of death was not significantly different, but fewer patients died from cerebral hypoxia / ischaemia in the transplanted DCD group. CT/MRI findings indicated more patients with severe infra-tentorial damage were in the transplanted DCD group. There was no significant difference in hospital type or vital signs prior to WRCS. However, more patients were managed with vasopressin in the transplanted DCD group. There was also no significant difference in the lung quality (donor age, oxygenation, chest radiograph, aspiration and smoking history), although more patients in the nonprogressed DCD

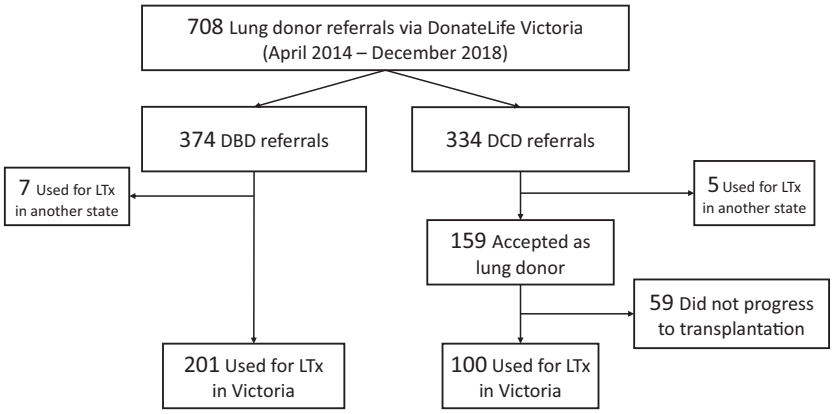

Figure 1 Disposition of donor lungs and subsequent lung donation. DBD, donation after brain death; DCD, donation after circulatory death; LTx, lung transplantation.

group were receiving a spontaneous mode of ventilation [pressure support (PS) and/or continuous positive airway pressure (CPAP)]. ICU LOS prior to the referral as a potential organ donor to our program was significantly longer in the nonprogressed DCD group than the transplanted DCD group. The best cut-off value was 4.6 days (Figure S1).

Figure 2 shows the cumulative incidence of death after WCRS. Most transplanted DCD donors died within 90 min after WCRS (the exceptions were three cases who were clearly progressing towards death at 90 min and died at 91, 107 or 110 min – these were all successfully utilized for LTx). In the nonprogressed DCD group, 26 (44%) died between 90 min and 6 h after WCRS, and 53 (90%) died within 24 h. Theoretically, an 'time-extended' DCD lung donation pathway could have had the potential to provide up to a further 26 donors within 6 h and 53 DCD donor lung grafts within 24 h (of which 13 were in-house cases at the Alfred Hospital) (Figure 3).

Predictors for progression within 90-minute

Logistic regression for DCD lung donor progression to actual donation is shown in Table 2. This model had an area under the receiver operator characteristic curve of 0.80 (95% CI: 0.72–0.87). Predictors of progression included ICU LOS $\leq$ 5 days, infra-tentorial severe damage indicated by CT/MRI and use of vasopressin [odds ratio 6.62 (95% CI: 2.94–14.92); $P < 0.001$, 3.05 (1.24–7.53); $P = 0.016$ and 13.17 (1.30–133.79); $P = 0.029$, respectively].

Predictors for progression beyond 90-minute

Multivariate COX regression indicated ICU LOS $\leq$ 5 days, total GCS score = 3, PS/CPAP and use of vasopressin as the relevant variables for the progression to death up to 24 h (Table 3). In a linear regression model including cause of death as covariates, ICU LOS and GCS score were also consistently related to the time to death (Table S1).

CART modelling

The CART analysis to predict DCD progression within 90 min included 5 variables (ICU LOS, GCS score, CT/MRI findings, vasopressin, ventilation mode), which yielded a three-level solution with five terminal nodes based on 153 intended DCD donors with complete variables (Figure 4). Four relevant variables were ICU LOS $\leq$ 5 days, PS/CPAP, GCS score = 3 and infra-tentorial severe damage indicated by CT/MRI. Assuming a terminal node (ICU LOS > 5 days and PS/CPAP without infra-tentorial severe damage) as nonprogressed donors (within a 90-minute time frame), the model had a sensitivity of 0.99 and a positive predictive value of 0.67 in the derivation data set. In the validation data set (30 transplanted and 25 nonprogressed DCD donors), the above model to exclude candidates with low probability of progression had a sensitivity of 1.00 and a positive predictive value of 0.56.

In addition, we created another CART model where we evaluated DCD donors who died within 6 h after WCRS (Figure S2). Similarly, the significant variables were ICU LOS $\leq$ 5 days, PS/CPAP, GCS score = 3 and infra-tentorial severe damage indicated by CT/MRI.

DCD LTx outcomes

In 100 recipients who received lungs from DCD transplanted donors between 2014 and 2018, the rate of primary graft dysfunction grade 3 at 24 and 72 h was 9% and 6%, respectively, with 90-day mortality of 3%. Late outcomes were also excellent with 1-year survival of 94% and 3-year survival of 79%, calculated by the Kaplan–Meier method.

Table 1. Characteristics of DCD lung donor referrals.

	Transplanted DCD group (n = 100)	Nonprogressed DCD group (n = 59)	P value
Time from WCLS to death (min)	14 [12–18]	411 [276-1023]	<0.001
Age (years)	52 [38–62]	50 [35–61]	0.64
Male	59 (59)	36 (61)	0.80
Height (cm)	170 [161–177]	170 [165–178]	0.36
Weight (kg)	80 [68–94]	80 [69–95]	0.93
Body mass index (kg/m^2)	28 [24–31]	26 [23–31]	0.41
Cause of death			
Cerebral hypoxia/ischaemia	38 (38)	28 (47)	0.28
Cerebral infarction	4 (4)	4 (7)	
Intracranial haemorrhage	28 (28)	13 (22)	
Trauma brain injury	18 (18)	12 (20)	
Others	12 (12)	2 (3)	
Hospital classification			
Tertiary (City)	81 (81)	52 (88)	0.47
Rural / Regional	4 (4)	2 (3)	
Others	15 (15)	5 (8)	
Public / Private			
Public	99 (99)	59 (100)	0.44
Private	1 (1)	0 (0)	
Heart rate (/min)	85 [70–99]	85 [75–99]	0.88
Systolic blood pressure	122 [105–146]	125 [111–140]	0.65
Mean blood pressure	82 [73–94]	82 [77–90]	0.90
Chronic heart disease	14 (14)	13 (22)	0.19
Total Fluid Hour Average	75 [47–112]	76 [59–103]	0.94
Blood transfusion > 10 units	10 (10)	9 (15)	0.32
Catecholamine (before WCRS)	44 (44)	19 (32)	0.14
Adrenaline	8 (8)	1 (1.7)	0.10
Noradrenaline	38 (38)	18 (31)	0.77
Vasopressin	13 (13)	1 (1.6)	0.015
P/F ratio	422 [362–486]	448 [348–488]	0.61
$PaCO_2$ (mmHg)	39 [35–42]	37 [33–41]	0.21
Compliance (ml/cmH_2O)	40 [31–56][a]	43 [36–62][b]	0.21
Ventilation mode: PS and/or CPAP	18 (18)	21 (36)	0.010
PEEP (cmH_2O)	10 [5–10]	10 [5–10]	0.76
Questionable aspiration	30 (30)	12 (20)	0.18
Abnormal chest radiograph	40 (40)	23 (39)	0.90
Tobacco history			
Never	43 (43)	18 (31)	0.27
Former	24 (24)	19 (32)	
Current	33 (33)	22 (37)	
Tobacco > 20 pack-years	10 (10)	5 (8)	0.75
Total Glasgow Coma Scale	3 [3–5][c]	3 [3–7][d]	0.017
Infra-tentorial severe damage indicated by CT/MRI	40 (40)	13 (22)	0.020
ICU length of stay (hours)	49 [18–107]	144 [81–259]	<0.001

All values reported as n (%) or median [interquartile range].

CPAP, continuous positive airway pressure; CT, computed tomography; DCD, donation after circulatory death; ICU, intensive care unit; MRI, magnetic resonance imaging; PEEP, positive end-expiratory pressure; P/F ratio, ratio of arterial partial pressure of oxygen to fraction of inspired oxygen; PS, pressure support; WCRS, withdrawal of cardiorespiratory support.

Donor information was unavailable for: [a]15 donors, [b]17 donors, [c]5 donors, [d]1 donor.

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Discussion

We retrospectively reviewed time of progression to asystole in an accepted DCD lung donor cohort with good oxygenation. The analyses indicated donation referrals occurring soon after admission to ICU, deep coma (GCS = 3), spontaneous ventilatory mode (PS/CPAP), use of vasopressin and infra-tentorial severe damage by CT/MRI findings as the relevant predictors of progression to death within 90 min. These features

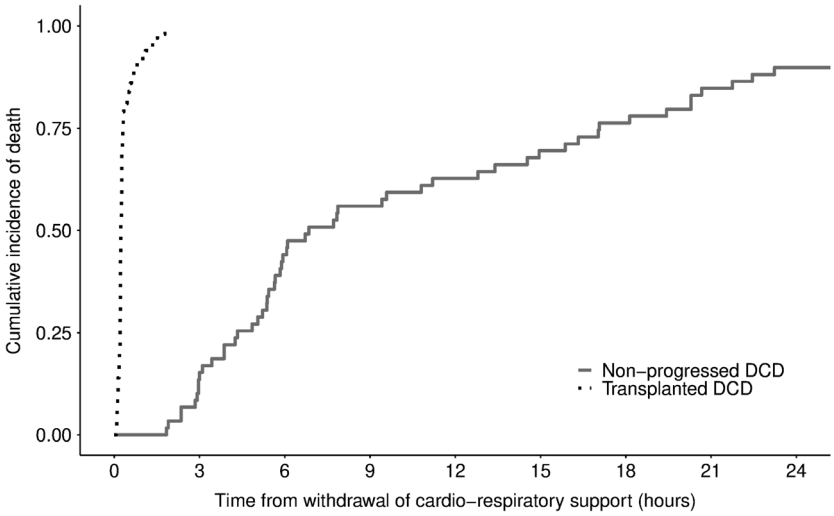

Figure 2 Cumulative incidence of death after withdrawal of cardiorespiratory support. DCD, donation after circulatory death.

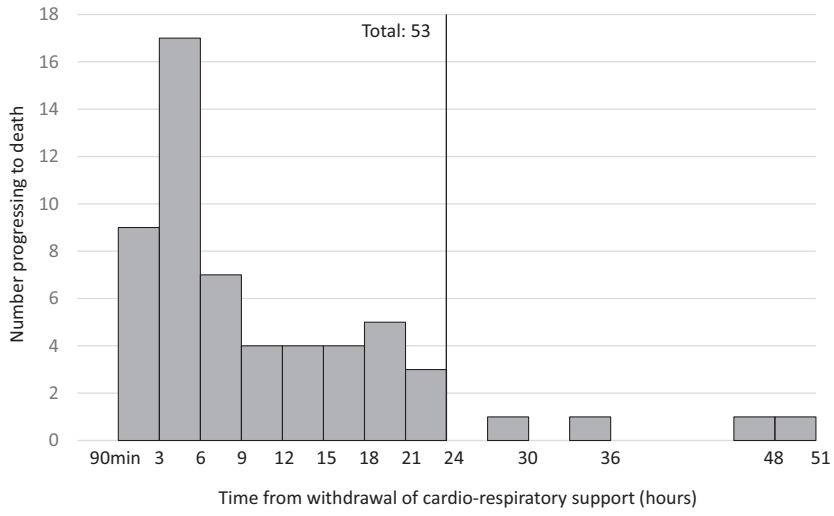

Figure 3 Distribution of time to death after withdrawal of cardiorespiratory support in nonprogressed DCD lung donors. Two nonprogressed DCD donors died 51 h after withdrawal of cardiorespiratory support. DCD, donation after circulatory death.

Table 2. Multivariate logistic regression for DCD donor progression to lung donation.

	Odds ratio (95% CI)	*P* value
ICU length of stay ≤ 5 days	6.62 (2.94–14.92)	<0.001
Ventilation mode: PS and/or CPAP	0.45 (0.19–1.07)	0.07
Total Glasgow Coma Scale score = 3	2.06 (0.93–4.59)	0.08
Infra-tentorial severe damage (by CT/MRI)	3.05 (1.24–7.53)	0.016
Use of vasopressin (before WCRS)	13.17 (1.30–133.79)	0.029

CPAP, continuous positive airway pressure; CT, computed tomography; DCD, donation after circulatory death; ICU, intensive care unit; MRI, magnetic resonance imaging; PS, pressure support; WCRS, withdrawal of cardiorespiratory support.

Table 3. Cox proportional hazards regression for DCD donor progression to death up to 24 h.

	Odds ratio (95% CI)	*P* value
ICU length of stay ≤ 5 days	2.13 (1.49–3.04)	<0.001
Ventilation mode: PS and/or CPAP	0.63 (0.42–0.95)	0.028
Total Glasgow Coma Scale score = 3	1.65 (1.15–2.36)	0.006
Infra-tentorial severe damage (by CT/MRI)	1.25 (0.87–1.79)	0.22
Use of vasopressin (before WCRS)	1.96 (1.07–3.58)	0.029

CPAP, continuous positive airway pressure; CT, computed tomography; DCD, donation after circulatory death; ICU, intensive care unit; MRI, magnetic resonance imaging; PS, pressure support; WCRS, withdrawal of cardiorespiratory support.

likely reflect the concept that the presence of significant brainstem damage (but insufficient to lead to brain death) will translate to a limited ability to sustain spontaneous unassisted ventilation post-WCRS, which makes a rapid progression to death more likely.

Historically, absent brainstem reflexes and higher levels of cardiorespiratory support were advocated as typical predictors of DCD time to death after WCRS [7,9–11]. ICU specialist opinion has been reported as the best individual predictor of death within 60 min in adult patients having a WCRS in ICU in Australia [8], with additional predictors noted to be pH, GCS, spontaneous respiratory rate, positive end-expiratory pressure and systolic blood pressure [20]. Among the predictors indicated by the present DCD lung donor study, early referrals (i.e. time from ICU admission to referral ≤ 5 days) may reflect the ICU specialist's assessment that a severe irreversible brain injury has occurred or ongoing ICU management is without patient benefit. Consistent with this, the use of vasopressin, a GCS of 3, and the absence of spontaneous ventilation indicate the high likelihood of a severe brainstem injury. Cerebral CT/MRI radiologist's findings of infra-tentorial injury provide a logical adjunct to the physiological signs of severe injury. Across multiple different types of analyses, early referrals and deep coma were indicated as relevant factors.

While other markers of brainstem reserve or function might be helpful to further assess brainstem function [11], it is not local practice to temporarily remove the ventilator as 'test' of apnoea [21,22], because of concerns that this could destabilize haemodynamics or lead to lung derecruitment in a situation where the patient is potentially suitable for DCD. Importantly, in an Australian context, the ICU clinical practice that utilizes these parameters to characterize irreversible severe damage and the potential for DCD donation does not come at the expense of DBD donation. Our controlled DCD program has increased potential lung donors without reducing DBD donor opportunities, subsequently resulting in increased LTx numbers with comparable outcomes to those seen following DBD [2,23,24]. We have previously reported no significant difference between DCD vs DBD LTx in 30-day and 3-year mortality [25], although more early postoperative events following DCD LTx have been reported in other studies [26,27].

For clinical applicability and future research, we adopted CART modelling to consider the huge variations in donor characteristics, ICU therapies and practice, as well as other organ procurement logistic factors. CART diagrams would be helpful clinically for ICU staff and LTx team prognostication and useful for future resource discussions. Especially it could exclude potential lung donor with low probability of DCD progression. Although the accuracy of our model (Figure 4) was not high enough to predict death in less than 90 min after WCRS completely, we have to consider not only donor factors, but also recipient factors (e.g. acuity and urgent requirement for LTx) and organizational logistics for organ procurement (e.g. team availability) in any decision to plan DCD lung procurement. Therefore, the model with a high sensitivity could be useful in informing decisions that aim to minimize the loss of lung donor opportunities while optimizing the expenditure of healthcare resource. Moreover, the model possibly retrieves additional DCD donor opportunities historically rejected as a result of clinician's low expectation of death within the 90-minute post-WCRS period.

Although several general prediction models have been already published (Table S2), there is no literature focussing on DCD lung donors with a 90-minute time frame. To our knowledge, this is the first study to explore the prediction for the progression of DCD in potential lung donors. Previous prediction models of DCD progression focussed on all potential DCD donors

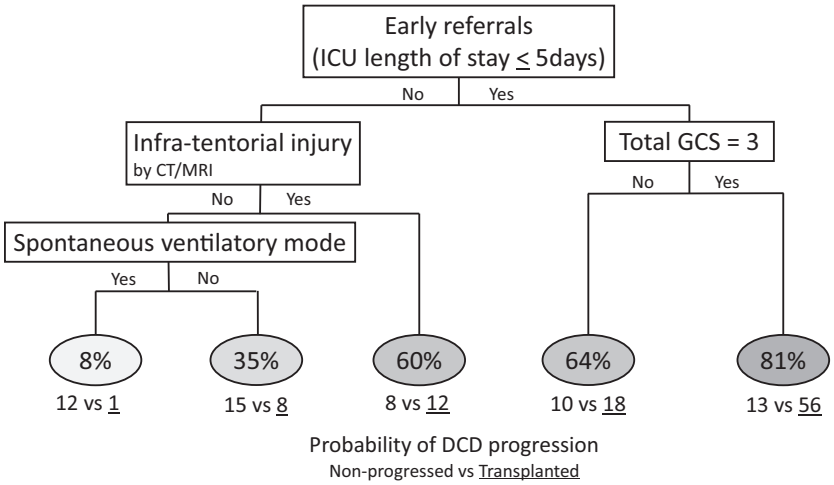

Figure 4 Classification tree for DCD donor progression to lung donation. Classification and regression tree model analysed 153 intended DCD donors because of missing GCS in 6 cases (1 nonprogressed donor and 5 transplanted donors). Spontaneous ventilatory mode includes pressure support and/or continuous positive airway pressure. CT, computed tomography; DCD, donation after circulatory death; GCS, Glasgow Coma Scale; ICU, intensive care unit; MRI, magnetic resonance imaging.

or patients with devastating neurological injury, which variables are common to our model, excluding the respect to our cohort which had good lung function and minimum heart failure. Indeed, very poor lung function actually enhances progression in nonlung DCD donors (e.g. kidney only DCD donors) which have historically contributed to the majority of DCD transplants. In the current study, 100 transplanted DCD donors successfully donated 77 kidney and 10 liver grafts to recipients. While recognizing the quality of donor organs are not necessarily comparable for an individual donor, at least part of these different DCD organ recovery rates reflect the significantly longer acceptable warm ischaemic time for lungs, compared to livers and kidneys. Considering all these points, our lung-specific model is therefore the most appropriate for assessing lung donation.

Moreover, considering that DCD donor lungs may be less impacted by warm ischaemic injury [6], the possibility of time-extended lung donation is real [12,13], and there may be significant unrealized potential lung donation opportunities. A time-extended DCD lung donation pathway using ≤ 6 h or ≤ 24 h post-WLST could provide up to additional 5 or 10 donor lungs per year, respectively. Referrals early after ICU admission and deep coma would have an important role for the prediction for time-extended DCD. While not required for controlled DCD LTx [6], EVLP is considered necessary for evaluation of time-extended DCD lungs. However, notably in this cohort, there were cases where DCD progression occurs in ≤ 6 h with haemodynamics that are well preserved until just before asystole, which may have been suitable for lung donation.

More accurate prediction of progression to death in a potential DCD donor is required to avoid disappointment for donor families if the donation process does not occur. The CART models developed in this study (Figure 4 and Figure S2) also may identify early in the consent process, potential lung donors that are unlikely to progress within 90 min but would be more possible to consider a time-extended DCD pathway ≤ 6 h.

Our study has several limitations. Firstly, there are variations in physiologic and clinical management over time in a potential lung donor, as well as across different ICU physicians, centres and countries. There are variations in experience with facilitating DCD donation. End of life care managements including comfort therapy during controlled DCD procedure also vary considerably, which could affect the interval between WCRS and cardiac arrest [28]. These variations might decrease the accuracy of CART model in the validation data set. Notably, the cut-off value of the period between ICU admission and donor referral (as used in our CART model) would need to be modified. Secondly, our review had relatively small sample size because it focussed on only DCD lung donors. In future, this prediction model needs to be validated and then recalibrated on a large-scale cohort. Finally, the present study is a retrospective review, which is unable to extract some relevant factors such as individual brainstem reflex examination findings. Surgical interventions such as decompressive craniotomies might also alter the

probability of DCD in our prediction model. In future, prospective studies including brainstem reflexes, spontaneous respiratory rate, comprehensive findings such as CT/MRI imaging, and interventions are warranted.

In conclusion, we reviewed DCD lung donor referrals and noted that early referrals after admission to ICU, with deep coma, and severe infra-tentorial damage according to CT/MRI were the predictors of DCD progression to asystole in potential lung donors at the time of donor referral. A time-extended DCD lung donation pathway could increase the donor pool and subsequent LTx activity. Our prediction model with high sensitivity and acceptable positive predictive value could minimize the loss of lung donation opportunities and reduce the burden imposed on healthcare resources.

Authorship

SO: participated in research design, literature search, data collection, interpretation, and analysis, writing and revision of the paper. BL, GS and DP: participated in research design, study supervision, literature search, data collection and interpretation, writing and revision of the paper. MM, RD and HO: participated in research design, data collection and interpretation, and revision of the paper. All authors reviewed the manuscript, approved its final version and contributed important intellectual content.

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Conflict of interest

The authors have no conflict of interest to disclose.

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Data availability statement

Access to the original data is restricted because of confidentiality requirements, but analytic code is available. A requirement for use of data provided by the Organ and Tissue Authority, DonateLife Victoria, The Alfred Hospital and the Department of Health in Victoria is that access to the original data is restricted to the study investigators only. All analytic code used to create the models is open and available on GitHub, at https://github.com/LTx-donor-reaserch/DCD.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Figure S1. Receiver operator characteristic curve of intensive care unit length of stay in predicting the DCD lung donor progression to transplantation.

Figure S2. Classification tree for DCD lung donor progression to death within 6 hours after withdrawal of cardiorespiratory support.

Table S1. Multivariable liner regression for the log transformed time-to-death.

Table S2. Summary of previous prediction model of death after withdrawal of cardiorespiratory support.

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