

Adult Extracorporeal Life Support: A Failed or Forgotten Concept?

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Summary

Background: Extracorporeal membrane oxygenation (ECMO) has shown excellent results for the newly born and children. Adult experience has been modest, and immediate results, poor. Intermediate survival, however, has been promising. We have been using extracorporeal membrane oxygenation for temporary mechanical circulatory support of adults that present acute refractory cardiogenic shock in our institution. No information on the use of this system for this scenario is available in Brazil.

Objective: To describe our experience with extracorporeal membrane oxygenation for circulatory support in adults.

Methods: Retrospective analysis of the medical files of patients submitted to the implant of extracorporeal membrane oxygenation system for circulatory assistance in acute and refractory cardiogenic shock.

Results: Eleven patients (63.5yo; 45.5% males) were considered for analysis from 2005 to 2007. Mean support time was 77 hours (10-240h); 5 patients survived 30 days (45.5%). Two patients were subsequently submitted to prolonged paracorporeal circulatory assistance. Mortality on ECMO (6 patients) was due to multiple organ failure (66.6%) and refractory bleeding (33.4%).

Conclusion: ECMO system is an option to be used in acute refractory cardiogenic shock as a bridge to recovery or selecto select patients that might benefit from prolonged paracorporeal assist devices (bridge to bridge). (Arq Bras Cardiol 2008;91(1):34-38)

Key words: Extracorporeal membrane oxygenation; thoracic surgery; heart arrest; multiple organ failure/cardiogenic shock.

Introduction

The Extra Corporeal Membrane Oxygenation system (ECMO) – a set of cannulae, an artificial oxygenation membrane, and a pump – provides pulmonary, heart, or cardiorespiratory support. When used for cardiorespiratory assistance, it is in the occurrence of heart failure, pulmonary failure, or both. It is an extra corporeal circulation closed circuit. Deoxygenated, carbon dioxide rich blood is drained from the venous system and pumped through an artificial oxygenation membrane, to then return to arterial system after oxygenation. It is a continuous flow. The aim is to keep tissue perfusion with oxygenated blood while waiting for the recovery of impaired organ: heart, lungs, or both. The concept is called recovery bridge. Particularly under heart failure condition, another aim when using the ECMO system is to act as a bridge to other prolonged circulation support devices in case native cardiac function is not restored. By doing that, better candidates for prolonged ventricular support can be selected, as well as costs optimized.

Extracorporeal life support for infants and children has been reported with excellent results^{1,2}. The experience using ECMO for adults is more modest, and immediate results are poor^{3,4}, and its use is controversial – whether for respiratory insufficiency or cardiogenic shock.

Patients presenting cardiogenic shock after acute myocardial infarction (AMI), cardiomyopathy, or cardiac arrest, among other conditions, report high hospital mortality rate. Even if primary etiological factor is managed through therapeutic approach (for instance: myocardial revascularization), hospital mortality rate is kept unchanged. Initial resuscitation through ECMO may improve hospital mortality rate in this scenario.

The purpose of the present paper is to report the experience of using ECMO for cardiopulmonary support of adult patients with primary, acute or refractory heart failure.

Methods

Materials were initiated in March, 2005, after minimum requirements were met for training and continuous education of ECMO specialists⁵, as well as the necessary institutional requirements for effective use of the method⁶ in compliance with Extra Corporeal Support Organization (ELSO).

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From March, 2005 through June, 2007 eleven adult patients were evaluated for mechanical circulatory support. All patients were on ECMO due to refractory, acute heart failure.

Endpoints for mechanic support implant were:

1) Cardiogenic shock refractory to at least two IV positive inotropic drugs with or without the use of intra-aortic balloon.

2) Cardiorespiratory Arrest.

Few patients presented invasive hemodynamic control at the point of initial evaluation; therefore, ventricular filling pressures and cardiac index were not considered for the purpose of decision making in regard to ECMO implant. On the other hand, all patients submitted to ECMO implant had their clinical course and hemodynamic management helped by intracavitary pressure measurement obtained from a pulmonary artery catheter.

Patients over 75 years of age with chronic, advanced heart failure condition, organic dysfunction other than renal, suspicion of sepsis or coagulation mechanism dysfunction were not considered for this therapeutic mode.

Patients originally ineligible for heart transplant had the ECMO system implanted in case recovery of ventricular dysfunction were anticipated, as it occurs with cardiogenic shock patients after cardiotomy or those presenting refractory cardiac arrest from unknown or treatable cause.

Device

The extra corporeal life support circuit is made up of an oxygenation membrane (Jostra Quadrox D, Maquet – NJ, EUA), a centrifugal pump, (Jostra Rotaflow, Maquet – NJ, EUA), silicone-coated cannulae with or without a circuit adapted hemofilter, an air mixer, and a heat exchanger.

Introducing the cannulae

The choice pathway for arterial perfusion was obtained via puncture of femoral or axillary dissection, or alternatively, the introduction of the cannula into ascending aorta. The venous drainage cannula was positioned in right atrium directly or through a femoral vein. Insertion sites of arterial and venous cannulae were depended on support indication, the urgency to restore blood flow, where the patient was located at the facility (emergency room, hemodynamic laboratory, intensive care unit or surgery room), in addition to patient's individual characteristics.

For patients under cardiogenic shock after cardiotomy cannulae were inserted preferably through central vessels surgery – the same vessels used for conventional extra corporeal circulation, whereas for cardiac arrest patients cannulae were preferably inserted in femoral or axilar vessels, or both.

Anticoagulation

Heart failure patients had heparin antagonization at 75% protamine administration after cardiotomy, which means to say, 75 IU of heparin for 1mg of protamine. Heparin was administered after mediastinal bleeding control, at the

point when mediastinal drainage was lower than 75ml/h for 3 hours. The purpose was to keep APTT (activated partial thromboplastin time) between 45 and 65 seconds, taking into account administration flow and other clinical characteristics of each patient. All other patients received IV non-fractionated heparin before cannulae insertion (100 IU/Kg).

All patients received non-fractionated heparin during circulatory support. Although activated coagulation time (ACT) was originally used to guide anticoagulation level, non-fractionated heparin coagulation adjustment through PTT every 4 hours was preferred. Additionally, at least one heparinase thromboelastogram (HepTEG) was performed daily for coagulation mechanism evaluation.

Patient management

Patients were typically submitted to biventricular ventilation mode, with 40% oxygen inspiration fraction or less. Respiratory rate was pre-fixed at 8-10 cycles/min with current 8-10mL/kg volume and positive end-expiratory pressure (PEEP) lower than 8 cmH₂O. Ventilation parameters were defined to prevent pressure peaks in upper airways to exceed 35 cmH₂O. Ventilatory parameters were changed to optimize arterial gasometry.

An air-oxygen mixer was used for membrane oxygenator ventilation. Centrifugal pump blood flow and membrane oxygenator air flow were kept at 1:1 to guarantee oxygenator efficient function.

Low dosing of inotropic drugs was used to keep ventricular contractility and to optimize ventricular decompression, in addition to preventing intracavitary blood stasis with formation of thrombi.

Most patients received concurrent intra-aortic balloon implant in an attempt to reduce left ventricle post-load, optimize coronary perfusion, and add pulsatility to circulation.

All patients were controlled through a pulmonary artery catheter and continuous central venous oxygen saturation and serial echocardiogram. From the eleven patients, nine were controlled through continuous electroencephalography during circulatory support.

Mechanical ventilation weaning

Ventricular function was evaluated clinically, hemodynamically, and echocardiographically at hospital bed. Direct, subjective visualization of heart in sternotomy patients was also utilized. Formal weaning attempts were started after at least 24 hours on ECMO support. During weaning attempts centrifugal pump flow was progressively reduced for ventricular ejection evaluation. Flows under 1l/min were allowed for short periods of time (under 2 minutes). ACT between 200 and 220 seconds and APPT between 65 and 90 seconds were used during those attempts. Additionally, the use of inotropic IV drugs and pulmonary vasodilators – such as nitric oxide and sildenafil – were added as needed. Mechanic ventilation parameters were adjusted and hematocrit kept above 30% was considered for all patients.

As cardiac function progressively improved, centrifugal



pump flow was progressively reduced. The ECMO system would be removed whenever the patient succeeded in reaching native cardiac index above 2.21/min/m², with optimized filling pressures during weaning tests.

Data collection and statistical analysis

Data were collected retrospectively through medical records. Statistical analysis was essentially descriptive.

Results

Patients' demographics can be found on Table 1.

Patients' mean age was 63.5 years of age (45.5% were males). Ischemic heart failure etiology was reported by 63.3% of patients; non-ischemic by 18.2%, and the impossibility of post-cardiotomy extracorporeal circulation weaning by 18.2%. Out of all patients, 18.2% were undergoing cardiorespiratory arrest and 36.4% had reported cardiorespiratory arrest within the 60 minutes prior to mechanic support. Time necessary for circulatory support as of cardiorespiratory resuscitation maneuvers for the two patients undergoing cardiorespiratory arrest was 30 and 45 minutes, respectively. Both were assisted at the hemodynamic laboratory. The second patient had the cannulae inserted through esternotomy, which was performed due to the impossibility of surgical access to peripheral vessels. From all patients, 73% presented post-AMI cardiogenic shock, and 63% was going through post-operative period after heart surgery.

Average support time was 77 hours (from 10 to 240 hours). During that time period major complications were related to bleeding and organic dysfunction, as shown in Table 2. From the eleven patients, nine were controlled through continuous electroencephalography, with no evidence of new neurologic events during support. From all patients, three (27.2%) had their cardiac function

Table 2 - Complications during ECMO Support

	(N = 11)
ECMO duration	77±74 hours
Polytransfusion	3 (27%)
Thrombo-embolism	0
Membrane Oxygenation Change	0
Ischemia of Limb	1/4 (25%)
ECMO Hemodialysis	8 (72.7%)

N - Number of Patients.

restored to allow the removal of the ECMO system; two others (18%) were submitted to prolonged para-corporeal ventricular device insertion. The five patients (45.4%) survived for at least 30 days. Two patients survived hospital discharge; one of them was submitted to heart transplant after prolonged left ventricle support. Six deaths were reported (54.5%) during support time course. Deaths causes included refractory bleeding (2 patients) and multiorgan failure (4 patients). (Table 3)

Discussion

Mechanical circulatory support to acutely failing heart is part of an institutionalized, multidisciplinary heart failure program.

The indications for mechanical circulatory support include chronic cardiac support and recovery and bridge to recovery, bridge to heart transplant, short-term support to post-cardiotomy cardiogenic shock, temporary support to high-risk percutaneous procedures, and emergency cardiac resuscitation in cardiorespiratory arrest. Additionally, the heart surgeon may be requested for the implant of circulatory support under scenarios that include, but are not restricted to, pulmonary embolus, hypothermy, and trauma.

Mechanical circulatory support for temporary, short-term cardiac support is necessary to manage acute heart failure under a number of different clinical settings. The evaluation

Table 1 – Demographics and Pre-operative Variables

Variables	(N = 11)
Age (Years; M ± SD)	63.5 ± 12
Weight (Kg; M ± Sd)	72 ± 16
Height (Cm; M ± Sd)	163 ± 14
Gender	n(%)
Males	5 (45.5%)
Females	6 (54.5%)
Etiology	n(%)
Ischemic	7 (63.6%)
Non-ischemic	2 (18.2%)
Post-cardiotomy	2 (18.2%)
Cra	n(%)
Present	6 (54.5%)
Absent	5

m - mean; *SD* - Standard Deviation; *Kg* - kilograms; *cm* - centimeters; *N* - number of patients; *CRA* - cardiorespiratory arrest.

Table 3 - Outcomes

	(N = 11) n(%)
Weaning	3 (27.2%)
Hospital Discharge	1
Heparin-induced Thrombocitopeny (death)	1
Stroke (death)	1
Bridge for prolonged support	2 (18.2%)
Transplant	1
Entero-mesenteric Infarction (death)	1
Death on ECMO	6 (54.6%)
Multi-organ dysfunction	4
Bleeding	2

N - Number of Patients.

of mechanical support devices under such scenario is not easy due to patients' clinical instability before devices implant as well as to the typically acute condition presented by this kind of patient. As opposed to most transplant candidate patients who turn eligible for chronic mechanical assistance (bridge to transplant), short-term support is usually associated to a high level of co-morbidities and ischemic insult to vital organs, in addition to hemodynamic instability. To establish the safety and efficacy level of temporary mechanical support devices in this complex population of patients is not an easy task.

The ideal strategy for short-term support should combine low cost, adaptability to distinctive applications, and individual requirements by each clinical scenario, in addition to easy, fast implementation. The ECMO system and its implementation logistics have shown to meet those requirements at this early stage.

Adult patients are posed with quite a number of limitations to use ECMO for circulatory support. A major concern is that left ventricular decompression is not appropriate, thus resulting in pulmonary hypertension, edema and hemorrhage⁷. In that respect, ventricular filling pressures control through pulmonary artery catheter is key to manage those patients. To tackle the problem, however, the use of intra-aortic balloon should be concurrent to ECMO, in addition to low doses or positive inotropic drugs as an attempt to reduce ventricular post-load and to make ventricular ejection easier. The use of transesophageal echocardiogram or specifically designed echo probe through mediastinal drain may lead therapy towards the ventricle decompression of patients whose pulmonary hypertension is kept after ECMO implant. Despite procedures as described, pulmonary hypertension should require surgical intervention for left ventricle decompression.

From the eleven patients, six (54.5%) were over 70 years old. Some authors take age range into account at the point of indicating or contra-indicating the procedure. The very poor survival rate of elderly patients should not justify this therapy, especially if renal or hepatic failure are present prior to ECMO, or if any neurologic damage is reported after ECMO⁴. ECMO should not be performed in this group of patients. However, if ECMO does get to be performed, and clinical improvement is not immediately reported, ECMO early discontinuation should be recommended.

Smedira et al⁴ reported a 38% 30-day survival rate among 202 adults on ECMO. The need for hemodialysis was 40%. In Materials, the present study reported 45.4% of patients were alive in the 30 days that followed; 72.7% had to be submitted to hemodialysis in the support period. From eight patients, two were submitted to hemodialysis; however, they had been on renal replacement therapy (RRT) when ECMO was implanted. Patient screening is closely related to results obtained from support. Renal dysfunction is one of the variables to most negatively affect weaning from the system and survival⁸.

Cardiogenic shock after acute myocardial infarction (AMI) reports mortality rates ranging from 55% to 81% within 30 days^{9,10} if management is optimized. Under such

scenario, myocardial revascularization – despite improving patients' survival rate in 6 months – does not succeed in changing their hospital mortality rate⁹. In the present study sample, most adults reported post-AMI cardiogenic shock. Although all obstructive coronariopathy patients had been submitted to myocardial revascularization (either percutaneous or surgical) while on ECMO a more aggressive strategy – which is appropriate for circulatory support to act as a bridge for recovery or for transplant – has been associated to better hospital mortality rates¹⁰.

The strategy for additional use of anticoagulation control through heparinase thromboelastography¹¹ may be associated to better coagulation mechanism control for those patients, although further studies are required. In our sample, with most patients having been controlled through continuous electroencephalography, no new cerebral events were identified during the ECMO period. Neither was pump or circuit thrombosis, or the need to change the oxygenation membrane in any of the patients.

Although ECMO does promote fast resuscitation, organic injury resolution, and time for pre-transplant heart evaluation, ventricular support devices allow low-risk prolonged circulatory support in addition to rehabilitation. Patients who do not survive initial ECMO period would not survive ventricular support devices. The strategy for ECMO use as a "bridge to a bridge" may optimize the use of devices and improve prolonged support results⁷.

The ECMO system can provide cardiopulmonary support and proper blood flow to the organs. However, complications related to that circulatory support mode – whether directly or indirectly – are still considerable, and prevent improvement of results if longer term devices are not available (bridge to bridge), especially in regard to younger patients (transplant candidates), which gives ground to a more aggressive clinical approach. Post-ECMO survival and system weaning rates have been kept unchanged along the last decade. Most significant advance has been witnessed at transplant and circulatory support centers where transplant candidates receive longer term devices after ECMO (bridge to bridge)¹². For the sake of results excellency, however, in addition to investments in human resources qualification, a wide range of device options should be available to meet the specific requirements by a population of acutely affected patients.

Conclusion

The ECMO system is an alternative for temporary circulatory support for adult patients with refractory acute heart failure and may be used as a bridge to recovery or for the purpose of screening candidates for prolonged circulatory support (bridge to bridge). The training of a multidisciplinary team, the availability of new technologies, and the refinement of methods are made necessary for results optimization.

Limitations

This is a retrospective analysis, based on one institution only, with a small sample of patients. Patients' management and



protocols used were altered along study time.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

References

1. Bartlett RH, Roloff DW, Custer JR, Younger JG, Hirschl RB. Extracorporeal life support: the University of Michigan experience. *JAMA*. 2000; 283: 904-8.
2. Magovern GJ Jr, Simpson KA. Extracorporeal membrane oxygenation for adult cardiac support: the Allegheny experience. *Ann Thorac Surg*. 1999; 68: 655-61.
3. Conrad SA, Rycus PT, Dalton H. Extracorporeal Life Support Registry Report 2004. *ASAIO J*. 2005; 51: 4-10.
4. Smedira NG, Moazami N, Golding CM, McCarthy PM, Blackstone EH, Cosgrove DM. Clinical experience with 202 adults receiving extracorporeal membrane oxygenation for cardiac failure: survival at five years. *Thorac Cardiovasc Surg*. 2001; 122: 92-102.
5. ELSO guidelines for training and continuing education of ECMO specialist. [acesso em 2007 mai 10]. Disponível em <http://www.else.med.umich.edu/WordForms/ELSO%20Guidelines-Specialist%202-05.pdf>
6. ELSO guidelines for ECMO centers. [acesso em 2007 maio 10]. Disponível em: <http://www.else.med.umich.edu/WordForms/ELSO%20Guidelines-Center%202-05.pdf>
7. Pagani FD, Lynch W, Swaniker F, Dyke DB, Barlett R, Koelling T, et al. Extracorporeal life support to left ventricular assist device bridge to heart transplant a strategy to optimize survival and resource utilization. *Circulation*. 1999; 100 (Suppl II): II-206 –II-210.
8. Miller LW. Patient selection for the use of ventricular assist devices as a bridge to transplantation. *Ann Thorac Surg*. 2003; 75: S66-S71.
9. Hochman JS, Sleeper LA, Webb JG, Sanborn TA, White HD, Talley JD, et al. Early revascularization in acute myocardial infarction complicated by cardiogenic shock. SHOCK Investigators. Should We Emergently Revascularize Occluded Coronaries for Cardiogenic Shock. *N Engl J Med*. 1999; 341 (9): 625-34.
10. Tayara W, Starling RC, Yamani MH, Wazni O, Jubran F, Smedira N. Improved survival after acute myocardial infarction complicated by cardiogenic shock with circulatory support and transplantation: comparing aggressive intervention with conservative treatment. *J Heart Lung Transplant*. 2006; 25 (5): 504-9.
11. Stammers AH, Willett L, Fristoe L, Merrill J, Stover T, Hunt A, et al. Morrow J, Newberry J. Coagulation monitoring during extracorporeal membrane oxygenation: the role of thrombelastography. *J Extra Corpor Technol*. 1995; 27 (3): 137-45.
12. Smedira NG, Blackstone EH. Postcardiotomy mechanical support: risk factors and outcomes. *Ann Thorac Surg*. 2001; 71: S60-S66.

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Study Association

This study is not associated with any graduation program.