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The Role of Extracorporeal Membrane Oxygenation

In Emergent Percutaneous Coronary Intervention for Myocardial Infarction Complicated by Cardiogenic Shock and Cardiac Arrest

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ABSTRACT: Patients with myocardial infarction (MI) who have out-of-hospital cardiac arrest and cardiogenic shock have a high mortality rate. Although intra-aortic balloon counterpulsation is frequently used in patients with cardiogenic shock, it does not provide complete hemodynamic support. We report 2 cases in which extracorporeal membrane oxygenation was instituted emergently in the cardiac catheterization laboratory in patients with MI and cardiac arrest who underwent percutaneous coronary intervention and who were hemodynamically unstable despite inotropic agents and intra-aortic balloon counterpulsation.

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Cardiogenic shock occurs in 5–10% of patients with ST-elevation myocardial infarction (STEMI) and is the most common cause of in-hospital death in these patients.^{1–3} The Should We Emergently Revascularize Occluded Coronaries for Cardiogenic Shock (SHOCK) trial reported improved 6-month, 1-year, and 6-year survival with early revascularization compared with initial medical stabilization and delayed revascularization in patients with STEMI complicated by cardiogenic shock.^{4–6}

Extracorporeal membrane oxygenation (ECMO) is a technology instituted in patients with severe cardiac or pulmonary dysfunction to provide extracorporeal gas exchange. ECMO can provide emergent circulatory support in patients presenting with cardiac arrest or with severe hemodynamic instability leading to multiorgan failure.^{7,8} The two most common forms are veno-arterial and veno-venous ECMO. Blood is removed from the venous circulation and oxygenated in both forms of ECMO. However, in veno-arterial ECMO, blood is pumped back into the arterial system through the femoral arterial cannula. In veno-venous ECMO, blood is pumped back into the venous system through the femoral venous cannula. Venovenous ECMO

is initiated in patients with preserved left ventricular function who have pulmonary disease. Cardiac support is provided only with veno-arterial ECMO.

There is limited experience with ECMO in patients who undergo emergent percutaneous coronary intervention (PCI) for MI complicated by cardiogenic shock and cardiac arrest. ECMO can be emergently implanted to provide circulatory support and prompt resuscitation. We report two cases where ECMO was emergently instituted in the cardiac catheterization laboratory in patients who underwent PCI for MI complicated by cardiogenic shock and cardiac arrest who were hypotensive despite inotropic agents and intra-aortic balloon pump counterpulsation.

Description of ECMO implantation. A Bio-Medicus femoral arterial cannula (Medtronic, Inc., Minneapolis, Minnesota) is inserted into the right common femoral artery over a 0.038 inch x 39 inch-long guidewire and then connected to the arterial tubing from the ECMO machine (Cobe Cardiovascular, Arvada, Colorado). A Bio-Medicus femoral venous cannula is inserted over a 0.038 inch x 71 inch-long guidewire into the right femoral vein and then connected to the venous tubing of the ECMO machine. The ECMO machine is connected to the patient with a Wolf custom-pack nonheparinized 3/8 inch tubing (Medtronic), with an AVecor membrane oxygenator (Medtronic), and a Bio-Therm heat exchanger (Medtronic). The activated clotting time is maintained at greater than 200 seconds to prevent thrombus formation in the cannulae. The ECMO can be set up to provide a flow of 4–5 L/minute delivered by a roller-pump system.

Case 1. A 45-year-old male with no significant past medical history experienced sudden onset of substernal chest pain and then had cardiac arrest. A coworker performed cardiopulmonary resuscitation until paramedics defibrillated the patient for ventricular fibrillation. After the patient was intubated, he was taken to the emergency room where he was found to have STEMI accompanied by cardiogenic shock. The patient had recurrent episodes of ventricular fibrillation requiring defibrillation and asystole requiring chest compressions, and was severely hypotensive. He was started on intravenous dopamine and amiodarone. The patient was subsequently transferred to the cardiac catheterization laboratory with a door-to-balloon time of 50 minutes. Coronary angiography demonstrated a 100% thrombotic occlusion of the left anterior descending artery (LAD), severe stenosis of the ostial ramus intermedius branch, non-obstructive disease in the left circumflex artery (LCX), and chronic total occlusion of the proximal right coronary artery (RCA), which was the dominant vessel. An intra-aortic balloon pump was inserted through the left femoral artery.

PCI was performed despite the patient being in asystole requiring chest compressions and multiple defibrillations for ventricular fibrillation. Dobutamine, norepinephrine and lidocaine were also initiated to treat refractory cardiogenic shock and ventricular fibrillation, respectively. Multiple balloon inflations were performed on the LAD. Because of severe diffuse narrowings in the LAD, 3 Mini Vision stents (Abbott Vascular, Abbott Park, Illinois) (2.5 x 23 mm, 2.5 x 28 mm, and 2.75 x 28 mm) were deployed in the LAD in an overlapping fashion. The patient was still extremely unstable with hypotension and recurrent episodes of cardiac arrest requiring chest compressions. The cardiac surgeon was consulted for emergent institution of ECMO. A guidewire was emergently introduced into the right femoral arterial sheath, and the sheath was exchanged for a 17 Fr arterial cannula. After right femoral venous access was obtained, a 25 Fr venous cannula was advanced over a guidewire into the right femoral vein. Total procedure time

to initiate ECMO was less than 10 minutes. After ECMO was initiated, a systolic blood pressure of 90 mmHg was achieved.

After predilatation, a 2.75 x 28 mm Mini Vision stent was deployed in the ostial ramus intermedius, but there was a filling defect consistent with thrombus at the ostium of the LCX. Kissing balloon angioplasty was performed in the ramus intermedius and LCX. Coronary angiography then revealed a filling defect at the ostium of the LAD. Trifurcation kissing-balloon angioplasty was performed in the ostia of the LAD, LCX and ramus intermedius branch, rendering a good angiographic result. However, there was a filling defect consistent with thrombus in the LAD stent that resolved after balloon angioplasty.

The patient maintained good urine output, but echocardiography demonstrated that his left ventricular ejection fraction remained at 20% and did not improve, thus ECMO could not be weaned off. The cardiac index was 1.9, the pulmonary capillary wedge pressure was 22 mmHg, and the patient's mixed venous oxygen saturation was 65%. Ten days after PCI, the patient underwent successful cardiac transplantation. In addition, the ECMO circuit was turned off, and the ECMO cannulae were removed in the operating room. A 5-0 purse-string was placed around the arterial cannulation site after removing the arterial cannula, and the femoral artery was then repaired with sutures. The 5-0 purse-string was also placed around the venous cannulation site after removing the venous cannula, and the femoral vein was repaired with sutures. Good hemostasis was established at the site of the incision. His postoperative course was uneventful, and he was discharged home. At 9-month follow up, the patient continues to do well with no adverse neurologic sequelae.

Case 2. A 65-year-old male with a 3-day history of chest discomfort had a cardiac arrest while being driven by his family to the emergency room. The patient was intubated, and cardiopulmonary resuscitation was performed in the emergency room. Dopamine was started for refractory hypotension, and he was taken emergently to the cardiac catheterization laboratory with a door-to-balloon time of 45 minutes. Coronary angiography revealed a 100% thrombotic occlusion of the proximal LCX, severe diffuse disease of the LAD, and a severe stenosis of the RCA, which was the dominant vessel. An intra-aortic balloon pump was inserted through the left femoral artery.

PCI of the LCX was performed. Thrombolysis in myocardial infarction (TIMI) 2 flow was achieved despite multiple balloon inflations of the LCX. A long, significant stenosis at the first obtuse marginal branch was treated with 3 Vision stents (2.0 x 15 mm, 2.0 x 20 mm, and a 2.5 x 18 mm) in an overlapping fashion. TIMI 3 flow was finally achieved after intracoronary adenosine 500 mcg and nitroprusside 300 mcg were administered in aliquots of 100 mcg. The patient continued to experience ventricular fibrillation which required multiple defibrillations and intravenous lidocaine. After predilatation, 2 Mini Vision stents (2.5 x 15 mm and 2.5 x 12 mm) were deployed in an overlapping fashion in the RCA. The patient went into asystole and cardiopulmonary resuscitation was restarted. Dobutamine and norepinephrine were initiated to treat refractory cardiogenic shock.

The cardiac surgeon was consulted for emergent institution of ECMO. A guidewire was introduced into the right femoral arterial sheath, and the sheath was exchanged for a 17 Fr

arterial cannula. After right femoral venous access was obtained, a 25 Fr venous cannula was advanced over a guidewire into the right femoral vein. Total procedure time to initiate ECMO was less than 10 minutes. The patient's blood pressure promptly increased to 100 mmHg, and sinus rhythm was restored.

In the intensive care unit, the patient maintained good urine output. The cardiac power output was 0.73, the cardiac index was 2.2, the pulmonary capillary wedge pressure was 20 mmHg, and the mixed venous oxygen saturation was 69%. Inotropic agents and ECMO were being weaned off. However, after 4 days of being on ECMO, the patient was not deemed a suitable candidate for cardiac transplantation because of severe anoxic brain injury and lack of neurological recovery. Care was withdrawn and the patient expired.

Discussion. The indications for using ECMO in the care of adult patients is not clearly defined by consensus and varies among institutions. This likely stems from the paucity of prospective, randomized, controlled trials which are practically and arguably ethically difficult to conduct in the setting of acutely ill patients near death. Nevertheless, the literature offers a few retrospective studies and case reports which highlight the potential applications of this technology. While ECMO originally made ground in the treatment of patients with acute, potentially reversible respiratory failure who failed conventional treatment, recent applications have shown ECMO to be potentially effective as a temporizing measure or bridge for therapeutic intervention in the setting of myocardial dysfunction and cardiogenic shock.

ECMO in post-cardiotomy myocardial dysfunction and prolonged, refractory cardiac arrest. Post-cardiotomy myocardial dysfunction occurs in as many as 3–5% of patients undergoing routine cardiac surgical procedures.⁹ Most of these patients can be successfully weaned from cardiopulmonary bypass with inotropes and/or intra-aortic balloon pump use, but approximately 1% of patients require prolonged postoperative circulatory support.^{9,10} In a prospective trial of 219 patients treated with ECMO for refractory postoperative cardiogenic shock, 134 (61%) patients were successfully weaned from ECMO; among those patients, 52 (39%) were successfully discharged from the hospital and of those, 37 (74%) were alive at 5 years with reasonable exercise capacity.¹¹ The predictors of in-hospital survival after initiating ECMO were younger age, absence of preoperative MI, absence of diabetes, use of an intra-aortic balloon pump, and if the surgical procedure performed prior to ECMO involved valve replacement and/or coronary artery bypass surgery.

Other studies have shown support for ECMO in patients with other forms of severe, potentially reversible myocardial dysfunction including myocarditis,¹² cardiomyopathy and prolonged cardiac arrest. Smedira et al analyzed a group of 202 adults who received ECMO for cardiac failure and found survival at 3 days, 30 days, and 5 years to be 76%, 38% and 24%, respectively.¹³ Massetti et al evaluated the outcomes of 40 patients who received ECMO cardiovascular support following prolonged, refractory cardiac arrest.¹⁴ Of the 18 patients who survived after 24 hours, 6 were successfully weaned off ECMO, 9 were bridged to a ventricular assist device and 2 patients were directly bridged to cardiac transplantation; 8 patients (20%) were alive 18 months later. Although ECMO is associated with significant morbidity and mortality, these studies highlight the use of ECMO as a justifiable alternative for patients who

fail to be weaned off cardiopulmonary bypass support and who may otherwise die when conventional therapy fails.

ECMO in planned cardiac catheterization. ECMO is occasionally employed in the cardiac catheterization laboratory. Several case reports and small retrospective studies have looked at the use of ECMO in the setting of PCI among both pediatric¹⁵ and adult high-risk patient populations. Magovern et al evaluated 27 adult patients who underwent planned PCI with ECMO support.¹⁶ The indications for using ECMO in these patients included high-risk patients with unstable angina or congestive heart failure with associated comorbidities including severe left ventricular dysfunction, lung disease, end-stage renal disease, peripheral vascular disease, advanced age, morbid obesity, constrictive pericarditis and terminal metastatic cancer. Revascularization was successful in 26 of 27 patients (96%), with an average of 1.6 vessels revascularized per patient, including 12 patients with left main coronary artery revascularization. Twenty-three of the 27 patients (85%) survived to discharge, and the cause of death in those who did not survive included cardiac arrest (2 patients) and heart failure (2 patients). The risks of PCI supported by ECMO in this high-risk population included significant bleeding at the cannulation site in 1 patient, surgical femoral vessel repair in 6 patients, heart block requiring a permanent pacemaker in 1 patient, MI in 2 patients and low cardiac output in 3 patients.

ECMO in emergent cardiac catheterization. Patients who may benefit from ECMO are those patients without previous heart failure who suffer a profound, acute, and potentially treatable cardiac insult such as MI complicated by cardiogenic shock and recurrent cardiac arrest. ECMO may be considered as a temporizing measure for conventional therapy to work or transplant to occur, as a bridge to another support modality such as a ventricular assist device, or as support during direct intervention, such as coronary revascularization. One advantage of ECMO compared to the TandemHeart percutaneous ventricular assist device (Cardiac Assist, Inc., Pittsburgh, Pennsylvania) during an emergency resuscitation procedure is that ECMO can be implanted expeditiously and simultaneously by a cardiac surgeon while PCI is being performed.

There is a paucity of data with the use of ECMO during emergent cardiac catheterization in the setting of cardiogenic shock secondary to acute MI. In a retrospective review of 36 patients with MI requiring cardiopulmonary resuscitation refractory to conventional therapies necessitating ECMO, PCI was attempted in 11 patients and was successfully performed in 7 patients.¹⁷ Although 4 of those patients were successfully weaned from ECMO after 48 hours, none survived to hospital discharge. In a retrospective analysis of 138 patients, the Cleveland Clinic reported improved in-hospital and 5-year survival in patients with MI complicated by cardiogenic shock who underwent revascularization and circulatory support including the use of ECMO and a left ventricular assist device as a bridge to cardiac transplantation.¹⁸

Complications associated with ECMO. The most common complication associated with ECMO is bleeding, mainly due to systemic heparinization. Severe bleeding after arterial cannulation may require surgical exploration. Treatment with heparin can also lead to thrombocytopenia. Ischemic injury can occur if the arterial cannula compromises perfusion to the lower extremity. Prolonged ECMO support can also predispose the patient to infection, which may necessitate early removal.

Conclusions. Early institution of ECMO in the cardiac catheterization laboratory in patients who present with MI, cardiogenic shock, repeated cardiac arrest and severe hemodynamic instability refractory to inotropic agents and intra-aortic balloon counterpulsation may provide prompt circulatory support. It may also serve as a bridge to heart transplantation to salvage those patients who otherwise have a high mortality rate. In view of the cost and complications of this therapy, ECMO should be subjected to randomized clinical trials that address both the hemodynamic effects and the efficacy of the device on meaningful clinical endpoints prior to widespread use.

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