4 Predicting the Likelihood a DCD Donor Will Expire

Lauren Ng, W. D. Freeman, and Eelco F. M. Wijdicks

Donation after circulatory death (DCD) was the primary source of organs for transplantation prior to the 1970s but fell out of favor once brain death was recognized as a legal definition of death [1]. However, organ transplantation was soon limited by the availability of deceased donors. In response to this, the University of Pittsburgh produced the first policy for the use of organs after the withdrawal of life support in 1992, initiating both legal and ethical debates. Despite controversy, DCD donors now account for 5% of all donors and have increased donation rates as high as 30% for certain organs [1, 2]. However, 20–30% of consented donors for DCD do not die within the time limits followed by transplant centers [2]. Predicting the likelihood that a DCD donor will expire is important for transplant programs attempting to determine the correct utilization of resources, particularly when traveling a significant distance for the procurement. Prediction is also important to manage expectations of the potential donor families and loved ones. In addition to questions about the patients' clinical condition, various logistic questions that may impact the utilization of the organs and likelihood that the donor will expire need to be asked. These include the following:

– Where will the care withdrawal take place (ICU/OR/others)?
– Will the patient be extubated at the time of care withdrawal?
– Does the patient have an arterial line to monitor blood pressure?

L. Ng (✉)
Department of Critical Care, Neurology and Neurosurgery, Mayo Clinic, Jacksonville, FL, USA
e-mail: ng.lauren@mayo.edu

W. D. Freeman
Department of Neurologic Surgery, Neurology, Mayo Clinic, Jacksonville, FL, USA

E. F. M. Wijdicks
Division of Neurocritical Care and Hospital Neurology, Department of Neurology, Mayo Clinic, Rochester, MN, USA

K. P. Croome et al. (eds.), *Donation after Circulatory Death (DCD) Liver Transplantation*, https://doi.org/10.1007/978-3-030-46470-7_4

– What is the mandatory wait time after circulatory arrest?
– Does the donor hospital recognize pulseless electrical activity (PEA) as circulatory arrest?

Prediction based solely on clinical impression may have variable reliability, and therefore various prediction tools have been developed in an attempt to predict time to death following withdrawal of life-sustaining therapy (WLST) to assist providers in identifying suitable donors. The following three main DCD prediction tools are available:

1. University of Wisconsin DCD tool
2. UNOS criteria
3. DCD-N tool

The first two tools require temporary disconnection of the patient from the mechanical ventilator, whereas the third does not.

University of Wisconsin Tool

The University of Wisconsin Hospital and Clinics was unique in that it continued to procure organs from DCD donors since 1974. They developed the UWDCD tool which was validated in 2003 to screen potential DCD donors for the likelihood to die within 60 and 120 minutes after WLST [3]. The population included patients with severe brain injury on mechanical ventilation who were either being evaluated for brain death and had a Glasgow Coma Scale less than 5 or where a physician was ordering WLST.

This tool incorporates a spontaneous breathing trial, use of vasopressors, age, airway type, and body mass index. In the spontaneous breathing trial, patients were disconnected from the ventilator for up to 10 minutes, and at the end of this period, respiratory rate, tidal volume, negative inspiratory force, and oxygenation saturation are all recorded (Fig. 4.1). If the patient becomes hemodynamically unstable (systolic blood pressure < 80 mmHG; oxygen saturation < 70%) or rapidly decompensates, the assessment is terminated, and the patient is deemed an appropriate candidate for DCD. Body mass index was not a component of the original DCD evaluation tool; however, higher BMI was shown in subsequent analysis to have a high correlation to expiration time after WLST and was added later in a post hoc analysis. The UWDCD scoring tool as well as probability of expiration ≤60 minutes can be seen in Tables 4.1 and 4.2, respectively.

The UWDCD tool was found to have a sensitivity and specificity of predicting death within 60 minutes of 0.83 and 0.84 and 0.85 and 0.45 for predicting time to death within 120 minutes [3]. However, external validation of this tool has not shown the same results.

Step One: Place a checkmark in the box next to the appropriate category in each table

Type of Intubation	
Endotracheal	
Tracheostomy	

Vasopressor/Inotrope Status	
None	
Single Vasopressor/Inotrope	
Two or More Vasopressors/Inotropes	

Step Two: Record the patient's vital signs prior to beginning the test.

Vital Signs	
Blood Pressure	
Pulse	
Oxygen Saturation	

Step Three: Disconnect the patient from the ventilator. *After 10 minutes** record the information in each of the tables below.

Respiratory Effort?	
Yes	
No	

If yes:

Respiratory Rate

Negative Inspiratory Force (NIF)*

Vital Signs	
Blood Pressure	
Pulse	
Oxygen Saturation	

Tidal Volume

*RT can do this measurement using a manometer

* If at any time the patient becomes unstable (pulse ox <70%, systolic BP <80), it is expected that the evaluation will stop and the above parameters will be recorded.

Fig. 4.1 Steps for evaluation using the University of Wisconsin DCD tool

UNOS Criteria

The United Network for Organ Sharing DCD Consensus Committee developed criteria for predicting death within 60 minutes based on expert opinion [4]. In 2008, DeVita et al. subsequently validated these criteria in a prospective multicenter study to develop a tool while also identifying other criteria that may be better predictors for death within 60 minutes of WLST [5]. They found that the UNOS criteria identify patients who are likely to die within 60 minutes of WLST and the odds ratio for death increases with the number of criteria met with odds ratios of 2.72, 4.62, and 10.6 for one, two, and three or more criteria, respectively. As 72.7% of patients with two or more criteria died within 60 minutes of WLST, the authors suggested using that as organizational policy. The UNOS criteria as well as the probability of expiration ≤60 minutes depending on the number of UNOS criteria present can be seen in Tables 4.3 and 4.4, respectively.

The authors also created two models using nonparametric classification and regression tree analyses for predicting death within 60 minutes of WLST. One

Table 4.1 UWDCD tool with points awarded for each criteria

Criteria	Assigned points
Patient age	
0–30	1
31–50	2
Over 51	3
Body mass index	
<25	1
25–29	2
>30	3
Intubation	
Endotracheal tube	3
Tracheostomy	1
Vasopressors/inotropes	
No vasopressors/inotropes	1
Single vasopressor/inotrope	2
Multiple vasopressors/inotropes	3
Spontaneous respirations after 10 min	
Rate > 12	1
Rate < 12	3
Tidal volume (TV) > 200 cc	1
Tidal volume (TV) < 200 cc	3
NIF < 20	3
NIF > 20	1
No spontaneous respirations	9
Oxygenation after 10 minutes	
O2 sat > 90%	1
O2 sat < 80–89%	2
O2 sat < 79%	3

Table 4.2 UWDCD tool: probability of expiration based on UWDCD tool score

UWDCD tool final score	Probability of expiration in <60 min	Probability of expiration in <120 min
	%	%
10	8	26
11	13	34
12	20	42
13	28	51
14	38	59
15	50	68
16	62	75
17	72	81
18	81	86
19	87	90
20	92	92
21	95	95
22	97	96
23	98	97

Table 4.3 UNOS criteria for predicting death within 60 minutes. A score is assigned between 0 and 5 based on how many criteria are met, with higher score associated with higher likelihood of death

UNOS criteria	Percent with death ≤ 60 minutes (%)
Apnea during trial off mech vent	77
RR < 8/min during trial off mech vent	67
RR > 30 during trial off mech vent	29
LVAD	100
RVAD	100
VA ECMO	0
Pacemaker-unassisted heart rate < 30	80
PEEP ≥10 and SaO2 ≤ 92%	78
FiO2 ≥ 0.5 and SaO2 ≤ 92%	67
V-V ECMO	80
Norepinephrine or phenylephrine ≥0.2	70
Dopamine ≥15	79
IABP 1:1 (or dopamine or dobutamine ≥10 and CI ≤ 2.2)	68
IABP 1:1 and CI ≤ 1.5	100

RR respiratory rate, *VA ECMO* veno-arterial extracorporeal membrane oxygenator, *IABP* intraaortic balloon pump

Table 4.4 Probability of death based on number of UNOS criteria met

Number of UNOS criteria present	Percent with death ≤ 60 minutes (%)
0	29
1	52
2	65
3	82
4–5	76

model incorporated only patient characteristics, while the second included patient characteristics and withdrawal process variables. In the first model, they found that the most powerful predictors of death were GCS equal to 3 or the combination of GCS > 3 with SaO2/FiO2 < 230 and peak inspiratory pressure ≥ 35. This model had a sensitivity of 79%, specificity of 63%, positive predictive value (PPV) of 63%, and negative predictive value of 78% [4]. This had even higher sensitivity and specificity if vasopressors >0.2 μg/kg/min and respiratory rate < 11 off the ventilator are included. The second model where all treatments are withdrawn within 10 minutes also had very high sensitivity, specificity, positive predictive value, and negative predictive value. These rules are relatively simple but have not been externally validated. Other risk factors independently associated with an increased risk of death within 60 minutes are listed in Table 4.5.

Table 4.5 Other risk factors independently associated with an increased risk of death within 60 minutes

Independent risk factors associated with time to death < 60 minutes
Glasgow coma scale of 3
$SaO_2/FiO_2 < 230$
Peak inspiratory pressure > 35
Respiratory rate off ventilator <8
Diastolic blood pressure (10 mmHg)
$PaO_2 < 72$
Epinephrine, norepinephrine, or phenylephrine >0.2
All treatments withdrawn within 10 minutes
Endotracheal tube withdrawn
Comfort medications given during first hour after WLST

DCD-N Tool

The previous two tools do not take into account the patient's neurologic status prior to WLST. The DCD-N tool predicts the onset of circulatory death in a comatose patient with catastrophic brain damage undergoing withdrawal of life-sustaining treatment. In an initial, single-center study by Yee et al., the authors showed an association between death in less than 60 minutes after extubation in patients with irreversible brain injury and coma and the following four variables: absent corneal reflex, absent cough reflex, absent motor response or extensor posturing, and high oxygenation index [6]. This was subsequently expanded upon in a large multicenter observational study which enrolled adult patients in coma due to an irreversible brain injury undergoing WLST [7]. Patients were excluded if they were not tracheal intubated or if they were brain dead.

Data collected included age, sex, corneal reflex, cough reflex, motor response to pain, oxygenation index, and time to death after WLST. In the multivariate analysis, absent corneal reflex, absent cough reflex, extensor or no response to pain, and higher oxygenation index were associated with death within 60 minutes after WLST. Oxygenation index was defined as 100 × ((FiO_2 × mean airway pressure in cm H_2O)/PaO_2 in torr) where mean airway pressure is (peak airway pressure in cm H_2O + peak end expiratory pressure in torr)/2. Using ROC curve, they determined that an oxygenation index of 3.0 had the highest sensitivity and specificity for death within 60 minutes of WLST. The authors then constructed a score based on the odds ratios for each variable (Table 4.6). The authors found that a score of 3 or more identified 72% of those dying within 60 min and a score of 0–2 identified 78% of those that did not die within 60 min. Probabilities of death within 60 minutes according to specific combinations of the variables can be seen in Table 4.7.

Other Studies

While the above three tools are the ones commonly described, several other studies have investigated predictors of time to death in potential DCD donors. A large UK study analyzed all DCD liver offers and derived validated models for both

Table 4.6 DCD-N scoring

Variables	Points
Absent cough reflex	2
Absent corneal reflex	1
Extensor or no motor response to pain	1
Oxygenation index >3.0	1

Table 4.7 Probabilities of death within 60 min according to the combinations of predictive variables

Absent corneal reflex	Absent cough reflex	Extensor or absent motor response	Oxygenation index > 3.0	Score	Probability
No	No	No	No	0	0.08
No	No	No	Yes	1	0.16
Yes	No	No	No	1	0.18
No	No	Yes	No	1	0.20
No	Yes	No	No	2	0.26
Yes	No	No	Yes	2	0.34
No	No	Yes	Yes	2	0.37
Yes	No	Yes	No	2	0.40
No	Yes	No	Yes	3	0.45
Yes	Yes	No	No	3	0.48
No	Yes	Yes	No	3	0.51
Yes	No	Yes	Yes	3	0.61
Yes	Yes	No	Yes	4	0.68
No	Yes	Yes	Yes	4	0.71
Yes	Yes	Yes	No	4	0.74
Yes	Yes	Yes	Yes	5	0.87

prediction of circulatory arrest and liver graft usability [8]. In that study of 621 potential DCD donors, 400 (64%) underwent circulatory arrest within 1 h from WLST. Factors that predicted cardiac arrest within 60 min were donor age > 40 years, use of inotropes, and absence of a gag/cough reflex.

Suntharalingam et al. investigated time to death in 91 potential DCD donors. In that study, they demonstrated that younger age, higher FiO2, and mode of ventilation were independently associated with shorter time to death [9].

A multicenter study by Brieva et al. evaluated death within 60 minutes after WLST in 318 DCD eligible patients [10]. In that study, three donor classification rules were expressed for the prediction of death in less than 60 min:

(i) Spontaneous resp. rate 0–10/min and GCS score 3
(ii) Spontaneous resp. rate 0–10/min and GCS score 4–15 and systolic BP 0–84 mmHg
(iii) Spontaneous resp. rate ≥ 11/min and PEEP ≥11

Using these three levels, the authors had a sensitivity of 0.82 and a positive predictive value of 0.80. Using only intensive care unit specialist prediction on whether the donor would expire or not within 60 min, the authors demonstrated comparable sensitivity (0.87) and PPV (0.78). Prediction of the time to death on the basis of clinical impression has previously been investigated [11]. In that study, clinical judgment of the treating intensivist had a sensitivity of 73% and a specificity of 56% to predict death within 60 minutes.

Conclusion

Several prediction models have been developed to assist providers in screening appropriate DCD candidates. As previous authors have stated, using indices to predict time to death inevitably will result in missed opportunities for donation [12]. Even patients who are deemed highly unlikely to expire within 60 minutes based on all of the scoring systems sometimes expire quickly. For each transplant program, there may be variability in the acceptable probability threshold for likelihood that the donor will expire within 60 minutes in order to commit to a DCD organ procurement. In addition, this threshold may also vary from case to case based on distance and potential resources consumed. The aforementioned scoring systems are useful in providing some guidance as to how likely it is that a donor will expire. While the three scoring systems highlighted above are the only ones which have undergone external validation, each is fraught with limitations. UNOS criteria relies heavily on hemodynamic support which may exclude other populations, both the UWDCD and UNOS criterias require that the patient be taken off the ventilator which is not often practical, and the DCD-N tool is validated in patients with severe brain injury. Over all, neurologic and respiratory characteristics are the most predictive of death within 60 minutes of WLST. These scoring systems are all designed to predict which patients will expire within 60 minutes. Since most programs accepting DCD livers have acceptable DWIT between 20 and 40 minutes, these models do not represent ideal tools for predicting a usable DCD liver graft. Additional studies are needed to develop a more sensitive and specific prediction tool to help capture appropriate patients for DCD; however, it is likely that with any potential DCD donor, there will always be a level of uncertainty.

References

1. Scalea JR, Redfield RR, Rizzari MD, Bennett R, Anderson ME, Anderson JE, Kaufman DB, Sollinger HW, Fernandez LA, D'Alessandro AM, Mexrich J. When do DCD donors die? Outcomes and implications of DCD at a high-volume, single-center OPO in the United States. Ann Surg. 2016;263:211–6.
2. Munshi L, Dhanani S, Shemie SD, Hornby L, Gore G, Shahin J. Predicting time to death after withdrawal of life-sustaining therapy. Int Care Med. 2015;41:1015–28.
3. Lewis J, Peltier J, Nelson H, Snyder W, Schneider K, Steinberger D, Anderson M, Krichevsky A, Anderson J, Ellefson J, D'Alessandro A. Development of the University of Wisconsin donation after cardiac death evaluation tool. Prog Transplant. 2003;13:265–73.
4. Bernat JL, D'Alessandro AM, Port FK, et al. Report of a national conference on donation after cardiac death. Am J Transplant. 2006;6:281–91.
5. DeVita MA, Brooks MM, Zaistowski C, Rudich S, Daly B, Chaitin E. Donors after cardiac death: validation of identification criteria (DVIC) study for predictors of rapid death. Am J Transplant. 2008;8:432–41.

6. Yee AH, Rabinstein AA, Thapa P, Mandrekar J, Wijdicks EFM. Factors influencing time to death after withdrawal of life support in neurocritical care patients. Neurology. 2010;74:1380–5.
7. Rabinstein AA, Yee AH, Mandrekar J, Fugate JE, de Groot YJ, Kompanje EJO, Shutter LA, Freeman WD, Rubin MA, Wijdicks EFM. Prediction of potential for organ donation after cardiac death in patients in neurocritical care state: a prospective observational study. Lancet Neurol. 2012;11:414–9.
8. Davila D, Ciria R, Jassem W, Briceño J, Littlejohn W, Vilca-Meléndez H, Srinivasan P, Prachalias A, O'Grady J, Rela M, Heaton N. Prediction models of donor arrest and graft utilization in liver transplantation from maastricht-3 donors after circulatory death. Am J Transplant. 2012;12(12):3414–24.
9. Suntharalingam C, Sharples L, Dudley C, Bradley JA, Watson CJ. Time to cardiac death after withdrawal of life-sustaining treatment in potential organ donors. Am J Transplant. 2009;9(9):2157–65.
10. Brieva J, Coleman N, Lacey J, Harrigan P, Lewin TJ, Carter GL. Prediction of death in less than 60 minutes after withdrawal of cardiorespiratory support in potential organ donors after circulatory death. Transplantation. 2014;98:1112–8.
11. Wind J, Snoeijs MG, Brugman CA, Vervelde J, Zwaveling J, van Mook WN, van Heurn EL. Prediction of time of death after withdrawal of life-sustaining treatment in potential donors after cardiac death∗. Crit Care Med. 2012;40(3):766–9.
12. Bradley JA, Pettigrew GJ, Watson CJ. Time to death after withdrawal of treatment in donation after circulatory death (DCD) donors. Curr Opin Organ Transplant. 2013;18(2):133–9.