ORIGINAL ARTICLE

EXTRACORPOREAL MEMBRANE OXYGENATION SUPPORT FOR POSTCARDIOTOMY SHOCK: SINGLE CENTER EXPERIENCE

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Abstract

Objectives: *We aim to report our experience on venoarterial extracorporeal membrane oxygenation (VA-ECMO) for postcardiotomy shock (PCS).*

Methods: Single center, retrospective study of all patients on VA-ECMO for PCS, from November 2006 to July 2019. Pediatric and adult patients were analysed separately. Primary outcomes were survival to discharge and one-year survival.

Results: *Twenty-nine patients were included. Pediatric group (group PED) (62%, n=18): mean age 1,3±2,1 years and 39% male. Adults (group AD) (38%, n=11): mean age 55,6±15,9 years and 64% male. Indications in group PED were complex congenital heart surgery (94%) and heart transplant (6%), with 27% being reoperations; in group AD valvular surgery (45%), aortic surgery (21%), coronary artery bypass grafting (18%) and pulmonary endarterectomy (9%); 45% were reoperations. ECMO support was initiated intraoperatively due to failure to wean from cardiopulmonary bypass in 28% of group PED and 73% of group AD. Central cannulation was performed in all pediatric patients and 82% adults. Bleeding was the most common complication in both groups (group PED 39%, group AD 45%). Mean ECMO support time was respectively 6,2±4,9 and 6,2± 3,6 days for group PED and group AD. Weaning rate was 44% in group PED (with 2 patients bridged to LVAD) and 45% in group AD. Survival to discharge as well as one-year survival were both 28% in group PED and 18% in group AD.*

Conclusion: *Despite low survival and high complication rates, VA ECMO support provides a survival benefit in refractory cases, with a dismal prognosis, that would otherwise die.*

INTRODUCTION

Cardiogenic shock following cardiac surgery is a life-threatening condition, causing severe myocardial contractile impairment and reduced organ perfusion.[1] Approximately 1% of patients on postcardiotomy shock (PCS) are refractory to inotropic support and/or intra-aortic balloon pump counter pulsation (IABP) support, have poor prognosis, and almost invariably die without urgent or emergent mechanical circulatory support (MCS).[2,3] Extracorporeal membrane oxygenation (ECMO) is a life-saving therapy for patients with unstable haemodynamics despite optimal loading and maximal dose of inotropes and it is increasingly used as the most advanced short-term therapy to promote cardiac recovery in PCS.[2,4] Venoarterial ECMO (VA-ECMO) provides both circulatory and respiratory support, allowing cardiopulmonary recovery.[5] Additionally, it is immediate availability and ease of application not only enables timely rescue and possible cardiopulmonary recovery, but also offers time for stabilization, identification of residual lesions or neurological compromise, and provides a bridge to decision, in which destination therapy with an upgrade to a ventricular assist device (VAD), heart transplantation, recovery or death will be the possible outcomes.[6,7] However, the exponential increase in ECMO use over the last decades has not been accompanied by improved early survival.[8]

We present our center's experience on VA-ECMO support for refractory PCS. This study aims to report and analyse the outcomes.

METHODS

We retrospectively reviewed all patients on refractory PCS who were on VA-ECMO for temporary circulatory support from November 2006 to July 2019 in

our center. Pediatric (group PED) and adult (group AD) patients were analysed separately. All data, including patient demographics, ECMO support data, complications, in-hospital and one-year survival, were collected from the hospital clinical records and the department's database. Primary outcomes were survival to discharge and one-year survival.

RESULTS

Patients characteristics

A total of 29 patients required VA-ECMO support for PCS between November 2006 and July 2019. Group PED (62%, n=18) had a mean age of 1,3 ± 2,1 years old (range 4 days - 8 years) and 39% were male. Group AD (38%, n=11) mean age was 55,6 ± 15,9 years old (range 30 - 76 years) and 64% were male.

Indications for PC-ECMO in group PED were complex congenital heart surgery in 17 patient and post-heart transplant in one patient; 27% of patients had history of previous cardiac surgery. In group AD, indications were valvular surgery (n=5), aortic surgery (n=3), coronary artery bypass grafting (n=2) and pulmonary endarterectomy (n=1); 45% were reoperations. Other baseline characteristics are listed in Table 1.

ECMO support characteristics

ECMO support was initiated intraoperatively due to failure to wean from cardiopulmonary bypass (CPB) – group PED 28%, group AD 73%; and due to refractory cardiogenic shock during the first postoperative day – group PED 50%, group AD 18%; between 24 and 48 hours after the surgery – group PED 11%, group AD 9%; and after 48 hours –group PED 11%. Central cannulation was performed in all pediatric patients and in 82% of the adults. ECMO support data is listed in Table 2.

Postoperative outcomes

Inotropic support over 48 hours and prolonged mechanical ventilation were the most common complications in both groups. Bleeding (need for transfusion support and/ or total bleeding at 48 hours exceeding 10ml/kg, haemorrhagic dyscrasia and upper gastrointestinal bleeding) was 39% in group PED and 45% in group AD. Other complications were cerebrovascular injury (group PED 28%, group AD 9%), renal failure requiring dialysis (group PED 22%, group AD (45%), infection (group PED 39%, group AD 18%) and limb ischemia (group PED 6%, group AD 9% with limb amputation). The remaining outcomes are listed in table 2.

In group PED, two patients who were eligible for assistance upgrade were bridged to LVAD (11%). The

Table 1 **Baseline characteristics**

	Group PED (n= 18)	Group AD (n= 11)
Age (years), mean±SD[a]	1,3 ± 2,1	55,6 ± 15,9
Male gender (%)	7 (39)	7 (64)
Body mass index > 30 (%)	-	2 (18)
Arterial Hypertension (%)	-	7 (64)
Diabetes (%)	-	2 (18)
Hyperlipidemia (%)	-	4 (36)
Smoker (%)	-	5 (45)
Arrythmia	6 (33)	4 (36)
Myocardial infarction (%)	-	3 (21)
Congestive Heart failure (%)	4 (22)	6 (55)
Lung disease (%)	-	1 (9)
Renal disease (%)	-	2 (18)
Cerebrovascular disease (%)	-	-
Peripheral vascular disease (%)	-	1 (9)
Procedure Complex congenital heart surgery Valvular surgery CABG Aortic surgery Heart transplant Pulmonary endarterectomy	 17 - - - 1 -	 - 5 2 3 - 1
Previous cardiac surgery (%)	5 (28)	5 (45)

[a]SD: standard deviation; [b]CABG: coronary artery bypass grafting.

Table 2 **ECMO data and postoperative outcomes**

	Group PED (n= 18)	Group AD (n= 11)
ECMO timming Intraoperative Postoperative	 5 (28) 13 (72)	 8 (73) 3 (27)
ECMO[a] cannulation (%) Central Peripheral	 18 (100) -	 9 (82) 2 (18)
ECMO weaning (%)	8 (44)	5 (45)
ECMO duration (days), mean±SD[b]	6,2 ± 4,9	6,2 ± 3,6
ICU[c] stay (days), mean±SD	24,8 ± 35,3	11,6 ± 9,5
Hospital stay (days), mean±SD	32,6 ± 46,3	12,5± 9,3
Complications (%) Bleeding Limb ischemia Cerebrovascular events Renal failure Inotropic support >48h Arrhythmias MV > 24hd Infection Technical	 7 (39) 1 (6) 5 (28) 4 (22) 18 (100) 3 (17) 18 (100) 7 (39) 1 (6)	 5 (45) 1 (9) 1 (9) 5 (45) 11 (100) 1 (9) 11 (100) 2 (18) -

[a]ECMO: extracorporeal membrane oxygenation; [b]SD: standard deviation; [c]ICU: intensive care unit; [d]MV: mechanical ventilation.

first patient was on ECMO support for 8 days and the second for 15 days, both for PCS following an atrial switch with coronary bypass grafting of the LAD due to ischemic injury. The first was on LVAD support for 14 days, complicated by intracranial haemorrhage and multiorgan dysfunction, and the other patient was one hour on LVAD, remaining refractory to any support. Both patients died in-hospital.

Mean ECMO support time was respectively 6,2 ± 4,9 and 6,2 ± 3,6 days in pediatric and adult groups. Mean ICU stay and mean hospital stay were 24,8 ± 35,3 and 32,6 ± 46,3 days in group PED, and 11,6 ± 9,5 and 12,5± 9,3 days in the group AD. Weaning rate was 44% in group PED and 45% in group AD.

Survival

Survival to discharge as well as one-year survival were 28% in group PED and 18% in group AD (table 3). In group PED, the cause of death was multiorgan failure in 7 patients, refractory cardiogenic shock in 5 patients and one patient died from haemorrhagic shock. In group AD there were 5 deaths due to multiorgan failure, 4 patients died from refractory cardiogenic shock and one patient from septic shock.

DISCUSSION

This retrospective study reports our center experience on VA ECMO as our first line MCS for patients on PCS refractory to optimized inotropic support and/or IABP support. Most reported data in the literature arise from retrospective series, mainly single-center experiences.[1] Recently, data from the Extracorporeal Life Support Organization (ELSO) Registry confirmed a substantial increase in PC ECMO use over the last 10 years.[8]

In our series, PC ECMO was performed in a total of 29 patients: 18 children and 11 adults. Survival to discharge was 28% in group PED and 18% in group AD, despite higher weaning rates of 44% (with 2 patients bridged to VAD, but neither of them survived) and 45%, respectively. Mean ECMO support time was respectively 6,2 ± 4,9 and 6,2 ± 3,6 days in pediatric and adult groups. These findings are in line with the literature. The latest expert consensus of EACTS/ELSO/STS/AATS reports a survival of 20-40%, despite a weaning rate of 40-60%; the duration of ECMO support necessary for adequate myocardial recovery is typically 5-7 days.[9] Successful weaning varies greatly within published series, ranging from 31% to 76%, with almost half of the reports showing a weaning rate at or slightly above 50%. Survival to discharge rates are far less, ranging

Table 3 **ECMO weaning, survival to discharge and one-year survival**

	Total Runs (n)	Weaning rate (%)	Survival to discharge (%)	One-year survival (%)
Group PED	18	44	28	28
Group AD	11	45	18	18

from 16% to 42%.[10-16] Biancari *et al*[17] showed a weaning rate of 60%, while hospital survival was 36%, probably owing to the combined impact of the underlying disease and the extent of the surgical procedure, along with further complications. Despite the technology improvements and increased experience in ECMO care management, survival has not improved in the last 20 years.[11] ELSO reported that has been a gradual decline in the survival after PC-ECMO.[7] This may be owing, at least in part, to more widespread application of this technology to higher risk patients.[1] Multiorgan failure, despite recovery from myocardial failure, is an important contributor to mortality.[18] In fact, the actual cause of death may be interpreted in a misleading fashion in ECMO patients, as reported by Rastan and colleagues who showed that in almost 30% of autopsies, an unexpected cause of death was found.[19] Another important finding in the present study is that all patients who survived the early postoperative period in both groups were alive at one--year follow-up. Although the follow-up period was short, it demonstrated that once successfully discharged from the hospital, the survivors remained alive. These results justify the use of aggressive treatment for patients with refractory PCS as confirmed by recent publications.[20-22]

The increased complication rate is due to both the ECMO circuit itself and the patients critical state, which can impact the immediate and remote outcomes.[23] Despite inotropic support over 48 hours and prolonged mechanical ventilation, bleeding was the most common complication (group PED 39%, group AD 45%). Other complications were cerebrovascular injury (group PED 28%, group AD 9%), renal failure requiring dialysis (group PED 22%, group AD 45%) and infection (group PED 39%, group AD 18%). The most common complication reported in the literature is bleeding.[24] Recently, Burrell *et al*[25] systematically reviewed 46 studies, encompassing 20375 patients. Likewise, bleeding occurred more frequently, followed by neurological and vascular complications. Intracerebral haemorrhage is a result of the challenging balance between adequate systemic anticoagulation therapy and thrombocytopenia induced by ECMO. Limb ischemia-related complications in peripheral ECMO cannulation can be avoided using a distal perfusion cannula, small femoral arterial cannula size and the use of a vascular graft anastomosed end-to-side to the femoral artery.[9] In our practise, the increased use of a distal perfusion cannula has contributed to minimize limb ischemia, with one case of amputation before its use. Comparable to our results, equipment failure is less reported.

Finally, severe ventricular dysfunction can lead to left ventricular (LV) distension, and VA ECMO may not be effective in decompressing the left side. The lack of evidence about the impact of LV venting on patient outcome, makes it impossible to provide conclusive recommendations for its use as a prophylactic procedure.[9] In our center, concomitant IABP is used to enhance LV unloading in selected cases of ineffective LV ejection with poor or absent aortic valve opening. In pediatric patients, our strategy for decompressing the LV consists in placing a vent through the right superior pulmonary vein.

In this study we reported our experience on PC ECMO and retrospectively analysed our outcomes. Regardless of the low survival rates and higher complication rate, these critical ill patients, from neonates to adults, would have had an even poorer prognosis and died without urgent or emergent rescue VA ECMO support. Increased MCS availability, advancements on ECMO equipment, care management and complication prevention are promising paths to improve the outcomes.

Limitations

Our report shares the limitations of a single center, retrospective study. Moreover, the sample size is small and heterogeneous, with a short follow-up period, which may underpower the conclusions. Long term outcomes analysis on survival and quality of life would be valuable contributors to this study.

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