

Extracorporeal Membrane Oxygenation in Stanford Type A Aortic Dissection

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Summary

The aim of this study was to summarize the clinical experience of postoperative extracorporeal membrane oxygenation (ECMO) support in Stanford type A aortic dissection (STAAD) patients.

We retrospectively reviewed 246 consecutive acute STAAD patients undergoing operations at our institution from January 2012 to December 2016. Postoperative ECMO was used in 7 patients. There were 5 males and 2 females with a mean age of 43.1 ± 9.3 years. All 7 patients with acute STAAD underwent ascending aorta replacement and total arch repair with a self-designed stent graft (Micropart Corp, Shanghai, China). Concomitant procedures were aortic root replacement in 1 patient and coronary artery bypass grafting (CABG) in 2 patients. All patients received veno-arterial ECMO through the femoral artery and vein. Five patients were extubated before being removed from ECMO. The mean ECMO supporting time was 244.5 ± 57.8 hours. All 7 patients were successfully weaned from ECMO support, and 6 (85.7%) patients survived to discharge. The average hospital time was 26.3 ± 8.8 days. One patient died of cardiac arrest after being weaned from ECMO. Two patients underwent reoperation for bleeding and 1 patient showed transient delirium. The remaining patients all survived during a median follow-up of 19 months.

ECMO provides a good temporary cardiopulmonary support in STAAD patients with refractory cardiogenic shock after surgery for aortic dissection. The early use of ECMO and preventing its complications actively can improve the patient survival rate.

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Key words: Coronary involvement, Low cardiac output syndrome

Low cardiac output syndrome (LCOS) is a major complication after cardiac surgery, especially in patients with preoperative heart failure or cardiogenic shock.¹⁻³⁾ In Stanford type A aortic dissection (STAAD) patients, LCOS is a serious complication after aortic surgery for 3 reasons: first, poor intraoperative myocardial protection can lead to myocardial stunning from myocardial ischemia or ischemia/reperfusion injury and a decrease in myocardial contractility, resulting in severe LCOS; second, the coronary artery can be affected by the aortic dissection and result in coronary ischemia, which potentially leads to severe myocardial damage; and finally, chronic atherosclerotic coronary artery disease can be undetected in emergency situations in some patients. It may be difficult to wean these patients from cardiopulmonary bypass (CPB) with large-dose inotropes. Extracorporeal membrane oxygenation (ECMO) support offers a temporary hemodynamic support for those patients with refractory cardiogenic shock after aortic surgery. We reviewed our 5-year experience regarding postoperative ECMO use in STAAD patients.

Methods

We retrospectively reviewed 246 consecutive acute STAAD patients who underwent operations at our institution from January 2012 to December 2016. Postoperative ECMO was used in 7 patients. The preoperative details of all 7 patients who used ECMO are summarized in Table I. There were 5 males and 2 females with a mean age of 43.1 ± 9.3 years. Four patients were initially misdiagnosed as having acute coronary syndrome. Three of these 4 patients underwent coronary angiography and coronary stent implantation, however, the chest pain could not be relieved after the stent implantation. Finally, computed tomography angiography (CTA) confirmed the diagnosis of STAAD, and the patients were transferred to our hospital. The other patient was misdiagnosed with an acute myocardial infarction after symptom onset, and was transferred to a local county hospital at first. Cardiopulmonary resuscitation was performed for the sudden onset of cardiac arrest in the ambulance. On day 6, she was transferred to a local city hospital due to persistent chest pain.

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Table I. Preoperative Data (*n* = 7)

Case No.	Gender	Age	Smoking	Hypertension (year)	Diabetes mellitus	CK-MB (IU/L)	ECG changes	Onset to hospital time (hour)	Onset to surgery time (hour)	Site of PCI
1	F	35	Y	5	N	1.4	Y	120	125	N
2	M	39	Y	3	N	10.5	N	7	11	N
3	M	37	N	3	N	19.4	Y	72	76	RCA
4	F	52	N	3	N	4.9	Y	36	42	RCA
5	M	56	Y	5	N	2.2	N	48	54	N
6	M	36	Y	-	N	1.8	N	36	40	N
7	M	42	Y	4	N	151.0	Y	22	24	RCA
Mean \pm SD		43.1 \pm 9.3				27.3 \pm 54.9		48.7 \pm 31.4		53.1 \pm 31.9

CK-MB indicates creatine kinase- MB fraction; RCA, right coronary artery; ECMO, extracorporeal membrane oxygenation; ECG, electrocardiogram; PCI, percutaneous coronary intervention; Y, Yes; and N, No.

Magnetic resonance imaging (MRI) confirmed the diagnosis of STAAD, and she was transferred to our hospital. The remaining 3 patients were directly diagnosed with acute STAAD at a local hospital and transferred to our hospital. All 7 patients underwent emergent surgery. During surgery, the blood cardioplegic solution (4°C, modified ST. Thomas solution) was administered antegradely through the coronary ostium in 6 patients and retrogradely plus antegradely through the nondissected left coronary ostium in 1 patient. Cardioplegic solution was reinfused every 30 minutes. The first infusion volume was 20-30 mL/kg. After the first infusion, the volume was 15-20 mL/kg in each infusion. A thin layer of ice slush was placed over the anterior surface of the heart for additional protection. All patients received veno-arterial ECMO through the femoral artery and vein because of the LCOS. To prevent lower extremity ischemia, a 2-cm Dacron side-graft (diameter 8 mm) to the femoral artery served as an arterial cannulation site. ECMO blood flow was maintained at 2000-3000 mL/minute. We monitored the activated clotting time (ACT) to maintain a value of 160 to 200 seconds. From the third day after ECMO support, we regularly monitored platelet count and recruited platelets if necessary. When reaching the removal criteria, ECMO was removed at bedside. The wound was primarily repaired.

In our series, the indications for ECMO use were: (1) dopamine > 20 ug/kg/minute and epinephrine > 0.2 ug/kg/minute, still unstable hemodynamics (SBP < 100 mmHg, MAP < 60 mmHg) and decreased urine volume; and (2) intraoperative esophageal echocardiography showed the ventricular wall motion was significantly decreased.

Criteria for ECMO removal: When the ECMO blood flow was reduced to 1500 mL/minute, and lasted for 2 hours, a patient was deemed weanable if they met the following criteria: (1) the transthoracic echocardiography showed good ventricular motion and the left ventricular ejection fraction (LVEF) was more than 45%; (2) dopamine < 10 ug/kg/minute and epinephrine < 0.1 ug/kg/minute; (3) the patient's hemodynamic status remained stable; and (4) peripheral perfusion was good.

Results

The postoperative details of all 7 patients who used

ECMO are summarized in Table II. All 7 patients with acute type A dissection underwent ascending aorta replacement and total arch repair with a stent elephant trunk.¹⁾ Concomitant procedures were aortic root replacement in 1 patient and coronary artery bypass graft (CABG) in 2 patients. ECMOs were placed in 6 patients during the operation and in 1 patient for severe LCOS on the first day after the operation. Two of 3 patients underwent percutaneous coronary intervention (PCI) prior to CABG; 1 patient who underwent PCI earlier did not undergo CABG because of a patent stent and well-functioning right ventricle. However, ECMO was instituted for the severe LCOS on the first post-operation day. The other patient who was diagnosed with STAAD with coronary involvement could not undergo CABG in the surgery because the right coronary artery was completely occluded and the lumen could not be visually confirmed after cutting. After the aortic surgery, right heart function was severely impaired and stable hemodynamics could not be maintained so ECMO became the last option to assist the right heart function. ECMO was used in the other 3 patients for agnogenic LCOS. Five patients were extubated within 7 days, which was earlier than the ECMO removal. Among these 5 patients, the minimum duration of extubation was 27 hours. The remaining 2 patients were extubated 288 and 357 hours, respectively, after the ECMO removal. The ECMO supporting time was 244.5 \pm 57.8 hours. All 7 patients were successfully weaned from ECMO support. In one patient, pericardial effusion was observed on the second day after the removal of ECMO by echocardiography. When preparing for drainage pericardiotomy under general anesthesia, the anesthesiologist noticed the intubation to the esophagus was incorrect. Cardiac arrest occurred during the tracheal intubation, and then the incorrect tube position was discovered and corrected. Despite successful cardiac resuscitation, the patient did not regain consciousness and suffered brain death. The patient's family abandoned the treatment. The 6 (85.7%) other patients survived to discharge. The average hospitalization time was 26.3 \pm 8.8 days. Two patients had renal failure requiring continuous renal replacement therapy (CRRT). Two patients underwent reoperation for bleeding and 1 patient showed transient delirium. No patient experienced lower leg ischemia or severe neurological complications. The remaining patients all survived during a me-

Table II. Postoperative Data ($n = 7$)

Case No.	Concomitant procedures	Method of myocardial protection	ACC time (minutes)	CPB time (minutes)	Timing of ECMO implantation	Intubation time (hour)	Peak CK-MB (IU/L)	ECMO time (hour)	Complications	Outcome
1	-	Antegrade plus retrograde	115	239	during the operation	27	3.2	295	-	survival
2	Bentall procedure	Antegrade	131	198	during the operation	129	68.3	332	transient delirium	survival
3	CABG	Antegrade	148	264	during the operation	288	2.1	281	reoperation for bleeding	survival
4	CABG	Antegrade	153	258	during the operation	161	4.0	186	reoperation for bleeding	survival
5	-	Antegrade	104	161	during the operation	357	3.0	220	renal failure	survival
6	-	Antegrade	100	134	during the operation	110	6.0	186	-	survival
7	-	Antegrade	101	147	postoperative day 1	189	5.7	211	renal failure	mortal
Mean \pm SD			121.7 \pm 22.4	200.1 \pm 54.3		180.1 \pm 111.3	13.2 \pm 24.3	244.5 \pm 57.8		

ACC indicates aortic cross-clamp; CK-MB, creatine kinase- MB fraction; CPB, cardiopulmonary bypass; CABG, coronary artery bypass grafting; and ECMO, extracorporeal membrane oxygenation.

dian follow-up of 19 months.

Discussion

Postoperative ECMO as a temporary assist device has been widely used in cardiovascular surgeries to provide ventricular and respiratory support. LCOS or cardiogenic shock was the main reason for using this supporting device. Several studies have demonstrated mortality rates from 50% to 70% among patients who required ECMO support.^{1,2)} For STAAD patients with LCOS, ECMO may be the only choice because the residual dissected thoracoabdominal aorta excludes the consideration of an intra-aortic balloon pump.³⁾ In our series, there were 7 of 243 patients who used ECMO for different reasons and had good outcomes.

In patients with acute myocardial infarction (MI), primary PCI is the most effective myocardial reperfusion therapy. In addition, patients who are diagnosed with ST-segment elevation myocardial infarction (STEMI) often undergo urgent primary PCI. However, these patients may actually have an aortic dissection. The incidence of aortic dissection manifesting as STEMI was 1.3% in patients who received primary PCI.⁴⁾ Actually, most cases were aortic dissection disease that involved the coronary arteries. Type A aortic dissection with coronary artery involvement often leads to myocardial ischemia, which is a negative prognostic factor of aortic dissection. Several studies have demonstrated surgical mortality rates from 20.0% to 33.3% among STAAD patients with coronary involvement.⁶⁻⁸⁾ The right coronary artery is more frequently affected than the left coronary artery, which results in postoperative right ventricular dysfunction. Early coronary revascularization may be necessary to reduce the area of the myocardial necrosis and minimize the risk of LCOS.

In our series, the coronary ischemia caused by STAAD was the main reason for using ECMO. Fifteen patients in the whole cohort (ratio 6.5%) were diagnosed with STAAD combined with coronary involvement, including 4 patients (ratio 0.4%) misdiagnosed as having acute MI. The right coronary artery was affected in all patients. Thirteen patients underwent CABG during the aortic surgery. Among these 4 misdiagnosed patients, 2 underwent PCI after the door-to-balloon time had exceeded 8 hours at a local hospital. After the aortic surgery and CABG, ECMO was used to assist right heart function and to allow the myocardium to recover. One patient who underwent PCI earlier did not receive CABG due to the patient stent and well-functioning right ventricle. However, ECMO was instituted due to severe LCOS on the first post-operation day. One patient could not undergo CABG for complete occlusion of the right coronary artery. After the surgery, right heart function was severely impaired and stable hemodynamics could not be maintained so ECMO became the last option. In the end, 3 patients survived after the use of ECMO, 1 patient died of cardiac arrest after the removal of ECMO, and the other 11 patients who were diagnosed with STAAD combined with coronary involvement without the use of ECMO all survived. The mortality rate of this group of patients was 6.67%. In our experience, the ECMO can improve the patient survival rate in STAAD patients who also have coronary involvement.

Poor myocardial protection was another reason for using ECMO in the study. Three other patients underwent ECMO for LCOS with unknown etiology. It is worth noting that chronic atherosclerotic coronary artery disease was undetected in emergency situations in some patients, which can also result in poor myocardial protection and affect the recovery of postoperative cardiac function. Two

of these 3 patients were less than 40 years old. The risk of coronary heart disease occurring in these young patients was low, although the coronary arteries were not examined. Therefore, we believe the postoperative LCOS was caused by poor myocardial protection. Recovery was possible by using ECMO wisely. ECMO had the advantages of easy application and feasibility, stabilization of the hemodynamics, and it provided a therapeutic window to rescue the stunning myocardium. Fortunately, these 2 patients survived after using ECMO. The other patient had LCOS after the surgery with unknown etiology and was 59 years old and survived after ECMO was used.

Although the mean age of patients with STAAD was 62 ± 14.6 years in the International Registry of Acute Aortic Dissection (IRAD),⁹⁾ there is a disparity between IRAD and China. The patients with STAAD in China had an earlier onset. The mean age of the patients with STAAD in the Registry of Aortic Dissection in China (Sino-RAD) was 50.5, which is significantly younger than those in IRAD.^{10,11)} In our series, the mean age of the 7 patients was 43.1 ± 9.3 years, which is younger than usual. We speculate that this might be associated with poor health awareness. Additionally, racial differences and inadequate medical consultation should also be considered.¹⁰⁾

In our series, the femoral artery served as an arterial cannulation site for the ECMO arterial cannula. Femoral cannulation is easier and faster to perform when the patient is suffering from an unstable hemodynamic condition. A 2-cm Dacron side-graft (diameter 8 mm) was anastomosed to the femoral artery cannulation site to avoid lower limb ischemia. In the series, no patient experienced lower leg ischemia.

Careful postoperative management is also critical to the survival of patients receiving ECMO. In most medical centers, patients are usually kept mechanically ventilated and sedated while receiving ECMO support.^{3,5,12)} On the contrary, our ECMO patients were encouraged to be extubated as soon as possible, which showed 3 advantages: First, early extubation will contribute to reducing the incidence of ventilator associated complications; Second, after extubation the confidence of the patient will be increased dramatically; and finally, oral feeding will increase appetite and be beneficial for administration of nutritional supplements. In our series, 5 patients were extubated before ECMO removal. With the exception of the 1 patient who died after reintubation of the trachea, the other 4 patients survived. Meanwhile, we regularly monitored activated clotting time and platelet count. Bleeding continues to be a major complication of ECMO support.³⁾ From the third day after ECMO support, we regularly monitored platelet count and maintained it at $50 \times 10^9 \sim 350 \times 10^9/L$ by recruiting platelets as necessary. In our series, there was no fatal complication caused by bleeding. Therefore, strict postoperative management is crucial to improve the pa-

tient survival rate.

Conclusions

ECMO provides a good temporary cardiopulmonary support in STAAD patients with refractory cardiogenic shock after surgery for aortic dissection. The early use of ECMO and active prevention of its complications can improve the patient survival rate.

Disclosures

Conflicts of interest: The authors declare there are no conflicts of interest.

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