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Original Article

Organ donation from extracorporeal membrane oxygenation and ventricular assist devices in Victoria, Australia: Characteristics and trends

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ABSTRACT

Objective: To describe the characteristics and the trend of organ donation from donors on extracorporeal membrane oxygenation (ECMO) or ventricular assist devices (LVAD).
Design: Retrospective, observational, cohort study from June 2014 to June 2021.
Setting: A multicentre study in Victoria, Australia, using DonateLife Victoria databases.
Participants: All patients on ECMO/LVAD were referred to DonateLife for organ donation.
Main outcome measures: Number, proportion, time trend and type of organ donations from the patients on ECMO/LVAD.
Results: There were 78 donor referrals [mean (SD) age 42 (18.8) yrs, 56 (72 %) males] from patients on Veno-arterial ECMO (73 %), Veno-venous ECMO (16 %) or LVAD (6.4 %), of which 37 (47 %) donated. The annual median (IQR) referral and donation rates were 8 (5–10)/year and 4 (3–7)/year, respectively. Medical contraindications were the main reason for declining organ donation [21(51 %)]. Donation after neurological determination of death (DNDD) occurred in 20 (54 %), and donation after circulatory determination of death (DCDD) in 17 (46 %). The median (IQR) time from admission to referral for donation was longer in DCDD compared to DNDD patients. Eighty-three organs were retrieved from 37 donors (2.24 organs per donor), out of which 68 organs (82 %) were transplanted in 68 recipients. Kidneys were the most common organs retrieved (73 %) and transplanted (79 %).
Conclusion: Organ donation on ECMO/LVAD occurs only in half of the referred patients. Further studies are needed to ascertain the barriers to donations and to assess the long-term outcomes of these donations.

1. Introduction

The use of extracorporeal therapies such as extracorporeal membrane oxygen (ECMO) and ventricular assist device (LVAD) has increased over time. The risk of mortality, however, remains high, particularly with extracorporeal cardiopulmonary resuscitation (E-CPR)[1] leading to the potential for organ donation once futility is established. In contrast to donation after neurological determination of death (DNDD) in which donation may not proceed due to significant cardiovascular instability,[2] DNDD on ECMO/LVAD support will have adequate end-organ perfusion to maintain organ perfusion until donation.[3] Thus, organ donation from ECMO/LVAD donors has the potential to reduce waitlist mortality in Australia. It is important to note here that ECMO support instituted post-mortem to support organ perfusion in deceased patients is not performed in Australia.

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The use of ECMO was first described in the early 1970s.[4] According to the Extracorporeal Life support Organisation (ELSO), between 2009 and 2022 there were 108,265 ECMO runs and nearly 40 % of the patients died either on ECMO or within 24 h of ECMO decannulation.[5] It is not clear how many donor referrals occur for patients dying on ECMO and whether it has any impact on increasing organ donation. A secondary analysis of a single-centre study from Prague found increased organ donation from patients receiving E-CPR for refractory out-of-hospital cardiac arrest.[6] Apart from this single-centre study the current data regarding donation on extracorporeal therapies are limited to case reports, and there is a paucity of data about which characteristics lead to successful donation.[7,8] The current study aims to explore the characteristics and trends in organ donation and transplantation over time from donors on extracorporeal therapies in an Australian jurisdiction with established organ donation and ECMO programs.

2. Methods

2.1. Study design

This study was a multicentre retrospective study using an organ donation database in Victoria, Australia. The characteristics of all the patients on ECMO/LVAD who proceeded to organ donation were reviewed over a seven-year period from 1st June 2014–1st June 2021.

2.2. Data collection

Data was obtained from the Electronic Donor Record (EDR) of organ donors maintained by DonateLife Victoria, a government-funded agency that coordinates organ donation in the state of Victoria in Australia. This database includes characteristics of all patients referred for donation, as well as a free text 'Course of Events' field for each patient. Prior to 2018, patients requiring extracorporeal therapies were identified by searching 'ECMO' or 'VAD' in the 'Course of Events' field. In 2018, a separate 'ECMO' search field was introduced and included start date, time and type of ECMO support (Veno-venous or Veno-arterial). Duplicates were identified and removed as patients post-2018 also had 'ECMO/VAD' in their 'Course of Events' field.

The data analyst at DonateLife Victoria conducted a database search for patients requiring ECMO/LVAD referred to donation and created two datasets (pre and post-2018). The course of events field of the entire cohort of patients over the seven-year period was manually searched to confirm each patient did receive ECMO/LVAD support. For patients prior to 2018, the 'Course of Events' field was searched for individual patients to identify the start date and type of ECMO, where available.

Inclusion criteria were patients referred for organ donation in which ECMO/LVAD was documented in the EDR. Duplicate entries, patients who did not receive or were not on ECMO/LVAD at the time of referral, or who had VAD documented representing 'voluntary assisted dying' rather than 'Ventricular Assist Device' were excluded from the analysis.

The EDR included the clinical characteristics and demographics of all patients on extracorporeal therapies who were referred for organ donation. Variables assessed included demographics such as age, sex, BMI, comorbidities and blood type; characteristics of support such as cardiac arrest downtime, CPR administration, ECMO initiation and support duration, physiological variables at the time of referral and donation workup. These variables were compared between donors and non-donors and between DNDD and donation after circulatory determination of death (DCDD) pathways. Primary outcomes were trends of donation rates over time and successful organ retrieval and transplantation. Successful organ retrieval was defined as the retrieval of heart, lung, kidney, liver, pancreas, or intestines from the organ donor after the organ was visualised and deemed suitable for retrieval during the organ retrieval procedure. Transplantation was defined as the organ being transplanted in a recipient.

For contextual background, summary data of patients who received ECMO and died in ICU in Victoria from 2018 to 2021 were extracted from the Australian and New Zealand Intensive Care Society (ANZICS) Adult Patient Database.

2.3. Ethical considerations

Alfred Hospital's Human Research Ethics Committee (Reference number: 711/21) approved the project as low-risk research project and waived the need for informed consent.

2.4. Statistical analysis

Descriptive statistics were used to analyse the data. Normal distribution data was analysed with the unpaired *t* test and non-normal distribution data with the Wilcoxon Ranksum test. The Normality of the data was ascertained using Graphical methods. Categorical data was analysed using Fisher's Exact test. Stata 18 (StataCorp LLC, Texas) was used for the analysis. Results are reported as n (%) for categorical data, mean (standard deviation) for Normally distributed data and median (interquartile range) for non-parametric data.

3. Results

3.1. Patient selection and characteristics

During the study period, there were 5334 referrals to DonateLife VIC, of which 1069 (20 %) proceeded to donation. Seventy-eight (1.5 %) patients referred for donation were receiving ECMO/LVAD, and of these, 37 (47.4 %) proceeded to organ donation (Fig. 1). During the period from 2018 to 2021, there were 240 deaths reported to the ANZICS Adult Patient Database in patients requiring ECMO support in Victoria state. Fig. 2 shows the trend in the organ donation referrals and the organ donations occurring on ECMO/LVAD. The annual median (IQR) referral and donation rates were 8 (5–10)/year and 4 (3–7)/year, respectively. There was an increase in organ donation referrals in 2019, and a subsequent decrease in 2020 and 2021. The proportion of patients donating successfully after referral was higher prior to 2019 compared to during and after 2019 ($p < 0.01$).

Table 1 provides characteristics of 78 patients on ECMO/LVAD referred for organ donation. Out of the 78 patients, 73 (94 %) were on ECMO and 5 (6 %) were on LVAD. Among ECMO patients, 57 (73 %) were on Veno-arterial and 16 (21 %) were on Veno-venous ECMO. There was no statistically significant difference between type of support between the group that donated successfully compared to the group that did not proceed to organ donation ($p = 0.80$). There was no statistically significant difference in the demographic characteristics, co-morbidities and clinical characteristics between the two groups. The predominant reason for non-donation was medical contraindication [21 (51 %)], followed by no consent for organ donation from family [10 (24 %)] (Table A1).

Among 37 patients that donated, 20 (54 %) were DNDD and 17 (46 %) were DCDD (Table 2). Brain death was determined on clinical criteria alone in 10 patients (50 %), while imaging testing was required in the remainder (nuclear medicine scanning in 9 and CT angiography in 1). Admission to referral time was shorter in those that proceeded to DNDD compared DCDD [4.1(IQR: 2.12–10.68)

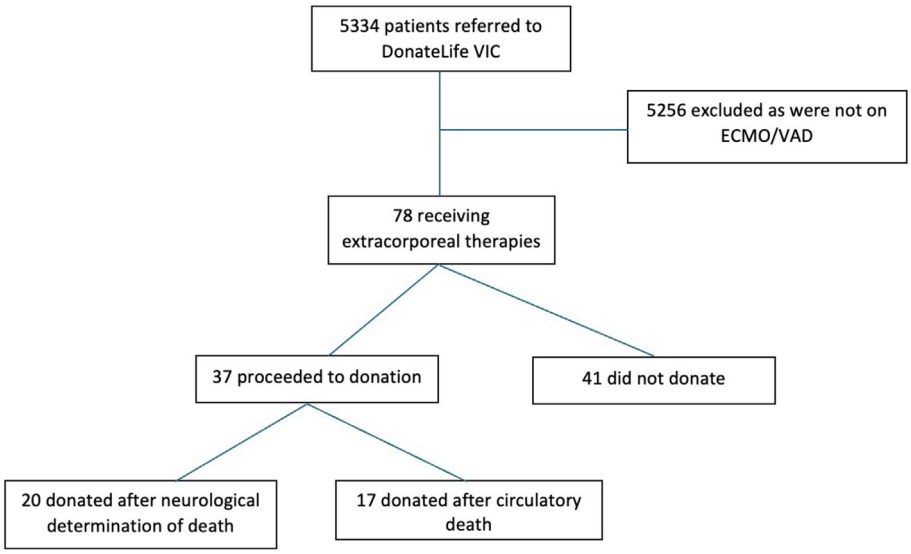

Fig. 1. CONSORT diagram of patient selection. ECMO- Extracorporeal membrane oxygenation, VAD- Ventricular assist device.

days vs 13.5 (IQR: 7.4–20.55) days; p value = 0.01]. There was no difference in the referral to organ donation time between the DNDD and DCDD groups. Also, there was no significant differences in the type of support and other clinical characteristics between the two groups. The predominant reason for referral was hypoxic ischaemic encephalopathy in both groups.

3.2. Organ donation and transplantation

There were 83 organs donated from 37 donors (2.24 organs/donor) and 68 (82 %) were transplanted. Table 3 shows the details of the organ transplantation. Renal transplantation formed most of the organ transplantation. Fourteen out of 37 (38 %) of kidney donors were on Continuous Renal Replacement Therapy (CRRT). 61 kidneys were retrieved and 54 (88 %) transplanted. The 7 kidneys retrieved but not transplanted were from donors on CRRT. The proportion of retrieved organs that were transplanted was similar in both DNDD [40 (82 %)] and DCDD [28 (82 %)] groups.

Some patients on extracorporeal therapies were planned for and worked up for donation, however, did not proceed to organ retrieval. The reasons for this are detailed in Table A2 and were largely due to the organ being diseased (65 % of hearts, 50 % of lungs, 13 % of kidneys, 48 % of livers, 26 % of pancreas).

4. Discussion

In this study of organ donation referrals from potential organ donors on ECMO/LVAD in the state of Victoria between 2014 and 2021 using the DonateLife Victoria database, we found that nearly half of the referred patients donated. The numbers of organ donation referrals ranged from 4 to 10 from 2014 to 2018, with most referrals consistently proceeding to donation until 2019. In 2019, although there was a large increase in referrals, less than quarter of the referred donors became actual donors. The proportion of donations remained lower in 2020 and 2021 compared to the previous years. The primary organ donated and transplanted was the kidney.

There could be many reasons for the reduction in the proportion of donors during the period 2019–2021. Automatic notification of patients at the end of life in ICU in the state of Victoria came into

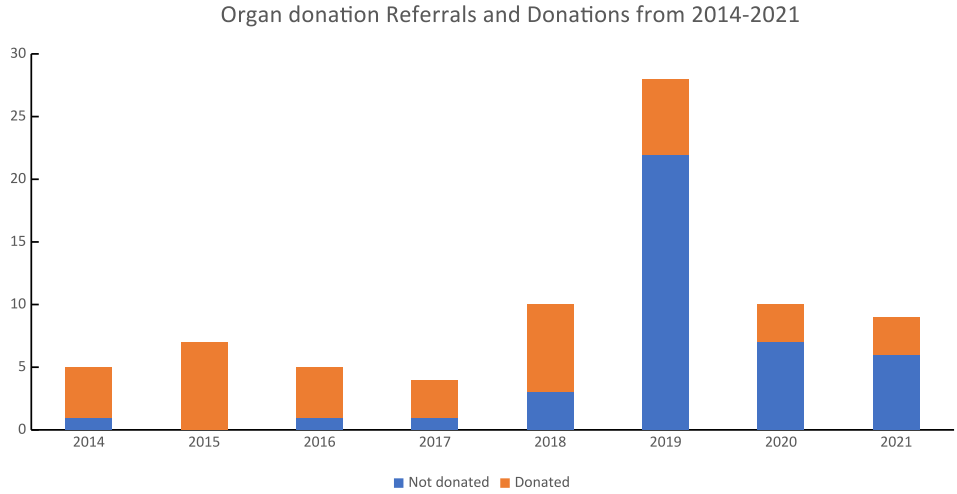

Fig. 2. Trend of organ donation referrals in patients receiving ECMO/LVAD from 2014 to 2021 in the state of Victoria. ECMO- Extracorporeal membrane oxygenation, LVAD- Ventricular assist device.

Table 1
Characteristics of the patients referred for donation on ECMO/LVAD.

Variables	All (N = 78)	Not donated (N = 41)	Donated (N = 37)	p-value
Age, mean (SD) yrs	42.0 (18.84)	43.7(19.41)	40.1 (18.26)	0.41
Sex, males, n (%)	56 (72)	29 (71)	27 (73)	0.83
BMI, mean (SD) kg/m^2	27.9 (7.18)	27.5 (6.41)	28.2 (7.71)	0.71
Comorbidities, n(%)				
Hypertension	54 (69)	18 (78)	36 (97)	0.13
Diabetes Mellitus	8 (10)	5 (12)	3 (8)	0.72
Smoking history	30 (38)	13 (31)	17 (41)	0.49
Blood group type[a], n(%)				
A	29 (47)	11 (44)	18 (48)	0.74
AB	2 (3)	0	2 (5)	
B	7 (11)	3 (12)	4 (11)	
O	24 (39)	11 (44)	13 (35)	
Cardiac arrest, n(%)	52 (67)	26 (63)	26 (70)	0.63
Type of support, n(%)				
VA	57 (73)	31 (76)	26 (70)	0.80
VV	16 (20)	8 (20)	8 (22)	
Ventricular assist device	5 (6.4)	2 (5)	3 (8)	
Physiological variables at the time of referral				
Heart rate, mean (SD) beats/min	88.4 (29.32)	82.4 (20.56)	90.9 (32.19)	0.37
Sinus rhythm, n(%)[a]	46 (88)	13 (87)	33 (89)	1.00
Mean arterial pressure, mean (SD) mmHg	76.5 (13.80)	75.5 (13.44)	76.9 (14.13)	0.75
Central venous pressure, mean (SD) mmHg	10.5 (3.82)	9 (3.2)	10.9 (3.99)	0.39
Temperature, mean (SD)◦C	36.8 (0.77)	36.8 (0.76)	36.7 (0.79)	0.65
PEEP, mean (SD) cmH_2O	10.1 (3.62)	10.3 (3.72)	9.9 (3.62)	0.72
Tidal volume, median (IQR) mL	410 (250–456)	400 (350–450)	425 (229–480)	0.87
Peak Insp pressure, mean (SD) cmH_2O	23.6 (5.08)	22.3 (5.16)	24.1 (5.04)	0.31
Continuous renal replacement therapy, n(%)	34 (44)	20 (49)	14 (38)	0.37
Admission to referral time, median (IQR) days	10.6 (3.45–15.58)	13.6 (2.56–35.64)	10.6 (3.45–15.46)	0.55
Cause of death[a], n(%)				
Hypoxic ischaemic encephalopathy	33 (59)	11 (58)	22 (59)	0.47
Cerebral infarction	6 (11)	2 (11)	4 (11)	
Intracranial haemorrhage	4 (7)	0 (0)	4 (11)	
Non-neurologic	13 (23)	6 (32)	7 (19)	

ECMO- Extracorporeal membrane oxygenation, LVAD- Left ventricular assist device, SD- Standard deviation, BMI- Body mass index, VA- Veno-arterial, VV- Veno-venous, IQR- Interquartile range, PEEP- Positive end-expiratory pressure.
[a] Blood group type was missing for 16 patients, rhythm data was missing for 26 patients and cause of death was missing in 22 patients.

effect in October 2018 which may have resulted in increased referrals to DonateLife Victoria of patients on ECMO/LVAD.[9] The total number of donors in Australia in 2019 actually decreased (548) as compared to 2018 (554).[10,11] There was a reduction in the total numbers of donors across Australia during 2020 and 2021, with a 16 % decrease in deceased organ donors in 2020, and a further 9 % decrease in 2021.[12,13] The 2020–2021 reduction could also be due to COVID-19 pandemic, and thus reduced rates could be attributed to multiple factors including suspension of elective surgeries and of kidney and pancreas transplant programs. COVID-19 hospital visitor restrictions, flight reductions and border closures, staff redeployments and furloughing may have also impacted donation rates, as well as changes to populations in ICUs and restrictions on acceptable criteria for donor referrals.[13,14] The rate of new registrations for organ donation increased substantially by 87 % in 2021, likely attributable to Australians registering for organ donation when accessing COVID-19 vaccination certificates through the required Medicare app, a mobile application run by the government health system.[15] It would have been interesting to see the effect of this in 2022, however as our study did not extend to 2022 period, we could not study this in the current study.

The number of deaths of patients requiring ECMO support in Victoria from 2018 to 2021 was 240 according to the ANZICS Adult Patient Database. However, only 66 (28 %) patients on extracorporeal therapies were referred for consideration of organ donation to DonateLife during this time. This may be because clinicians managing patients dying on ECMO support might not have referred patient to DonateLife Victoria. Another point to consider while interpreting this data is that the 240 deaths reported in the ANZICS APD is for ICU deaths. It is possible that some of the patients might have died after decannulation from ECMO while in ICU and therefore, were not referred as potential donors on ECMO support. Also, in our analysis, we only included patients who were on ECMO/LVAD support at the time of referral.

Multiple previous studies have demonstrated DNDD makes up a higher proportion than DCDD amongst donors on ECMO.[6,16,17] In contrast, our study demonstrated similar proportions of DNDD and DCDD. This could be secondary to the increasing evidence of positive outcomes from DCDD in Australia and the UK.[18] This may also be due to sampling error as we had a small sample size.

It was interesting to note that in DNDD group, brain death confirmation was done on clinical grounds alone in majority of the patients. Due to the presence of the membrane oxygenator in the ECMO circuit, performance of apnoea test to confirm brain death in VA ECMO patients is challenging. However, there are many case reports and guidelines which demonstrate that by careful control of the fresh gas flow in the ECMO circuit it is possible to achieve $PaCO_2$ >60 mmHg in systemic circulation of VA ECMO patients to perform apnoea test to confirm brain death.[19,20]

The primary organ donated was kidneys in our study which is similar to the distribution of organs donated in Australia with kidneys being the most common donated organ.[10–13,15] Nearly 40 % of patients proceeding to donation were on continuous renal replacement therapy (CRRT), and all of them donated kidneys. We noted that three of four kidneys donated were transplanted. It was interesting to note that all the kidneys that were not transplanted were from donors on CRRT. This could be related to the fact that there is paucity of evidence regarding long term outcomes of renal transplantation from donors requiring renal replacement therapy, which could lead to decreased acceptance of kidneys from these donors.

Table 2
Characteristics of organ donations on ECMO/LVAD.

Variables	DNDD (N = 20)	DCDD (N = 17)	p-value
Age, mean (SD) yrs	42.3 (17.40)	37.6 (19.44)	0.44
Sex, males, n (%)	14 (70)	13 (76)	0.66
BMI, mean (SD) kg/m^2	28.8 (7.83)	27.4 (7.73)	0.58
Comorbidities, n(%)			
Diabetes Mellitus	2 (10)	1 (6)	0.65
Hypertension	20 (100)	16 (94)	0.65
Smoking history	10 (50)	7 (52)	0.83
Blood group type, n(%)			
A	13 (65)	5 (29)	0.02
B	1 (5)	1 (6)	
AB	3 (15)	1 (6)	
O	3 (15)	10 (59)	
Cardiac arrest, n(%)	15 (75)	11 (65)	0.72
Type of support, n(%)			
VA	17 (85)	9 (53)	0.11
VV	2 (10)	6 (35)	
LVAD	1 (5)	2 (12)	
Admission to referral time, median (IQR) days	4.1 (2.12–10.68)	13.5 (7.40–20.55)	0.011
Referral to donation time, median (IQR)days	1.6 (1–2.27)	1.25 (0.88–1.40)	0.094
Referral reason, n(%)			
Hypoxic ischaemic encephalopathy	14 (70)	8 (47)	0.11
Cerebral infarction	3 (15)	1 (6)	
Intracranial haemorrhage	2 (10)	2 (12)	
Non-neurologic condition	1 (5)	6 (35)	
Brain death diagnosis method, n(%)			
Clinical only	10 (46)	NA	NA
Nuclear medicine	9 (45)		
Both clinical and nuclear medicine	1 (4)		
CT angiogram	1 (5)		
Referral to WCRS time		1.2 (0.84–1.38)	
Laboratory parameters, median (IQR)[a]			
P/F Ratio	300 (166–367)	306.7 (260–454)	0.49
Urea, mmol/L	13.0 (9.7–21.9)	15.4 (12.2–18.9)	0.66
Creatinine, μmol/L	185.5 (143–233)	120 (80–209)	0.048
Estimated creatinine clearance, (mL/min)	52 (35–68.5)	7 (52–106)	0.046
Total protein, g/L	44.5 (37.5–47.5)	50 (42–53)	0.043
Albumin, g/L	21 (19–23)	23 (19–26)	0.40
Bilirubin, μmol/L	19 (14–39.5)	18 (8–36)	0.45
ALT, U/L	161.5 (73–359.5)	117.5 (37.5–176.5)	0.23

ECMO- Extracorporeal membrane oxygenation, LVAD- Left ventricular assist device, DNDD- Donation after neurological determination of death, DCDD- Donation after circulatory determination of death, SD- Standard deviation, BMI- Body mass index, VA- Veno-arterial, VV- Veno-venous, IQR- Interquartile range, WCRS- Withdrawal of cardio-respiratory support, P/F ratio-ratio of partial pressure of oxygen in arterial blood to the fraction of inspiratory oxygen concentration, ALT- Alanine aminotransferase.
[a] Laboratory parameters at the time of referral.

Table 3
Organs retrieved and donated from patients on ECMO/LVAD.

Patients	All (N = 37)	DNDD (N = 20)	DCDD (N = 17)
Heart, n(%)			
Retrieved	2 (5)	1 (5)	1 (6)
Transplanted	2 (5)	1 (5)	1 (6)
Lungs, n(%)			
Retrieved	7 (19)	5 (25)	2 (12)
Transplanted	5 (14)	3 (15)	2 (12)
Kidneys, n(%)			
Right			
Retrieved	31 (84)	17 (85)	14 (82)
Transplanted	28 (76)	15 (75)	13 (76)
Left kidney			
Retrieved	30 (81)	16 (80)	14 (82)
Transplanted	26 (70)	15 (75)	11 (65)
Liver, n(%)			
Retrieved	7 (19)	7 (35)	0
Transplanted	6 (16)	6 (30)	0
Pancreas, n(%)			
Retrieved	6 (16)	3 (15)	3 (18)
Transplanted	1 (3)	0	1 (6)
Intestines, n(%)			
Retrieved	0	0	0
Transplanted	0	0	0
Total organs transplanted/Retrieved, n/N (%)	68/83 (82)	40/49 (82)	28/34 (82)

ECMO- Extracorporeal membrane oxygenation, LVAD- Left ventricular assist device, DNDD- Donation after neurological determination of death, DCDD- Donation after circulatory determination of death, SD- Standard deviation, BMI- Body mass index, VA- Veno-arterial, VV- Veno-venous, IQR- Interquartile range, WCRS- Withdrawal of cardio-respiratory support, P/F ratio-ratio of partial pressure of oxygen in arterial blood to the fraction of inspiratory oxygen concentration, ALT- Alanine aminotransferase.

Multiple studies have looked at the 1-year kidney graft survival and function between recipients from donors on ECMO compared to those not on ECMO.[21–24] Carter et al. showed no significant difference in delayed graft function between these two groups.[21] In fact, Gregorini et al. found that patients who received renal transplants from donors requiring ECMO had lower rates of delayed graft function, a lower need for dialysis and lower length of hospital stay as compared to DCDD not on ECMO.[23] In contrast, Wen et al. found a higher risk of delayed graft function in donors that had undergone dialysis as compared to those that did not, but no significant difference in graft failure or death.[24] Future studies looking at long-term outcomes of kidney donations from patients on ECMO who are on CRRT are needed.

In the current study, all liver donations were from DNDD, of which 71 % were on Veno-arterial ECMO. There can be concerns regarding liver transplantation from donors on ECMO given the documented risk of congestive hepatopathy while on Veno-arterial ECMO.[25] However, this study showed that most livers that were retrieved were successfully transplanted. The one liver that was retrieved but not transplanted was due to ischaemic changes on biopsy during the organ retrieval.

4.1. Strengths and limitations

The main strengths of this study are that it is a multicentre review using a thorough, well-maintained database to retrieve details of donor characteristics, and organs donated and transplanted.

The main limitation of our study is that it has a small sample size. During data collection, given there was no specific ECMO 'field' prior to 2018 and this information was entered free text, some patients may have been missed. However, each referred patients have a case summary in the database entered by trained personnel, and it would be highly unlikely for that summary to not include ECMO given it is such a significant detail of their care. Regarding donor characteristics, some variables including CRRT had missing values. Also, the study only captured patients who were referred to DonateLife Victoria.

5. Conclusion

Organ donation from ECMO/LVAD occurs only in half of the referred patients with the kidney being the most common organ retrieved and transplanted. Further studies are needed to ascertain the barriers to donations and the long-term outcomes of donated organs.

CRediT authorship contribution statement

The authors confirm their contribution to the paper as follows: **Viveka Nainani:** Conceptualisation, Methodology, Investigation, Data Curation, Writing – Original draft, Writing – Review and editing, Project administration. **Byron Arcia:** Data Curation**. David Pilcher:** Conceptualisation, Writing – Review and Editing. **Joshua Ihle:** Conceptualisation, Writing – Review and Editing. **Arne Diehl:** Conceptualisation, Writing – Review and Editing. **Samuel Radford:** Conceptualisation, Writing – Review and Editing. **Rohit D'Costa:** Conceptualisation, Writing – Review and Editing. **Vinodh Nanjayya:** Conceptualisation, Methodology, Validation, Formal analysis, Writing – Review and Editing, Supervision, Project administration.

Conflict of interest

David Pilcher declares he is employed as a medical advisor for Donate Life.

All other authors declare that they have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ccrj.2025.100102.

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