REVIEW

Liver transplantation from brain-dead donors on mechanical circulatory support: a systematic review of the literature

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SUMMARY

Mechanical circulatory support (MCS) refers to a range of rescue devices to assist circulation for the treatment of heart failure, including venoarterial extracorporeal membrane oxygenation (VA-ECMO) and ventricular assist devices (VADs). This review aims at evaluating the transplant outcome of the livers procured from brain-dead donors on MCS, who are currently considered as having extended criteria. We identified 22 records (17 on VA-ECMO and 5 on VADs), most of which (68.2%) were case reports. We performed a meta-analysis only when the outcome was reported homogeneously among studies; otherwise, we illustrated the results with narrative synthesis. A total of 156 liver transplants (LTs) have been reported, where VA-ECMO was initiated in the donor with resuscitative intent or as a bridge to donation. Early graft survival approached 100% in most studies. The pooled rate of primary nonfunction was 1% (95% CI: 0–3%). Only three successful LTs from VAD donors have been reported. Particular attention should be paid to cardiological history, biochemical tests, and imaging, as well as MCS parameters, to determine graft eligibility for transplantation. Although further analysis is needed in this field, the results of this review advocate a more systematic consideration of brain-dead patients on MCS as potential liver donors.

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Introduction

Liver transplantation is the definitive treatment for end-stage liver disease and some primary and secondary hepatic tumors, but donor shortage still represents the primary limitation to its widespread availability. Therefore, in recent years, extended criteria for graft selection have been introduced to expand the brain-deaddonor pool. In this context, even brain-dead patients on mechanical circulatory support (MCS) have been considered for organ donation [1].

Mechanical circulatory support refers to a range of rescue devices to assist circulation for the treatment of heart failure, including venoarterial extracorporeal membrane oxygenation (VA-ECMO) and ventricular assist devices (VADs) [2]. VA-ECMO is a form of partial cardiopulmonary bypass for short- and intermediate-term support of respiratory and cardiac function,

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which is employed for patients with cardiac failure unresponsive to maximal medical therapy. Conversely, venovenous ECMO (VV-ECMO) is reserved for the treatment of acute respiratory distress syndrome, without providing any circulatory support [3,4]. Left VAD (LVAD) is commonly used as a bridge to heart transplantation or as a definitive solution for patients with severe cardiac failure, with a 10-fold increase in the rate of implantation during the last 10 years. In the case of biventricular failure or right ventricular failure, a bilateral VAD (BiVAD) or a right VAD (RVAD) could be implanted, respectively [5,6].

The number of reports on brain-dead donors on MCS is currently increasing, but the experiences are heterogeneous, and MCS still appears not to have shared indications in this field. Therefore, this review aims at analyzing the available literature and evaluating the results in terms of patient and graft survival as well as complications of the liver transplants from these donors, who are currently considered as having extended criteria. We have also tried to define possible indications concerning the use of MCS in organ donation and the acceptance criteria of the liver grafts according to the existing evidence.

Methods

Study identification

We performed a systematic search on PubMed (National Center for Biotechnology Information). The search was limited to articles in English only and updated on 17 May 2020. The search strings and terms of the query are reported in Table S1. All abstracts were independently screened by two authors, and full texts of the selected papers were obtained for a supplemental screen. Pertinent articles not captured in the database search but cited in the references of the selected papers were included as well.

Inclusion and exclusion criteria

Inclusion criteria were as follows: (i) donation after brain dead (DBD), (ii) adult liver transplants, (iii) case reports, cohort, and case–control studies. Exclusion criteria were as follows: (i) donation after circulatory death (DCD), (ii) preclinical studies, (iii) venovenous ECMO, (iv) reviews, commentaries, and congress abstracts.

Outcome variables

Primary outcomes of this review were early patient and graft survival and primary nonfunction. Secondary outcomes were adverse events and technical failure during organ recovery, liver use, early allograft dysfunction (EAD), post-transplant complications (vascular and biliary), and hospital stay. Primary nonfunction (PNF) was defined as death or retransplantation within the first post-transplant week without an identifiable cause. EAD was defined according to Olthoff *et al.* [7]. Each eligible study was investigated, and the outcome variables described above were extracted. We used a narrative synthesis to illustrate the results, whenever a quantitative synthesis was not possible [8].

Statistical analysis

We decided to carry out a formal meta-analysis only when all studies included in each of the considered subgroups (DBD donors on VA-ECMO and VAD donors) reported the outcome of interest in a homogeneous way. Studies reporting outcomes for a single case report were excluded a priori from the meta-analysis. Proportions were pooled with random-effects meta-analyses using the arcsine transformation and reported in a forest plot along with their 95% confidence intervals (95% CI).

Results

The search identified 136 records, and 22 of them (17 on VA-ECMO and 5 on VAD) matched the inclusion criteria. The PRISMA flow chart describes the selection process (Fig. 1). The majority of studies (68.2%) were case reports. Given the high heterogeneity observed in the reported outcomes and that the completeness of the considered outcomes varied widely among studies, we were able to carry out a formal meta-analysis only on PNF in liver transplants from DBD donors on VA-ECMO.

VA-ECMO

A total of 156 liver transplants from donors on VA-ECMO have been reported to date. Main donor and recipient's characteristics, as well as transplant outcomes and complications, are summarized in Tables 1 and 2. The median donor age exceeded 60 years in only one report [9].

Applications of VA-ECMO in DBD

There are two possible scenarios where VA-ECMO has been applied in context of organ donation from DBD. VA-ECMO can be initiated with resuscitative intent in patients suffering from refractory cardiac failure, which eventually results in brain death because of cerebral anoxia or

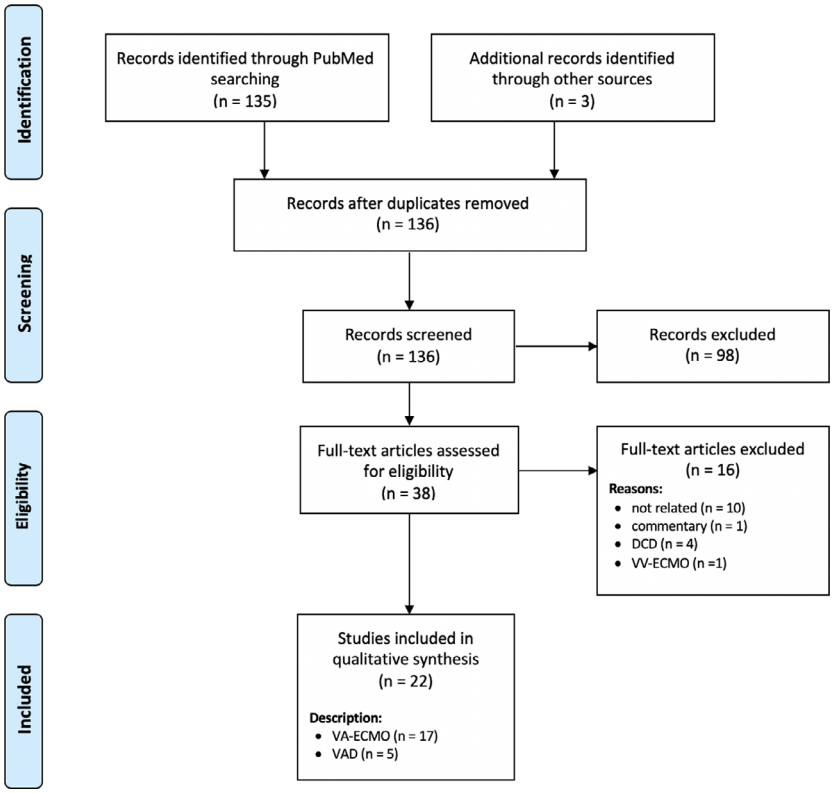

Figure 1 Selection process of the articles included in the review (PRISMA flow chart).

bleeding, and continued until organ donation; otherwise, VA-ECMO can be used as circulatory support for hemodynamically unstable donors during or after brain death assessment, thus reducing the need for vasopressors (i.e., bridge to donation). Overall, we counted 88 cases in the first scenario and 70 cases in the second scenario.

Extracorporeal membrane oxygenation as a bridge to organ donation can be initiated after brain-dead declaration. However, some authors have reported its use also during or even before death declaration [10–14]. Possible indications for VA-ECMO in these cases are summarized in Table 3.

Duration of VA-ECMO

The duration of VA-ECMO before organ recovery is not always reported clearly in all studies. Total duration of VA-ECMO ranges between 3 and 96 h. Bronchard *et al.* [4] accurately reported in their series a median ECMO duration of 2 days.

Liver graft use and selection during VA-ECMO

The liver use rate is rarely reported, and no cases of adverse events or technical failure during organ recovery are described. Carter *et al.* [15] reported 63% liver use rate, which was lower compared to published standards for DBD donors.

Zhu *et al.* [16] suggest ultrasound monitoring of hepatic artery and portal blood flow for real-time calibration of VA-ECMO perfusion, as well as liver function tests, to assess graft viability. Only two other studies reported criteria for liver graft selection on VA-ECMO, which still lack validation (Table 4) [17,18]. Fan *et al.* [17,19] adopted similar transaminase thresholds to that suggested by the Barcelona group for DCD donors on NRP (higher than fourfold of the upper limit of normal reference value) in conjunction with liver biopsy (<40% macrovesicular steatosis or <50% mixed steatosis). De Carlis *et al.* [18] extended this transaminase threshold up to 1000 IU/l and also considered the downward trend in serum lactate during perfusion. The macroscopic aspect is part of the liver evaluation process in only one record, but it can also guide the decision to perform a liver biopsy or not [3,18].

Donor operation and liver splitting on VA-ECMO

Although some authors refer to aortic cannulation as in standard donor operation, in most reports, the

Table 1. Characteristics of the included studies (DBD donors on ECMO – observational/cohort studies).

Author, year (country)	Study type	Comparator group	N. LTs	ECMO type	Duration of ECMO (median)	Indication for ECMO	Median donor age (years)	Liver use *n* (%)	Urgent indication for LTs (*n*, %)	Recipient MELD (median)	PNF (*n*, %)	EAD (*n*, %)	Biliary compl. (*n*, %)	Vascular compl. (*n*, %)	Median hospital stay (day)	Graft survival (%, f-u)	Patient survival (%, f-u)
Carter, 2014 (USA) [15]	Retrospective analysis	SRTR database	14 DBD (+1 DCD)	VA-ECMO	N/A	Patient resuscitation	40	15/24 (63%)	N/A	N/A	0 (0%)	N/A	N/A	N/A	N/A	93%, 12 months	93%, 12 months
Teng-Wei, 2014 (Taiwan) [14]	Retrospective cohort study	Non-ECMO DBD	6	5 VA-ECMO (+1 VV-ECMO)	76.1 h	Bridge to donation (before/ during BDD)	48	N/A	N/A	13	0 (0%)	N/A	1 (16.7%)	N/A	N/A	N/A	100%, 60 months
Valenza, 2015 (Italy) [3]	Retrospective cohort study	Standard DBD; DBD with transient CA	4	VA-ECMO	49.5 h	Patient resuscitation	54	N/A	0 (0%)	18	0 (0%)	N/A	1 (25%)	0 (0%)	22	100%, 30 days	100%, 30 days
Fan, 2016 (China) [17]	Retrospective cohort study	DBD with vasopressors	13	VA-ECMO	5.2 h	Bridge to donation (after BDD)	48.1	13/19 (68.4%)	N/A	18.9	0 (0%)	N/A	N/A	N/A	22.3	100%, 22.3 days	100%, 22.3 days
Zhu, 2016 (China) [16]	Observational retrospective study	NA	40	VA-ECMO	N/A	Bridge to donation (after BDD)	37.2	N/A	N/A	N/A	0 (0%)	N/A	N/A	N/A	N/A	100%, 3 months	100%, 3 months
Bronchard, 2017 (France) [4]	Retrospective cohort study	Non-ECMO DBD	37 (2 splits)	84.4% VA-ECMO (15.6% VV-ECMO)	48 h	Patient resuscitation	39.5	35/64 (54.7%)	1 (2.7%)	N/A	1 (2.7%)	N/A	0 %	2 (5.4%)	N/A	86.5%, 12 months	N/A
De Carlis, 2018 (Italy) [18]	Retrospective cohort study	DCD	17	VA-ECMO	64.8 h	Patient resuscitation	57	N/A	0 (0%)	13	1 (6%)	7 (44 %)	1 (6%)	0 (0%)	16	87%, 1 year	87%, 1 year
Total: 131 LTs (6 retrospective cohort studies/analyses, 1 observational study)																	

BDD, brain death declaration; CA, cardiac arrest; DBD, donation after brain dead; DCD, donation after circulatory death; EAD, early allograft dysfunction; ECMO, extracorporeal membrane oxygenator; f-u, follow-up; LTs, liver transplants; LVAD, left ventricular assist device; PNF, primary nonfunction; USA, the United States of America.

Table 2. Characteristics of the included studies (DBD donors on ECMO – case reports/series).

Author, year (country)	Study type	No. of LTs	ECMO type	Duration of ECMO (median)	Indication for ECMO	Median donor age (year)	Liver use (*n*, %)	Urgent indication for LT (*n*, %)	Recipient MELD	PNF (*n*, %)	EAD (*n*, %)	Biliary compl. (*n*, %)	Vascular compl. (*n*, %)	Hospital stay (days)	Graft survival (%, f-u)	Patient survival (%, f-u)
Johnson, 1996 (USA) [1]	Case report	1	ECMO (VV converted in VA)	1 day (VA-ECMO)	Patient resuscitation	15	N/A	1 (100%)	N/A	0 (0%)	1 (100%)	0 (0%)	0 (0%)	22	100%, 4 months	100%, 4 months
Vivien, 2010 (France) [40]	Case report	1	VA-ECMO	96 h	Patient resuscitation	40	N/A	N/A	N/A	0 (0%)	N/A	N/A	N/A	N/A	100%, 45 months	100%, 45 months
Peris, 2010 (Italy) [41]	Case series/ report	1	VA-ECMO	33 h	Patient resuscitation	19	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hsieh, 2011 (Taiwan) [12]	Case series	3	VA-ECMO	11 h	Bridge to donation (before/ during BDD)	31.8	3/6 (50%)	N/A	N/A	0 (0%)	N/A	N/A	N/A	N/A	N/A	N/A
Isnardi, 2013 (Italy) [10]	Case report	1	VA-ECMO	3 h	Bridge to donation (after BDD)	14	N/A	N/A	N/A	0 (0%)	N/A	0 (0%)	0 (0%)	N/A	100%, 15 months	100%, 15 months
Migliaccio, 2013 (Italy) [9]	Case series	5	4 VA-ECMO (+1 VV-ECMO)	14 h	Patient resuscitation	67	5/8 (62.5%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tazarourte, 2013 (France) [42]	Observational study/case report	1	VA-ECMO	N/A	1 Patient resuscitation; 9 bridge to donation	40	1/10 (10%)*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lee, 2015 (Korea) [13]	Case report	3	VA-ECMO	19.7 h	Bridge to donation (before/ during BDD)	33	N/A	1 (33.3%)	N/A	1 (33.3 %)	N/A	N/A	N/A	N/A	66.7%, 12 months	66,7 %, 12 months
Assalino, 2017 (Switzerland) [20]	Case report	2 (splits)	VA-ECMO	32.5 h	Patient resuscitation	19.5	N/A	0%	26	0 (0%)	3 (75 %)	1 (25%)	0 (0%)	Adult: 9 and 47 Pediatric: 22 and 30	100 %, 2 months	100 %, 2 months
Chang, 2018 (Korea) [11]	Case series	7	VA-ECMO	47 h	5 Patient resuscitation; 4 bridge to donation (during BDD)	35	7/9 (77.8%)†	N/A	N/A	0 (0%)	N/A	N/A	N/A	N/A	N/A	N/A
Total: 25 LTs (10 case reports)																

BDD, brain death declaration; CA, cardiac arrest; DBD, donation after brain dead; EAD, early allograft dysfunction; ECMO, extracorporeal membrane oxygenator; f-u, follow-up; LTs, liver transplants; LVAD, left ventricular assist device; PNF, primary nonfunction; USA, the United States of America.

*1/1 (100%) patient resuscitation; 0/9 (0%) bridge to donation.

†Liver use for ECMO indication not specified.

Table 3. Indications for VA-ECMO as bridge to donation.

Author, year	Criteria
Hsieh, 2011 [12]	Unstable hemodynamics (SBP ≤90 mmHg or MAP ≤50 mmHg nonresponse to vasopressors) $SatO_2$ ≤90–98%, PaO_2/FiO_2 <100 mmHg, or FiO_2 ≤80%
Isnardi, 2013 [10]	MAP ≤50 mmHg $SatO_2$ <98%
Teng-way 2014 [14]	Unstable hemodynamic status despite administration of at least 3 types of inotropic agents and vasopressors PaO_2/FiO_2 <100 mmHg
Fan, 2016 [17]	MAP <60 mmHg, ineffective action of large amount of vasoactive drug CO_2 retention under the condition of FiO_2 >90%, PaO_2/FiO_2 <100, and P_{plat} >30 cmH_2O
Chang, 2018 [11]	SBP <80 mmHg $SatO_2$ <80%

FiO_2, fraction of inspired oxygen; MAP, mean arterial pressure; PaO_2, partial pressure of oxygen; P_{plat}, plateau pressure; $SatO_2$, oxygen saturation; SBP, systolic blood pressure.

Table 4. Indications for functional assessment and selection of the liver graft during VA-ECMO.

Author, year	Acceptance criteria
Zhu, 2016 [16]	Monitoring total bilirubin, ALT, and lactic acid during ECMO Ultrasonographic monitoring of the liver blood flow and real-time calibration of ECMO No suggested cutoffs
Fan, 2016 [17]	ALT and AST <4-fold of the upper limit of normal Macrosteatosis <40% and microvesicular or mixed steatosis <50%
De Carlis, 2018 [18]	ALT ≤1000 IU/l Downward trend in serum lactate Good macroscopic aspect Macrosteatosis ≤30% and fibrosis Ishak score ≤1

ALT, alanine transaminase; AST, aspartate transaminase; ECMO, extracorporeal membrane oxygenation.

procedure is modified to allow continuance of VA-ECMO through the femoral cannulas until cold perfusion [1,14]. In the first reported case, Johnson *et al.* [1] cannulated the common iliac artery on the opposite side, while VA-ECMO was continued via the contralateral femoral artery. Instead, other authors suggest performing cold perfusion directly through the same arterial cannula of the VA-ECMO circuit [18].

Only two studies reported split liver from donors maintained on ECMO, with a total of four cases [4,20]. Details on surgical technique and transplant outcomes are available only in the case report by Assalino *et al.* [20], who described two cases of in situ splitting during VA-ECMO with immediate graft function of both adult and pediatric hemilivers.

Allocation and results of liver transplants from donors on VA-ECMO

Some authors suggest allocating liver from VA-ECMO donors preferably on low-risk patients [18]. However, such grafts have also been transplanted in urgent recipients with good results [1,4,13].

Overall, 14/17 (82.4%) studies have a follow-up no longer than 1 year. Early graft survival approaches 100% in most studies. The pooled PNF rate was 1% (95% CI: 0–3%), as shown in Fig. 2. Only Lee *et al.* [13] reported a 66.7% graft survival at 11.6 months with a PNF rate of 33.3%. The incidence of early allograft dysfunction is rarely reported or derivable from data provided by the authors. Teng-Wei *et al.* [14] reported significantly elevated transaminase levels in donors maintained with ECMO compared with non-ECMO donors, which, however, recovered quickly within the first three postoperative days, and no difference in complication rate and survival. Biliary and vascular complications are rarely reported and lack a clear distinction of types. Overall, the incidence of biliary complications ranges from 0% to 25%. Only Bronchard *et al.* [4] reported vascular complications in 5.7% of cases.

VADs

Overall, only three liver transplants from VAD-supported donors have been reported to date. In two reports, the liver was evaluated for transplant but eventually discarded because of fibrosis. Table 5 shows the main donor and recipient's characteristics, as well as transplant outcomes and complications.

Liver graft selection from VAD donors

Right heart failure complicates 10–40% of LVAD implants and determinates elevated hepatic venous pressure, which is transmitted to the sinusoids and may progress to fibrotic and cirrhotic changes, with a typical macroscopic aspect described as nutmeg liver [21-25].

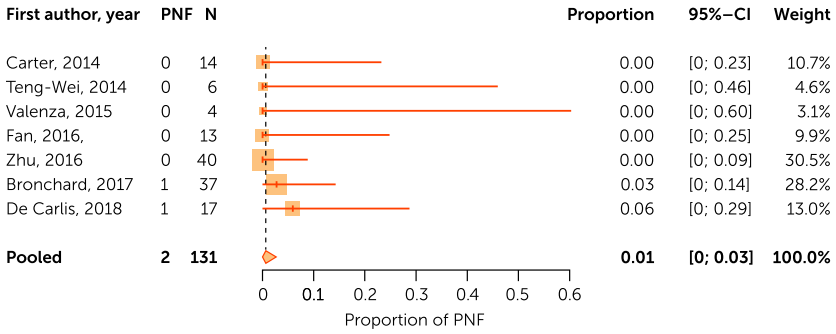

Figure 2 Forest plot of the meta-analysis of PNF rates among liver transplants from DBD donors on ECMO.

In addition to prior cardiac clinical history, also the LVAD running time plays a crucial role, as the degree of cardiac hepatopathy is partly time-dependent. All authors suggest paying a particular attention to laboratory tests and radiological examinations, to exclude signs of congestive hepatopathy. In the three transplanted cases, liver function tests were normal, and the median LVAD running time was 59 months.

Liver biopsy to assess possible chronic damage to the liver was reported only in two of five records included in this review. Kamei *et al.* reported the case of unexpected congestive fibrosis in an LVAD donor, which eventually lead to liver discard. The only altered liver test in this case was serum bilirubin of 4.5 mg/dl [26]. Conversely, De Arroyabe *et al.* [27] successfully transplanted a liver with normal aspect, but chronic inflammation and mild fibrosis at microscopic examination during procurement.

Donor operation in VAD donors

Ventricular assist device donors have a previous sternotomy. Therefore, a standard midline incision and resternotomy should be performed, paying special attention to avoid damaging the VAD drivelines, and initial abdominal exposure could be limited because the left upper quadrant is occupied by the LVAD [26]. Cold perfusion is generally infused through the aortic (or iliac) cannula stopping the LVAD system. Only Angona *et al.* reported the case of a liver procured from a donor on BiVAD, where systemic perfusion was performed directly through the LVAD. Briefly, the reservoir for the cold preservation solution was connected to the inflow of the LVAD, and drainage of the circuit was obtained through the right atrial cannula of the RVAD [28].

Results of liver transplants from VAD donors

Two of the three livers, which were successfully transplanted from VAD donors, maintained good function over a 6- and 8-month follow-up, while in one report, data on the short-term follow-up were missing. The reported complications were acute rejection, biliary obstruction, and pulmonary infection [27,29].

Discussion

The use of ECMO in DBD dates back to 1997 when Johnson *et al.* [1] first reported the case of a successful liver transplant from a 15-year-old donor maintained initially on VV-ECMO, which was subsequently converted to VA-ECMO because of the occurrence of cardiac arrest.

Although DBD donors on VA-ECMO may resemble features of DCD donors treated with normothermic regional perfusion (NRP), they do not experience the stand-off period needed to determine death according to circulatory criteria [3,19]. Of course, VA-ECMO donors still suffer an ischemic insult because of cardiac arrest or hemodynamic instability, but this is generally distant in time enough to allow functional recovery of the liver. Moreover, brief and reversible cardiac arrest in organ donors has been demonstrated not to affect post-transplant allograft survival and function, even though liver function test values are higher for these donors [30,31].

Donors on ECMO are usually young, but they have more severe medical conditions than the general DBD population [4]. Brain death entails the loss of blood pressure autoregulation and sympathetic tone, with a reduction in systemic vascular resistance and subsequent hemodynamic instability. In this context, VA-ECMO allows stopping the administration of pressor agents and thus avoids damage to the liver graft [16]. Moreover, VA-ECMO improves organ perfusion because of the increased partial pressure of arterial oxygen and decreased lactic acid levels [18,20,32].

The indications for the initiation of VA-ECMO as a bridge to donation remain debated. The reported criteria aim at capturing potential donors more susceptible to

Table 5. Characteristics of the included studies (DBD-LVAD-BiVAD).

Author, year (country)	Study type	N. LTs	Circulatory support	VAD duration (days)	Donor age (year)	Technical failure (*n*, %)	Liver biopsy	Liver use (*n*, %)	Urgent indication for LT (*n*, %)	PNF (*n*, %)	EAD (*n*, %)	Biliary compl. (*n*, %)	Vascular compl. (*n*, %)	Hospital stay (days)	Re-LT (*n*, %)	Graft survival (%, f-u)	Patient survival (%, f-u)
Mohite, 2014 (UK) [43]	Case report	1	LVAD	1	44	0 (%)	N/A	1/1 (100)	N/A	N/A	N/A	N/A	N/A	N/A	NA	N/A	N/A
De Arroyabe, 2015 (Italy) [27]	Case report	1	LVAD	59	64	0 (%)	Yes	1/1 (100)	0 (%)	0 (%)	0 (%)	0 (%)	0 (%)	24	0 (%)	100%, 8 months	100%, 8 months
Munawar, 2020 (USA) [29]	Case report	1	LVAD	270	61	0 (%)	N/A	1/1 (100)	0 (%)	0 (%)	0 (%)	1/1 (100%)	0 (%)	17	0 (%)	100%, 6 months	100%, 6 months
Kamei, 2018 (Japan) [26]	Case report	0	LVAD	240	40	0 (%)	Yes	0/1 (0)	–	–	–	–	–	–	–	–	–
Kykalos, 2019 (Greece) [44]	Case report	0	BiVAD	N/A	42	0 (%)	N/A	0/1 (0)	–	–	–	–	–	–	–	–	–
Total: 3 LTs (5 case reports)																	

BiVAD, bilateral ventricular assist device; DBD, donation after brain dead; EAD, early allograft dysfunction; f-u, follow-up; LTs, liver transplants; LVAD, left ventricular assist device; PNF, primary nonfunction.

sudden onset of cardiac arrest [10–12,14,17]. Moreover, the use of VA-ECMO in DBD with respiratory failure seems to prevent further development of circulatory instability by providing additional blood oxygenation [17]. Overall, despite a certain variability in the specific cutoffs, there is agreement among authors in using VA-ECMO in case of unstable hemodynamics, nonresponsiveness to vasopressors, and respiratory failure. Conversely, there are no clear indications on the duration of VA-ECMO before organ recovery. Only a few papers included in this review address the problem of graft selection, and the proposed criteria, based essentially on transaminase and liver biopsy, are quite variable and still lack validation [16–18].

The use of VA-ECMO during or even before death declaration could be controversial and entails some ethical problems [11–14]. Moreover, the apnea test requires an ad hoc modification of the protocol in ECMO-treated patients [10]. However, some authors have suggested that VA-ECMO should be considered in this case as a rescue maneuver during brain death diagnosis and not as a means for organ preservation, the fact that organs are available for transplant being the consequence and not the goal [9].

The surgical technique for organ procurement in donors on VA-ECMO is not substantially different from that of standard donors, but some aspects need to be considered. Lowering the temperature during extracorporeal perfusion until cold flushing or the use of machine perfusion after organ recovery is an alternative technique, which has been explored in the DCD donors, but not yet in DBD donors on VA-ECMO [33–35]. However, these two approaches might bring advantages in terms of graft preservation and evaluation.

Organs procured from DBD donors on VA-ECMO, despite the more complicated clinical course, seem similar to those of standard donors in terms of PNF, postoperative complications, and short-term graft survival. Biliary complications seem not to be as frequent as in DCD, but definitive conclusions cannot be drawn as only a few studies report on biliary complications, and the use of NRP has proven effective in reducing such complications also in DCD [36].

Ventricular assist device patients are at increased risk for a cerebrovascular accident because of the anticoagulation regimen. Ischemic stroke is more common than intracerebral hemorrhage, but the latter is more likely to be disabling or fatal, and these patients may become organ donors [37]. Overall, the selected records on VAD donors are very few and often lack sufficient information to draw significant conclusions on the postoperative outcomes. Considering that VAD donors may have a cardiogenic hepatopathy, particular attention should be paid to the cardiological history, preoperative examinations, and macroscopical and microscopical liver examination to define the organ eligibility [26,27]. Transient elastography, which is recommended for the evaluation of various chronic hepatic pathologies, could theoretically provide in this context additional information before donation but is not always available [38,39].

The main limitations of the studies included in this review are the relatively low number of cases, the incomplete description of ECMO (type and indication), the mix of brain-dead and DCD donors in some cases, and the not always clear definition of the transplanted organs. Moreover, despite the promising results in the short term, the current lack of data on long-term follow-up makes it difficult to assess the utility of these transplants conclusively.

Conclusions

MCS is increasingly used in clinical practice to offer temporary or long-term support to patients with cardiac failure. MCS donors are usually considered as having extended criteria because of their complicated clinical course, and some centers may be concerned about transplanting such organs, especially in high-risk patients. However, the observed results suggest that the outcome of transplants from MCS donors is good under the conditions indicated in each of the studies. Although further analysis is needed in this field, this review advocates a more systematic consideration and utilization of DBD donors on MCS.

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Conflicts of interest

The authors have declared no conflicts of interest.

SUPPORTING INFORMATION

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

Table S1. Search strings and terms of the search.

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