Emergent Circulatory Support Using ECMO

Using extracorporeal membrane oxygenation during PCI complicated by cardiogenic shock.

BY MICHAEL S. LEE, MD, AND MICHAEL WOLFE, BS

A 42-year-old man with no significant medical history experienced sudden onset of substernal chest pain preceding cardiac arrest while working at a construction site. He received cardiopulmonary resuscitation from a coworker until the paramedics arrived. The patient was defibrillated for ventricular fibrillation, intubated, and transported to the emergency department. Upon arrival, the patient was found to have stent thrombosis (ST)-elevation myocardial infarction (MI) complicated by cardiogenic shock, and he continued to have episodes of ventricular fibrillation requiring numerous defibrillations, asystole necessitating chest compressions, and severe hypotension requiring multiple inotropic agents.

The patient was emergently transferred to the cardiac catheterization laboratory. Coronary angiography was performed, which revealed total thrombotic occlusion of the left anterior descending (LAD) artery (Figure 1), severe stenosis of the ostial ramus intermedius (RI) branch (Figure 2), nonobstructive disease of the left circumflex (LCX) artery, and chronic total occlusion of the proximal right coronary artery with bridging collaterals (Figure 3).

DECISION POINT 1

What Are the Treatment Options?

Data from the SHOCK (Should We Emergently Revascularize Occluded Coronaries for Cardiogenic Shock) trial indicate significant reductions in mortality at 6 months, 1 year, and 6 years in patients who underwent early revascularization as compared with those who received initial medical stabilization with delayed

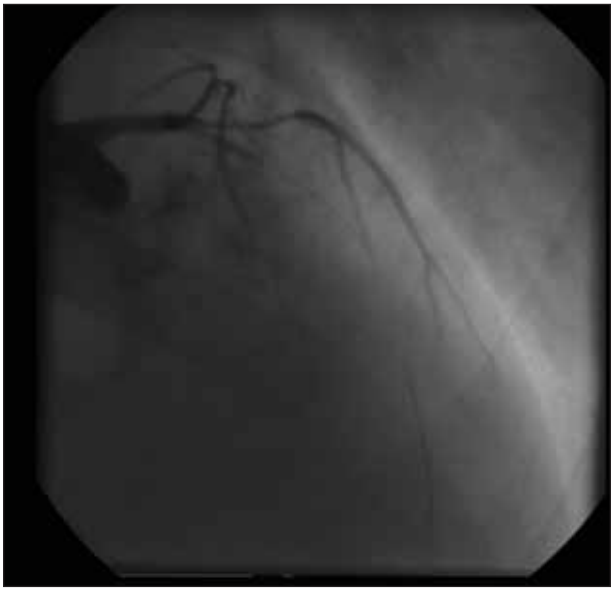

Figure 1. A coronary angiogram reveals total thrombotic occlusion of the LAD.

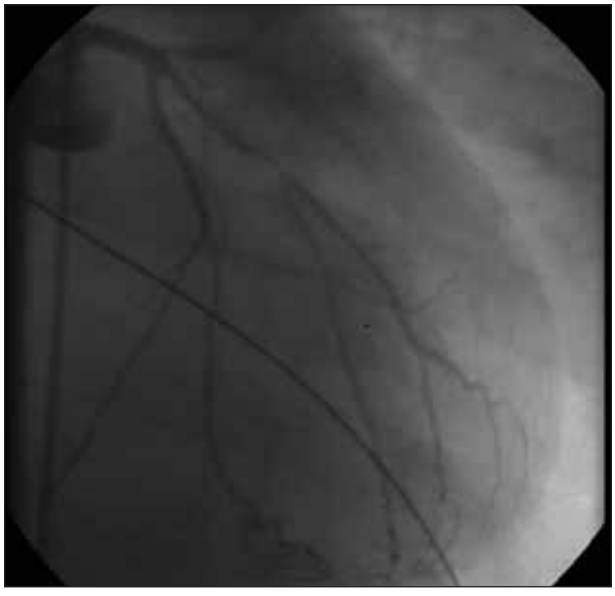

Figure 2. An angiogram showing severe stenosis of the RI branch.

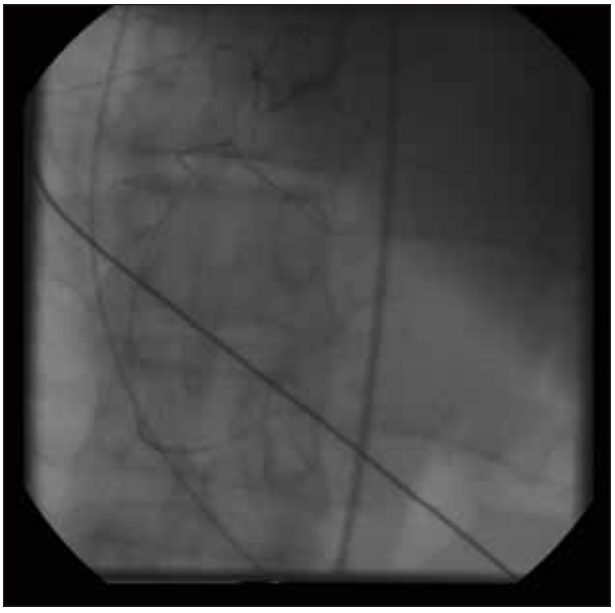

Figure 3. The right coronary artery is totally occluded and has bridging collaterals.

revascularization.[1] Emergent reperfusion is essential, making revascularization with percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG) the primary treatment options.

PCI and CABG have shown similar rates of 1-month and 1-year survival when performed to treat cardiogenic shock secondary to acute MI.[2] Because our patient continued to experience arrhythmic and hemodynamic instability, prompt intervention was performed using multiple balloon inflations of the LAD, with a door-to-balloon time of 50 minutes. PCI was chosen over CABG because it allows for a thrombotic occlusion to be opened more quickly and also prevents potential major complications of CABG, such as infection and stroke. The patient also received three Mini Vision stents (2.5 X 23 mm, 2.5 X 28 mm, and 2.75 X 28 mm; Abbott Vascular, Santa Clara, CA) in the LAD in an overlapping fashion.

Despite the administration of multiple inotropic agents, including dopamine, dobutamine, epinephrine, and norepinephrine, the patient was still hypotensive and remained hemodynamically unstable.

DECISION POINT 2

What Hemodynamic Support Devices Are Available to Manage Cardiogenic Shock?

In cases of cardiac insufficiency resulting in hemodynamic instability, several hemodynamic support devices can be used, including (1) an intra-aortic balloon pump (IABP), (2) the TandemHeart device (CardiacAssist, Inc., Pittsburgh, PA), (3) the Impella Recover LP 2.5 device (Abiomed, Inc., Danvers, MA), and (4) extracorporeal membrane oxygenation (ECMO) (Table 1).

Initial stabilization is often achieved with the use of an IABP. A balloon placed in the aorta inflates during diastole and actively deflates during systole. This moderately increases cardiac perfusion pressure and decreases systolic afterload, respectively, and offers other beneficial outcomes, such as reduced heart rate, left ventricular end-diastolic pressure, and myocardial oxygen use.[3] An IABP was inserted in our patient through the left femoral artery before PCI but was not considered a sustainable option because it was ineffective in achieving hemodynamic and arrhythmic stability and is largely reliant on at least some degree of preserved left ventricular function.[3,4]

The TandemHeart device is a left ventricular assist device (LVAD) that establishes a blood shunt by withdrawing oxygenated blood via an inflow cannula from the left atrium and pumping it to the abdominal aorta via an outflow cannula inserted into the femoral artery. It is inserted percutaneously and thus can be inserted in the cardiac catheterization laboratory. The TandemHeart shares many of the benefits as an IABP but may be more advantageous because it is able to quickly unload the left ventricle and provide hemodynamic support in the setting of left ventricular failure and cardiogenic shock. Increased cardiac output (up to 5 L/min) and tissue perfusion with the TandemHeart increases hemodynamic

TABLE 1. HEMODYNAMIC SUPPORT DEVICES

Devices	Insertion	Oxygenation	Ability to Reverse Cardiogenic Shock
IABP	Percutaneous	No	No
TandemHeart	Percutaneous	No	Yes
Impella	Percutaneous	No	Unclear
ECMO	Surgical	Yes	Yes

Abbreviations: ECMO, extracorporeal membrane oxygenation; IABP, intra-aortic balloon pump.

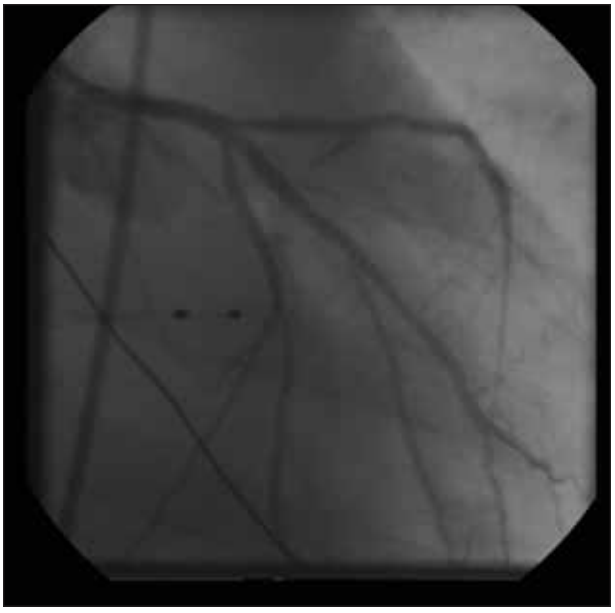

Figure 4. Final angiographic result in the caudal projection.

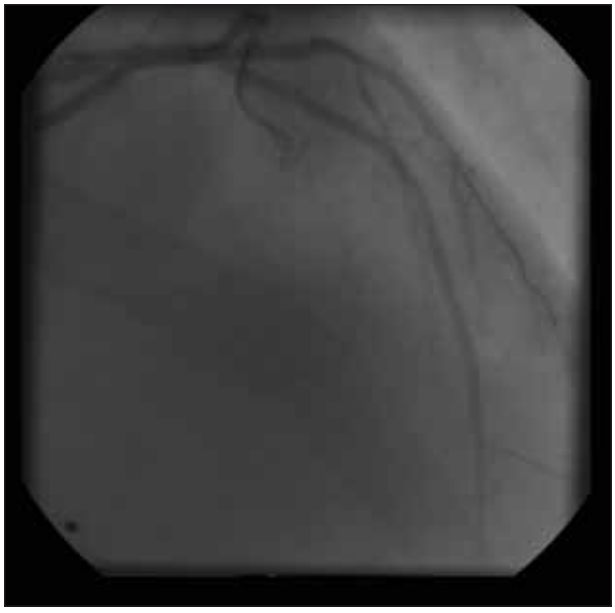

Figure 5. Final angiogram in the anteroposterior cranial view shows excellent results.

stability and has the potential to reverse cardiogenic shock.[4] The disadvantage is that it requires a transseptal puncture, which is a complex procedure that is not performed by many interventional cardiologists.

The Impella Recover device is another LVAD that can be promptly implanted percutaneously and provides rapid unloading of the left ventricle and hemodynamic stabilization. Using a rotary pump, blood is withdrawn from the left ventricle and is actively emptied into the ascending aorta. The Impella pump increases cardiac output up to 2.5 L/min and, in patients experiencing cardiogenic shock, has also been shown to improve mean arterial pressure and reduce pulmonary capillary wedge pressure.[3,4] The ISAR-SHOCK trial compared the use of the Impella with an IABP in treating cardiogenic shock secondary to acute MI. Several hemodynamic benefits were found using the Impella, including a significant increase in cardiac index, as well as increases in diastolic arterial pressure and mean arterial pressure 30 minutes after implantation.[5] Therefore, the Impella device may be considered a reasonable option for patients presenting with acute MI complicated by cardiogenic shock.

ECMO can be instituted to provide cardiac or pulmonary support. There are two main types of ECMO—venovenous and venoarterial. In both forms, blood is taken from the venous circulation, usually through the femoral vein, and is oxygenated outside the body using a membrane oxygenator. In venovenous ECMO, the blood is then returned to the femoral vein, offering respiratory support for patients with preserved left ventricular function. In venoarterial ECMO, blood is returned to the femoral artery. This offers circulatory support for patients with critical hemodynamic instability or during cardiac arrest.[6]

ECMO was emergently instituted in our patient, with a cardiac surgeon completing the procedure in < 10 minutes. Briefly, a 0.038- X 39-inch guidewire was inserted through the arterial sheath in the right femoral artery. The sheath was replaced with a 17-F Bio-Medicus arterial cannula (Medtronic, Inc., Minneapolis, MN) that was then connected to the ECMO machine's arterial tubing. A 0.038- X 71-inch wire was used to guide a 25-F Bio-Medicus femoral venous cannula, which was connected to the ECMO machine's venous tubing. Wolf custom-pack nonheparinized 0.375-inch tubing (Medtronic, Inc.) with an Avecor membrane oxygenator (Medtronic, Inc.) was used to connect the ECMO machine to the patient. After ECMO, the patient's systolic blood pressure reached 90 mm Hg.

DECISION POINT 3

What Are the Ideal Revascularization Strategies for Nonculprit Vessels?

The American College of Cardiology/American Heart Association guidelines recommend prompt PCI of infarct-related arteries in ST-elevation MI because it leads to substantial increases in survival, whereas primary PCI of non-infarct-related arteries is contraindicated for patients who are hemodynamically stable.[7] However, in high-risk patients with cardiogenic shock, total revascularization may be considered, although it is unsupported by clinical

data. Thus, PCI of nonculprit arteries may be reasonable in the setting of ongoing cardiogenic shock.

Because our patient was still in cardiogenic shock, PCI was performed on the large RI branch. After predilatation, a 2.75- X 28-mm Mini Vision stent was deployed in the ostial RI. However, a filling defect indicative of thrombus in the LCX was seen, thus kissing balloon angioplasty was performed in these branches. Subsequent angiography revealed a filling defect in the ostium of the LAD, which was treated with trifurcation kissing balloon angioplasty of the LAD, LCX, and RI (Figure 4). Another filling defect indicative of a thrombus in LAD was effectively treated with balloon angioplasty. Final angiography showed patent arteries with TIMI grade 3 flow (Figure 5). PCI of the right coronary artery occlusion was not attempted given the risk of contrast-induced nephropathy in the setting of cardiogenic shock.

DECISION POINT 4

After Revascularization, What Treatment Options Exist?

Despite successful reperfusion of the infarct-related artery, the ECMO could not be weaned off due to persistent poor cardiac output. Attempts should be made to wean patients off ECMO within the first 7 to 10 days. Longer duration of therapy may increase the risk of infection and bleeding-related complications. Echocardiography revealed an ejection fraction of 20%, which did not improve. Although orthotopic heart transplantation is more frequently used in cases of chronic heart failure, it has proven to be very effective for the treatment of acute heart failure, including those who experience cardiogenic shock secondary to MI.[8] However, maintaining the patient until a donor heart becomes available often presents a challenge.

The expeditious implementation and use of LVADs or ECMO as a bridge support until longer-term solutions such as transplantation can be performed is vital in patients who do not improve despite revascularization and who remain in cardiogenic shock. Our patient remained on ECMO for 10 days until transplantation could be performed. After transplantation, ECMO was removed. At 3-year follow-up, the patient continued to do well.

CONCLUSION

Because cardiogenic shock is the leading cause of death in cases of acute MI, prompt and aggressive treatment is essential. Current strategies mainly focus on revascularization, but mortality rates still remain unacceptably high, especially in cases of MI complicated by cardiogenic shock. Active hemodynamic support offers a means to maintain a patient until the heart recovers or transplantation can be performed. The preceding case illustrates the successful use of one form of hemodynamic support, ECMO, which can be rapidly established in cardiogenic shock patients requiring circulatory support. Although the use of ECMO in cases of pump failure is not entirely novel, a consensus for its use, especially in such emergent cases as cardiogenic shock secondary to MI, has not been established. However, in our case, ECMO was used successfully in a patient who presented with out-of-hospital cardiac arrest and continued to have severe hemodynamic and arrhythmic instability. ECMO not only provided initial hemodynamic support, allowing for a high-risk PCI, but also acted to bridge the patient to successful transplant surgery. ■

"Active hemodynamic support offers a means to maintain a patient until the heart recovers or transplantation can be performed."

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