

Extracorporeal Membrane Oxygenation-Assisted Percutaneous Coronary Intervention in Extremely High-Risk Patients

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To the Editor: High-risk percutaneous coronary intervention (PCI) remains a viable revascularization strategy for patients who refuse or are not suitable for surgery.^[1] Extracorporeal membrane oxygenation (ECMO) can direct blood flow from the body, oxygenate it, and then return it, thus completely or partially replacing the function of the heart and lungs and increasing the likelihood of functional recovery.^[2] Selective PCI supported by ECMO is a viable alternative for patients who are at very high risk for coronary artery bypass grafting (CABG).^[3] A previous study found that ECMO-assisted PCI for patients with acute myocardial infarction complicated by profound cardiogenic shock might have improved 30-day and 1-year survival rates,^[4] and we believe that ECMO is a viable mode of hemodynamic support in high-risk cases.

Our hospital has used ECMO in critically ill patients with aortic dissection or acute myocardial infarction and has achieved good results. The departments of anesthesia and heart surgery in our hospital cooperate to combine ECMO with primary PCI for treatment of patients with acute myocardial infarction complicated by cardiogenic shock, and have completed seven cases to date, among which four have survived. This new application exhibits a higher survival rate than that achieved with intra-aortic balloon counterpulsation (IABP)-assisted PCI.

Case 1: A 52-year-old man was admitted due to precordial pain for 5 h. He denied a previous history of hypertension and diabetes but had a more than 30-year smoking history. The electrocardiogram (ECG) showed 0.2–0.5-mV ST elevation in V1–V4, and a qR in II, III, and aVF. After admission, the patient's status rapidly deteriorated. The chest pain continued, breathing difficulty gradually developed, blood pressure (BP) dropped to 70/40 mmHg (1 mmHg = 0.133 kPa), and blood oxygen saturation (SpO₂) decreased to 82%. The diagnosis was myocardial infarction complicated by cardiogenic shock, IABP was implanted, and dopamine was administered. The patient remained hemodynamically unstable and had frequent episodes of ventricular tachycardia. The patient then underwent IABP- and ECMO-assisted emergency coronary angiography, which showed multiple coronary lesions and acute occlusion of the anterior descending branch. A stent was successfully implanted, and 7000 U of heparin was given. The patient recovered consciousness 3 h later, and the ECMO flow rate was reduced to 1000 ml/min

7 h later, 500 ml/min 10 h later, and was gradually weaned 12 h later. The hemodynamics stabilized, and he was discharged 9 days after surgery.

Case 2: A 67-year-old man was admitted due to persistent precordial pain combined with nausea and vomiting for more than 1 h. This patient developed sudden precordial pain without obvious cause 1 h before admission. He had a history of hypertension but did not smoke. The ECG revealed the arch of the R-wave and 0.2–0.5-mV ST elevation in II, III, aVF, V7–V9, and V3–V5, with second-degree atrioventricular block. Real-time ECG revealed weak left ventricular and posterior wall motion and an ejection fraction (EF) of 42%. With the diagnosis of cardiogenic shock, IABP, and a temporary pacemaker was implanted, with concurrent successful right coronary artery stenting. After surgery, cardiac function continued to deteriorate, wet rales appeared, and the SpO₂ decreased. Mechanical ventilation and percutaneous ECMO were initiated. The patient was hemodynamically stable, and ECMO was discontinued after 18 h of adjuvant treatment. Anticoagulant and antiplatelet drugs were continued, heart function improved, and the patient was discharged 24 days after admission with overall improvement.

Case 3: A 67-year-old man was admitted with sudden-onset chest pain for 5 h and loss of consciousness for 40 min. The patient had a 10-year history of diabetes, hypertension for 3 years, and a history of smoking. He underwent elective PCI due to an anterior myocardial infarction 3 years before admission, with stent implantation in the anterior descending branch and right coronary artery. After admission, he was sent directly to the Department of Cardiology for emergency PCI. However, after transport to the operating room, he developed sudden ventricular fibrillation. Cardiopulmonary

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resuscitation (CPR) was performed, vasopressors were given, and acidosis was corrected. Sinus rhythm was restored. Examination showed BP 70/45 mmHg, moist and cool skin, diffuse wet rales, distant heart sounds, a soft abdomen, and lower extremities without edema. Emergency echocardiography showed left atrial size 33 mm, left ventricular size 49 mm, and decreased wall motion. The RCA was considered responsible for the myocardial infarction, and emergency PTCA was performed. The postoperative blood flow recovered to thrombolysis in myocardial infarction (TIMI) level 3. The patient received postoperative ECMO support was improved by the next day, and was able to communicate; tracheal intubation was removed. After 3 days of ECMO support, the flow was gradually weaned off, but the patient remained on IABP support. Follow-up color Doppler revealed EF 39%. However, the patient subsequently developed a pulmonary infection and acute renal failure and died of multiple organ failure 9 days after admission.

Case 4: A 68-year-old man was admitted due to intermittent precordial pain for 6 years, with worsening for 7 h before admission. The patient had a history of hypertension for more than 10 years. He was diagnosed with type 2 diabetes mellitus (T2DM) 6 years prior, with poor blood glucose control, and had smoked for more than 40 years. On admission, he had slightly cyanotic lips, no jugular venous distension, coarse breath sounds, but no dry or wet rales. The diagnosis was coronary heart disease, Killip Grade 1, with acute lateral wall myocardial infarction, T2DM, and primary hypertension (very high risk). The patient underwent emergency intervention for the circumflex branch, but it was still difficult to implant a stent. The patient received simultaneous intervention for the anterior descending circumflex branch, and a stent was implanted in the circumflex branch, anterior descending branch, and diagonal branch. Routine anticoagulation and antiplatelet therapy were performed, but chest pain recurred 3 days after surgery. The ECG showed ST elevation in anterior and posterior leads and was thought to have subacute in-stent thrombosis. ECMO was initiated at a flow rate of 4000 ml/min and rotation speed of 3900/min. ECMO-assisted coronary angiography revealed in-stent thrombosis in the anterior descending branch, and the lumen was 100% occluded; an embolus shadow was observed in the circumflex branch, with TIMI level 3 blood flow. After intervention for the anterior descending branch, angiography showed TIMI level 3 blood flow. The patient had intermittent postoperative consciousness recovery but eventually died of multiple organ failure.

Case 5: A 62-year-old woman was admitted to the intensive care unit for mechanical ventilation due to intermittent precordial discomfort for more than 2 years and wheezing for 2 h. The patient had a history of hypertension for 16 years. The patient denied a history of diabetes, had right ovarian resection more than 20 years prior, and did not drink alcohol or smoke. The heart was enlarged, but auscultation was unremarkable. Initial myocardial marker levels were normal but were significantly increased after admission. The diagnosis was cardiogenic shock, acute myocardial infarction, respiratory failure, pneumonia, hypertension Grade 3, very high risk, sequelae of cerebral hemorrhage, and unilateral ovariectomy. After admission, IABP was implanted and ECMO was initiated at a flow rate of 2800 ml/min and rotation speed of 3000/min. Emergency angiography revealed 3 lesions. The RCA and circumflex artery exhibited chronic occlusion. The postoperative RCA and circumflex artery achieved Grade 3 blood flow. Postoperative ECMO-assisted flow was adjusted according to cardiac function, and ECMO was removed 2 days later, with IABP removed 5 days later, when the vital signs were stable. The

patient underwent bypass surgery 6 weeks later for multiple lesions and recovered well.

Case 6: A 43-year-old woman was admitted due to sudden chest pain with diaphoresis for 2 h. The patient denied a previous history of hypertension or diabetes and did not smoke. On admission, she was unconscious, with diffuse diaphoresis, cyanotic lips and skin, absent pulse and BP, jugular venous distension, and scattered wet rales. Despite immediate IABP implantation and tracheal intubation, so simultaneous ECMO and primary PCI were planned. Coronary angiography revealed thrombosis in the left main stem, TIMI level 0 blood flow in the anterior descending branch and TIMI level 1–2 blood flow in the circumflex branch. The postoperative cardiac function was restored, but at postoperative 50 h, the limb with implanted ECMO became pale, and the skin temperature decreased. Ultrasound revealed that lower limb blood flow was occluded, and ECMO was removed. Hemodynamic stability could not be maintained, and the patient died of heart failure.

Case 7: A 68-year-old man was admitted due to sudden chest pain for 2 h. The patient had a history of hypertension, diabetes, and smoking. Emergency ECG showed ST elevation in V1–V5, with ST-segment depression in other leads. The diagnosis was acute anterior myocardial infarction, Grade 3 hypertension, very high risk, and T2DM. After admission, the patient developed wheezing and diaphoresis. Real-time ultrasound revealed acute left anterior myocardial infarction, with EF 33%. Emergency angiography revealed 3 lesions. After embolus aspiration and PTCA, the blood pressure was restored to TIMI level 3. ECMO was maintained for 7 days, and was gradually weaned and successfully removed. Nine days after surgery, tracheal intubation was removed, and after a 4-week postoperative recovery, the patient underwent CABG with good results.

The common feature in these seven patients was acute coronary syndrome. Hypertension was present in six cases, diabetes mellitus in five, old myocardial infarction in two (28.6%), and cerebral hemorrhage in one. The seven patients all developed cardiogenic shock or sudden cardiac death, three underwent CPR, and all seven underwent invasive mechanical ventilation and ECMO-assisted PTCA. Coronary angiography revealed multiple lesions, but the infarct-related vascular opening rate reached 100%, and all patients achieved TIMI level 3 blood flow.

Of the seven patients, four lost consciousness in the acute phase. As these patients have a high mortality rate, time is critical and only maintenance of vital signs can provide an opportunity for additional life support measures. ECMO can provide good life support and an opportunity for emergency PCI. The seven patients achieved successful emergency PCI under the assistance of ECMO, and three survived (the survival rate was 57.1%). Among the three deaths, two had a history of old myocardial infarction and very poor heart function. Of the two patients who died of multiple organ failure, one died of cerebral hemorrhage, and one died of heart failure, with no intervention-related deaths. Acute myocardial infarction is life-threatening, especially in the early stage. Timely opening of infarct-related blood vessels is the key to treatment, and many studies have confirmed that implementing emergency PCI as early as possible can reduce mortality in patients with ST-elevation myocardial infarction by at least 25%.^[5] Patients with established cardiogenic shock are unstable, with acid-base imbalance, increasing the risk of emergency intervention. Some studies have reported clear benefit with ECMO in severe myocarditis, acute myocardial infarction, and cardiogenic shock, compared with other rescue treatments.^[6–8] Therefore, ECMO assistance can be

used during interventional treatment to quickly achieve stability, thus gaining time for further treatment and successful intervention surgery.

Our ECMO implantation selected V-A mode, with catheterization in the inferior vena cava and descending aorta; the blood in the inferior vena cava was directly pumped into the descending aorta through the centrifugal pump, and the heart load was reduced. With the flow rate set at about 3000 ml/min, heart work can be assisted by about 70%. However, because the blood flow through the heart is reduced, the coronary blood supply is likely to be affected, and concurrent IABP support is needed, even though the IABP parameters do not change. It is noteworthy that among the four patients with loss of consciousness, three died, but the patients without loss of consciousness all survived, suggesting that the timing of ECMO intervention is very important. Once irreversible organ dysfunction occurs, ECMO will not achieve good results. Other research^[7] also emphasized the importance of ECMO implantation timing, which can have a great impact on prognosis. In conclusion, the study showed that implantation of ECMO resulted in a 100% success rate for emergency intervention, thus providing a strong likelihood of rescue. However, we only experienced seven patients; not only was the case number relatively small, but three deaths occurred among seven patients. Peripheral vascular disease can coexist with coronary heart disease. However, the diameter of an ECMO catheter is about 7 mm, which may impair limb blood supply after implantation. If ECMO implantation is likely to cause serious limb ischemic damage, additional catheterization should be performed to create a lateral path for prevention of lower limb ischemia. At the same time, the postoperative limb blood supply must be closely monitored. In addition, the status of each patient should be carefully monitored during ECMO-assisted surgery, with intraoperative anticoagulation, prevention of infection, and maintenance of limb blood supply. ECMO-anticoagulant therapy is currently adjusted according to the activated clotting time, but when a patient develops circulatory and respiratory failure, the metabolic state may be different from that under normal conditions. Therefore, the management of anticoagulant therapy during ECMO should also be further explored.

Declaration of patient consent

This study was conducted in accordance with the *Declaration of Helsinki*. This study was conducted with approval from the Ethics Committee of the People's Hospital of Xinjiang Uygur Autonomous

Region. The authors certify that they have obtained all appropriate patient consent form. In the form, the patients have given their consent for his images and other clinical information to be reported in the journal. The patients understand that their name and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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