Feasibility of smaller arterial cannulas in venoarterial extracorporeal membrane oxygenation

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Objectives: To facilitate venoarterial extracorporeal membrane oxygenation (ECMO) insertion for cardiogenic shock, we recently adopted a strategy of using a 15F arterial cannula in all patients, rather than 1 designed to maximize flow. We aimed to compare the clinical outcomes of these 2 strategies.

Methods: In this retrospective study, 101 consecutive patients supported with ECMO via femoral cannulation between March 2007 and March 2013 were divided into 2 groups: Group L (17F-24F arterial cannula to accommodate full flow [ie, cardiac index of 2.5 L/m^2/min]; n = 51) and Group S (15F arterial cannula; n = 50). The primary outcomes of interest were patients' overall status at 24 hours of support and cannulation-related adverse events.

Results: There were no significant differences in patient demographics, etiology of cardiogenic shock, or severity of illness before ECMO initiation between the 2 groups. Group L had significantly higher ECMO flow than Group S (flow index at 24 hours: 2.2 ± 0.7 vs 1.7 ± 0.3 L/m^2/min; $P < .001$). However, there was no significant difference in use of vasoactive medication/hemodynamic parameters/laboratory parameters. Group L had higher incidence of cannulation-related adverse events (35% vs 22% in Group S [$P = .14$]), particularly in cannulation site bleeding (28% vs 10% [$P = .03$]). Thirty-day survival was 55% in Group L versus 52% in Group S ($P = .77$). Bleeding complication occurred in 53% in Group L versus 32% in Group S ($P = .03$).

Conclusions: Compared with the use of larger cannulas, ECMO with a 15F arterial cannula appears to provide comparable clinical support with reduced bleeding complications. (J Thorac Cardiovasc Surg 2015;149:1428-33)

See related commentary pages 1434-5.

Despite significant progress in medical management, cardiogenic shock remains a disease entity with a high in-hospital mortality rate. Cardiogenic shock complicating acute myocardial infarction (the most common and widely studied etiology of cardiogenic shock) has been reported to carry a 30-day mortality ranging between 50% and 80%.[1-3] In a recent prospective randomized control study, intraaortic balloon pump counterpulsation, the most widely used form of mechanical circulatory support, was shown to add no survival benefit when compared with medical management in this group of patients.[1] Evolving mechanical circulatory support technology has been applied to address the unmet therapeutic needs of patients with cardiogenic shock.[4] In fact, the updated American College of Cardiology/American Hospital Association guideline for the management of ST-elevation myocardial infarction states that ''alternative left ventricular assist device (LVAD) for circulatory support may be considered in patients with refractory cardiogenic shock'' as a Class IIb recommendation.[5]

Durable LVAD technology has become the standard of care for patients with end-stage chronic heart failure, with established benefit in improving survival and quality of life of patients.[6,7] However, the application of LVAD to acutely ill patients with cardiogenic shock has not been as successful.[8,9] Durable LVADs have unfavorable characteristics as a cardiogenic shock therapeutic modality, including support limited to the left ventricle (unless a temporary right ventricular assist device is placed), prolonged time needed to establish support, and significant resource use (surgical team/equipment and cost). Instead, short-term mechanical circulatory support devices have been found to be more appropriate for this application.[10-13] Among these, extracorporeal membrane oxygenation (ECMO) has increasingly been used for cardiopulmonary failure in adult patients.[14-16] Unique features of venoarterial (VA) ECMO compared with other mechanical circulatory support devices, such as speed and ease of insertion, biventricular support, and simultaneous pulmonary support, make it an attractive

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Disclosures: Authors have nothing to disclose with regard to commercial support.
Received for publication Oct 31, 2014; revisions received Jan 12, 2015; accepted for publication Jan 29, 2015; available ahead of print March 5, 2015.

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0022-5223/$36.00

http://dx.doi.org/10.1016/j.jtcvs.2015.01.042

Abbreviations and Acronyms
ECMO = extracorporeal membrane oxygenation
LVAD = left ventricular assist device
VA = venoarterial
VIS = vasoactive-inotrope score

modality for patients experiencing cardiogenic shock, especially when emergent support is needed.[3]

This device is based on the principles of cardiopulmonary bypass developed for open heart surgery, and allows surgeons increased flexibility when compared with other devices, particularly in the selection of hardware such as cannulas, pump, and oxygenator as well as in the choice of procedural details such as access site and cannulation method. Despite these options, a paucity of evidence exists regarding optimal cannulation methodology.

An arterial cannula is conventionally chosen to accommodate calculated full flow, corresponding to a cardiac index of 2.2 to 2.5 L/m^2/min. Whereas generating full flow from the VA ECMO circuit might have theoretical appeal, it is not always necessary and may, on occasion, even be detrimental. Increased left ventricular afterload with VA ECMO support can lead to left ventricular distension, pulmonary edema, hypoxia, and/or left ventricular thrombus formation.[17,18] Reducing the VA ECMO flow rate and supporting the left ventricle with inotropes may be required to ameliorate this condition. In addition, femoral artery cannulation can cause arterial injury and subsequent limb ischemia, bleeding, thromboembolism, and other vascular complications. Surprisingly, very few published studies of ECMO use discuss or analyze the influence of flow rate on the outcome of support. Thus, an important question remains unanswered: What is the most appropriate flow with VA ECMO support in patients experiencing cardiogenic shock?

In an effort to balance the risks and benefits of a full-flow approach, our program changed the arterial cannulation strategy in November 2011 from the conventional approach (using a 15F-24F cannula) to 1 that used a smaller arterial cannula (ie, a 15F cannula). The aim of our study was to compare the clinical outcomes of these 2 strategies. This study was unique in its focus on the detail of the ECMO logistics. Currently, VA ECMO is largely managed on the basis of what is believed to be the best practice, which is frequently based on a few centers' or individuals' experience. There is very limited evidence on the logistics of this therapy.

METHODS

This study was approved by our institutional review board with waiver of informed consent.

Among 146 patients who were placed on VA ECMO between March 2007 and March 2013, we retrospectively reviewed charts of 101 consecutive patients experiencing cardiogenic shock who underwent femoral vessel cannulation. Patients who underwent central aortic cannulation or axillary artery cannulation were excluded because arterial cannula selection in these configurations is not limited by the size of the artery and thus the same clinical concern does not exist. Before November 2011, the arterial cannula was selected among 15F to 24F cannulas to accommodate full-flow support (ie, cardiac index of 2.5 L/m^2/min). Since then, the smaller, 15F cannula has been the arterial cannula of choice. Group L included the 51 patients who received a 17F to 24F cannula and Group S included the 50 patients who received a 15F cannula. In all cases, for venous drainage a 23F femoral venous cannula was used except for a few cases in which a 21F cannula was used at the surgeon's discretion because of the patient's small size.

Patient Management Algorithm

Our algorithm of bridge-to-decision device therapy for refractory cardiogenic shock during the study period has been previously described.[19] Cardiogenic shock is treated with vasopressors and inotropes with or without addition of an intraaortic balloon pump. Refractory cardiogenic shock is characterized by a systolic blood pressure <90 mm Hg, a cardiac index <2.0 L/m^2/min, pulmonary capillary wedge pressure >16 mm Hg (or evidence of pulmonary edema in the absence of a pulmonary artery catheter), and evidence of end-organ failure or the inability to be weaned from cardiopulmonary bypass for postcardiotomy shock despite the aforementioned measures. These patients are rapidly evaluated by our multidisciplinary mechanical circulatory support device heart team. Contraindications to mechanical circulatory support include the patient's or family's will against mechanical circulatory support, clinical judgment against mechanical circulatory support by the primary team, more than 30 minutes of ongoing cardiopulmonary resuscitation (from the beginning of the cardiopulmonary resuscitation until the arrival of the mechanical circulatory support device heart team at the bedside), septic shock, and extremely short-term predicted life expectancy due to comorbidities. A bridge-to-decision device (short-term external ventricular assist device or VA ECMO) is promptly placed. VA ECMO is preferred when a patient has unclear neurologic status due to prolonged cardiopulmonary resuscitation or other reasons, when hemodynamic parameters of a patient are too unstable to safely transfer the patient to the operating room, or when a patient has developed severe coagulopathy due to shock liver, potent antiplatelet therapy before percutaneous coronary intervention, or other causes.

VA ECMO is established through a percutaneous femoral arterial and venous cannulation or through a surgical cut-down. Although femoral vessel cannulation is preferred, central cannulation is used when the patient's chest is already open or when peripheral access is not attainable. Axillary arterial cannulation is chosen in selected cases. The choices of these procedural details are at the discretion of the attending physician. Only the patients with femoral cannulation were included in our study. The VA ECMO circuit consists of a Quadrox D oxygenator (Maquet, Rastatt, Germany), Rotaflow (Maquet, Rastatt, Germany), and Smart-coating tubing (Sorin, Milan, Italy).

Patients undergoing VA ECMO are managed in our specialized intensive care units. Tissue perfusion, monitored by mixed venous oxygen saturation, lactate, and end organ function, is optimized by adjusting the VA ECMO flow as well as by titrating the inotropic agents. Anticoagulation with heparin (goal partial thromboplastin time of 45-60 seconds) begins immediately after hemostasis is achieved. Patients are supported with mechanical ventilation and rested in bed. Sedation is transiently turned off each day to assess mental status. Hypothermia protocol with a goal temperature of 33°C to 34°C for 24 hours is implemented for patients with possible ischemic neurologic injury according to the decision of the multidisciplinary mechanical circulatory support device heart team, intensivists, and neurologists. Ipsilateral leg ischemia is closely monitored by confirming Doppler signals in the dorsalis pedis and/or posterior tibial artery. If the signal is lost, a distal perfusion cannula is inserted through a cut-down