Veno-arterial extracorporeal membrane oxygenation using Levitronix centrifugal pump as bridge to decision for refractory cardiogenic shock

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Objectives: Cardiogenic shock still carries a very high mortality. We adopted veno-arterial extracorporeal membrane oxygenation using the Levitronix centrifugal pump (Levitronix LLC, Waltham, Massachusetts) as a first-line treatment of cardiogenic shock in a ''bridge to decision'' strategy. This article provides our experience of this clinical approach.

Methods: Since 1988, 160 ventricular assist devices have been implanted at our hospital for heart failure. Since 2005, 15 consecutive patients have been treated with veno-arterial extracorporeal membrane oxygenation for refractory cardiogenic shock. Veno-arterial extracorporeal membrane oxygenation has been implanted either centrally or peripherally.

Results: Mean age was 44.7 ± 20.0 years (2–78 years). There were 5 women. Veno-arterial extracorporeal membrane oxygenation was implanted peripherally in 8 cases (53.4%) and centrally in the remaining 7 (46.6%). Mean veno-arterial extracorporeal membrane oxygenation duration was 11.5 ± 8.1 days (range, 1–30). No patient experienced any neurologic event or vascular complication at the cannulation site. Twelve patients (80%) were weaned from veno-arterial extracorporeal membrane oxygenation or bridged to either a long-term left ventricular assist device or heart transplantation. Three patients died during veno-arterial extracorporeal membrane oxygenation support secondary to multi-organ failure. Seven patients (46.6%) were discharged from the hospital, with a 100% survival at follow-up. The survivors include 2 patients affected by fulminant myocarditis, who were bridged to recovery, and 5 patients who were bridged to heart transplantation. Survivors were younger than nonsurvivors (mean age, 28.5 vs 58.8 years, respectively).

Conclusions: In our experience, the use of veno-arterial extracorporeal membrane oxygenation as bridge to decision has been effective to promptly restore adequate systemic perfusion, allowing further time to evaluate myocardial recovery or candidacy for ventricular assist device or heart transplantation. Younger patients, with no or mild end-organ injury, had the best outcomes. Peripheral cannulation decreases the surgical trauma and makes emergency implantation possible, even in the intensive care unit. (J Thorac Cardiovasc Surg 2010;140:1416-21)

Refractory cardiogenic shock (RCS) still carries a very high mortality.[1] In some cases of RCS mechanical circulatory support (MCS) represents the only therapeutic tool to rescue the patient's life if an intra-aortic balloon pump (IABP) is not able to provide sufficient cardiac support. However, uncertainty of patient clinical conditions and prognosis (ie, reversibility of myocardial damage, end-organ failure, and possible neurologic impairment), in addition to the time-pressure imposed by the severity of RCS, as well as logistical issues (ie, transportability of the patient and availability of an operating room), makes the proper selection of MCS more complex.

At Niguarda Hospital, experience with MCS started in 1988: until July 2009, 160 implants of monoventricular or biventricular ventricular assist device (VAD) have been performed. Since 2005, in severely ill patients with RCS requiring emergency MCS, we have been using veno-arterial extracorporeal membrane oxygenation (VA-ECMO) using the Levitronix CentriMag centrifugal pump (Levitronix LLC, Waltham, Mass) as a ''bridge to decision.''[2] In this article, we review our experience in this clinical setting.

MATERIALS AND METHODS

We retrospectively reviewed our experience with VA-ECMO for RCS since 2005. The study was approved by the Hospital Review Board. Between February 2005 and July 2009, 15 consecutive patients were treated with VA-ECMO, using a Levitronix CentriMag Blood Pumping System (Levitronix LLC) as first-line emergency mechanical support for RCS. All patients were on maximal medical therapy, including at least two high-dose inotropes, mechanical ventilation, and IABP, if feasible (Table 1). Profound, rapidly progressing ventricular dysfunction with

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Abbreviations and Acronyms

ACT = activated coagulation time
BSA = body surface area
CS = Cardiogenic shock
HTx = heart transplant
IABP = intra-aortic balloon pump
LV = left ventricle
LVAD = left ventricular assist device
RCS = refractory cardiogenic shock
MCS = mechanical circulatory support
VAD = ventricular assist device
VA-ECMO = veno-arterial extracorporeal membrane oxygenation

persistent low blood pressure (systolic blood pressure $\leq$ 80 mm Hg for adults; $\leq$ 60 mm Hg for children) as measured by arterial lines and oliguria ($\leq$ 0.5 mL/kg/hr) for at least 4 hours despite maximal intropic support and IABP, which were promptly considered to be an indication for emergent VA-ECMO implantation. When the implantation was performed in the intensive care unit, all of the ECMO setup was obtained from the operating room. The Levitronix CentriMag Blood Pumping System is an extracorporeal short-term VAD composed of a single-use centrifugal blood pump, a motor, a console, and a flow probe. The CentriMag motor is based on bearingless technology that combines the drive, magnetic bearing, and rotor into a single unit. This system can generate flows up to 10 L/minute with a priming volume of 31 mL, and in Europe the system is licensed for use for 30 days. Alongside the Levitronix CentriMag, we assembled an ECMO circuit that included a hollow fiber membrane oxygenator, the Quadrox D (Maquet, Hirrlingen, Germany), and a heater-cooler (Stockert, Munchen, Germany). If anatomically feasible, a femoral approach was our first choice for implantation. For femoral cannulation, we adopted percutaneous arterial (16–20 French) and venous (20–22 French) cannulas (Edwards Lifescience, Irvine, Calif). In 1 case, due to severe femoral artery disease, the axillary artery was cannulated. Patients were given a bolus of 100 UI/kg of heparin, and after surgical dissection, the proximal common femoral vessels were cannulated. Only in 1 case we inserted the femoral cannulas percutaneously. As described elsewhere,[3] to allow both to perfuse and drain of the distal limb, two 6-mm right-angled soft balloon-tipped coronary cannulas for selective anterograde cardioplegia infusion (Maquet, Hirrlingen, Germany) were inserted, respectively, into the common femoral artery and vein, distally to the main cannulation sites, and secured by pursestring sutures. Such small cannulas were connected to three-way stopcocks to allow both to perfuse and drain the distal limb. The clinical status of the limb-skin color and temperature (presence of edema) was evaluated every hour. To prevent thrombosis of distal venous drainage line, it was flushed with heparinized saline every 2 hours. In case of unfeasibility of femoral cannulation, because of small or severely atherosclerotic vessels, or in cases of postcardiotomy shock, we performed a central implant through standard pursestring sutures placed on the aortic arch and right atrium. In such case, we adopted a standard aortic cannula (20–22 French; Edwards Lifescience) and a 2-stage (36/46 French) venous cannula (NGC Medical Spa, Italy). The speed of the pump was then increased to provide a pump flow greater than 2.2 L/min/m^2. Echocardiography was used to assess cardiac anatomy, ventricular function, and proper venous cannula placement. We used an IABP[4] and low-dose epinephrine[5] to reduce afterload and increase ventricular contractility to unload the left ventricle (LV). Heparin was infused to maintain an ACT of 160 to 180 seconds for the first 4 days to reduce the incidence of bleeding from the implantation site. After day 4, heparin dosing was increased to maintain an ACT of 180 to 200 seconds. Close monitoring of hemostasis was performed by means of serial thromboelastography. End-organ function was closely monitored. Appropriate enteral or parenteral nutrition was used.

Weaning From ECMO

In cases in which recovery was expected (fulminant myocarditis or acute myocardial infarction), weaning was usually first attempted after 4 days of circulatory support, with normal end-organ function. The VA-ECMO flow was reduced to 500 mL/minute, and provided the LV ejection fraction (EF) of $\geq$ 40% and adequate hemodynamic parameters that were maintained with low-dose inotropes, from which the patient was weaned from support. However the weaning trial was discontinued in the case of unsatisfactory cardiac performance and a new attempt was made the following day.

RESULTS

Preoperative and mechanical support data for each patient are reported in Tables 1 and 2. Mean age was 44.7 $\pm$ 20.0 years (2–78 years) and there were 5 females (33.3%). The VA-ECMO was implanted peripherally in 8 cases (53.4%) and centrally in the remaining 7 (46.6%). In 5 cases the implant was performed in the intensive care unit. In 1 case (6.6%), we resorted to direct left atrial venting to effectively decompress the left ventricle. Mean time on ECMO was 11.5 $\pm$ 8.1 days (range, 1–30). Full circulatory support was achieved in all patients, with flows of up to 5.2 L/minute. Three patients were extubated while undergoing VA-ECMO through femoral cannulation. Overall preoperative data and outcomes are reported in Table 3. Bleeding requiring reoperation or more than 6 units of blood occurred in 4 patients (26.6%) who had a gross coagulopathy. Two patients experienced pulmonary infections, as diagnosed by culture of bronchial secretions and radiologic evidence. No patient experienced any neurologic clinical event, defined as a neurologic deficit permanent or persistent for more than 24 hours, documented by means of computed tomography or at necropsy. We did not observe any mechanical device failure or mechanical hemolysis (plasma-free hemoglobin > 50 mg/L). Twelve patients (80%) were weaned from VA-ECMO or bridged to left ventricular assist device (LVAD) or heart transplant (HTx). Three patients died (20%) during ECMO support.

Seven patients (46.6%) were discharged from the hospital, with a 100% survival at follow-up (mean duration of follow-up, 26.1 months). The VA-ECMO successfully bridged to recovery 2 patients suffering from fulminant myocarditis, while the other 5 were bridged to HTx. Survivors were younger than nonsurvivors (mean age, 28.5 vs 58.8 years, respectively) without any differences in length of ECMO support (mean support, 11 vs 12 days, respectively). Prior to VA-ECMO implantation, both mean serum creatinine and total bilirubin were higher in nonsurvivors (1.3 $\pm$ 0.4 mg/dL and 1.5 $\pm$ 1.0 mg/dL, respectively), as compared to survivors (1.0 $\pm$ 0.5 mg/dL and 1.3 $\pm$ 0.9 mg/dL, respectively). The cause of in-hospital death was multiorgan failure in 6 of 8 cases (75%), pulmonary artery