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Extracorporeal membrane oxygenation for refractory cardiogenic shock after cardiac surgery: predictors of early mortality and outcome from 51 adult patients

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Abstract

Objective: Extracorporeal membrane oxygenation (ECMO) offers temporary haemodynamic support for those with refractory cardiogenic shock after cardiac surgery. We review our 5-year experience regarding ECMO use on those who cannot be weaned from cardiopulmonary bypass after cardiac surgery. We analyse our cases, predict the prognostic factors of survival and compare the short-term and medium-term results. **Methods:** From January 2002 to December 2006, 1764 patients underwent cardiac surgery with cardiopulmonary bypass in our division. Among these, 51 patients (2.9%) required venoarterial-mode ECMO for haemodynamic support because of refractory postcardiotomy cardiogenic shock. The indication of ECMO was refractory cardiogenic shock despite adequate filling volumes, large-dose inotropes and intra-aortic balloon pump support. The following cardiac surgical procedures were performed: coronary artery bypass grafting (CABG), $n = 27$; valvular surgery, $n = 11$; CABG plus valvular surgery, $n = 7$; heart transplantation, $n = 4$ and other procedures, $n = 2$. **Results:** Average age was 63.0 ± 15.7 years. There were 36 male and 15 female patients. Average duration of ECMO was 7.5 ± 6.7 days. Twenty-seven (53%) patients could be successfully weaned from ECMO. The 30-day and 3-month mortalities were 49% (25/51) and 65% (33/51). The in-hospital mortality was 67% (34/51 patients). Seventeen (33%) patients could be successfully discharged. Fifteen (29%) patients were still alive at 1-year outpatient department (OPD) follow-up. **Conclusions:** ECMO provides a good temporary cardiopulmonary support in patients with postcardiotomy shock. The preoperative risk factors of failure to withdraw ECMO are poor left-ventricular ejection fraction, systolic blood pressure <90 mmHg and refractory severe metabolic acidosis. The peri-ECMO predictors of mortality include low serum albumin level, low platelet count, low oxygen pressure of the venous tube of the ECMO and poor cardiac systolic function.

Keywords: Extracorporeal membrane oxygenation; Postcardiotomy syndrome; Cardiogenic shock; Intra-aortic balloon pump; T-graft peripheral cannulation

1. Introduction

The incidence of postcardiotomy myocardial dysfunction is about 3—5% after cardiac surgical procedures [1]. The majority of these patients could be weaned from cardiopulmonary bypass with inotropes or intra-aortic balloon counterpulsation [1]. Despite the abovementioned treatments, 1% of these patients still had refractory cardiac and/or pulmonary dysfunction and needed advanced mechanical circulatory support [2,3]. Centrifugal pumps or pneumatic pulsatile pumps are practicable for these critical patients [4,5]. Extracorporeal membrane oxygenation (ECMO) is another treatment modality for temporary mechanical circulatory support. The first successfully employed venoarterial (V-A) ECMO was reported in 1972 for a shock lung syndrome [6]. Because of the advancement of medical technology, several studies have reported the successful use of ECMO for temporary circulatory support in patients with refractory heart failure [3,7—10]. The purpose of this study was to evaluate the early, short-term and middle-term outcomes after ECMO support for postcardiotomy cardiogenic shock. We also analyse 51 cases, predict the prognostic factors of survival and discuss our general care for those with V-A ECMO.

2. Patients and methods

From January 2002 to December 2006, 1764 patients underwent cardiac surgery in our hospital. Of these, 51

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patients (2.9%) had refractory postcardiotomy cardiogenic shock and needed V-A ECMO for haemodynamic support. The indication for ECMO was failure to maintain normal systolic blood pressure (SBP <90 mmHg) caused by poor cardiac contractility despite adequate filling volumes, large-dose inotropes and intra-aortic balloon pump (IABP) support. It is our institutional policy to treat the cardiogenic-shock patients with ECMO rather than with a ventricular assistance device (VAD) because of its high cost and unpopularity. Heart transplantation is scheduled if indicated. The following cardiac surgical procedures were performed: coronary artery bypass grafting (CABG), *n* = 27; valvular surgery, *n* = 11; CABG plus valvular surgery, *n* = 7; heart transplantation, *n* = 4 and other procedures, *n* = 2.

2.1. ECMO circuit

The ECMO circulation system contains a heparin-coated polypropylene oxygenator (Affinity, NT; Medtronic, Minneapolis, MN, USA) and a centrifugal pump (BPX-80 Bio-Pump, Medtronic, Minneapolis, MN, USA). Blood flow was monitored by a Doppler flow probe attached to the arterial tube of the ECMO. We maintained the maximal blood flow up to 3.5 l min^{-1} to avoid severe haemolysis. An integrated heat exchanger was included in the oxygenator unit to prevent hypothermia. Partial oxygen pressure of the arterial and venous tubes was monitored. We maintained the oxygen pressure of the arterial tube at more than 300 mmHg and the oxygen pressure of the venous tube was recorded.

Femoral cannulation was performed through a cut-down method with an 8 mm Hemashield prosthesis graft anastomosed to the femoral artery for all patients. It is our current policy to employ IABP support with the ECMO procedure to decrease the afterload. Another subclavian arterial tube was considered if blood flow to the head or upper limbs was inadequate. Venous drainage was achieved with a 19 or 21 French cannula inserted directly into the femoral vein with placement of the tip just proximal to the right atrium if possible. Another venous tube was considered if the femoral venous drainage was insufficient.

2.2. Multidisciplinary management strategy

The optimal ECMO blood flow was adjusted to maintain the systolic blood pressure at >90 mmHg, but 3.5 l min^{-1} was the upper limit to avoid destruction of blood cells. Oxygen flow (FiO_2) was adjusted to maintain a postoxygenator partial oxygen pressure of 300 mmHg or greater. Carbon dioxide was maintained within the normal range (37–42 mmHg). The oxygenator was changed if the partial oxygen pressure could not be maintained at more than 300 mmHg or if excessive plasma leakage or clot formation was noted in the oxygenator.

Intravenous heparin was administered and titrated to achieve an activated clotting time (ACT) of 140–160 s; however, in the first 2 days after the operation, heparin is not used to avoid massive mediastinal bleeding. Single-donor platelets were transfused to maintain a platelet count of $>100 \times 10^3$ μl^{-1} as far as possible. Fresh frozen plasma, coagulation factors and cryoprecipitates were administered as required.

Inotropic agents including dopamine and dobutamine were reduced to the minimum necessary (5–10 $\mu g\ kg^{-1}\ min^{-1}$) to decrease the load on the heart and to allow for myocardial recovery. Norepinephrine was employed only when peripheral vascular resistance was low. IABP support was employed in all patients to decrease the afterload, increase coronary perfusion and increase pulsatility.

Patients were weaned from ECMO support as soon as possible. The flow was tapered gradually if the systemic perfusion was adequate and the systolic blood pressure was more than 120 mmHg. Cardiac function was continuously monitored through transthoracic echocardiography and a Swan–Ganz catheter during the weaning process, while ventilator settings and dosage of inotropic agents were adjusted as required. Removal of the ECMO support was considered if a cardiac index of more than 2.0 l min^{-1} m^{-2} could be generated when the ECMO support was reduced to less than 0.6 l min^{-1}.

2.3. General patient care

For our patients, we prescribed opioid and midazolam to ensure patient comfort, and neurologic assessment was conducted every morning. Moreover, a muscle relaxant would be added if the patient was still agitated despite the abovementioned drug therapy. Mechanical ventilation with a positive airway pressure was maintained. The ventilator was set at a tidal volume of 6–8 ml kg^{-1}, a rate of 10–12 breaths min^{-1} and a positive end-expiratory pressure (PEEP) of 6–10 cmH_2O to prevent alveolar collapse. High PEEP (>10 cmH_2O) was avoided to prevent suppression of cardiac diastolic function. The peak airway pressure was maintained at less than 35 cmH_2O to avoid barotraumas, especially in acute respiratory distress syndrome (ARDS) lung. $PaCO_2$ was maintained within the normal range to prevent organ damage. Fraction of inspiratory oxygen (FiO_2) was maintained at 40–60%. ECMO flow was never reduced to less than 0.6 l min^{-1} to avoid blood clots. Enteral feeding with an elemental diet was administered in all patients on the first postoperative day and peripheral parenteral nutrition (PPN) was prescribed if enteral feeding could not be tolerated [11]. Pantoprazole 40 mg was administered every 12 h in all patients. We routinely transfused 25% human albumin 150 ml during the operation. During the ECMO circuit, we routinely transfused 25% human albumin 50 ml every 12 h till ECMO was removed. Broad-spectrum antibiotics were used in all patients. Continuous infusion of insulin was also prescribed for hyperglycaemia. A detailed physical examination was conducted every 8 h. Routine blood, biochemistry and culture examinations for possible infection were performed. All surviving patients were followed-up after hospital discharge every month in our OPD.

2.4. Data collection

We collected the data retrospectively and focused on preoperative and peri-ECMO data, especially the evaluation of heart function, other morbidities, duration of support, blood product use, daily biochemistry data during ECMO and complications of ECMO. Data were also obtained for 1-month, 3-month, in-hospital and 1-year mortality results after ECMO. Demographics and preoperative characteristics of the 51

Table 1
Preoperative patient characteristics.

	Total	CABG	Valvular surgery	CABG + valvular surgery	HTx	Others[a]
Number	51	27	11	7	4	2
Male	36 (71%)	22 (81%)	8 (72%)	3 (43%)	3 (75%)	0
Female	15 (29%)	5 (19%)	3 (28%)	4 (57%)	1 (25%)	2 (100%)
Age (years)	63.0 ± 15.7	67.4 ± 12.4	55.1 ± 20.7	64.3 ± 15.2	53.8 ± 15.1	61.5 ± 19.1
BMI (kg m^{-2})	25.1 ± 4.1	26.7 ± 4.1	21.9 ± 2.8	22.5 ± 2.8	26.7 ± 2.1	27.3 ± 4.1
LVEF (%)	40.1 ± 17.9	36.2 ± 15.4	39.6 ± 20.7	42.0 ± 20.3	62.5 ± 6.5[b]	45.0 ± 21.2
NYHA function class	2.3 ± 1.0	2.0 ± 1.0	2.6 ± 1.2	2.6 ± 1.0	1.2 ± 0.3[b]	2.5 ± 0.7
SBP <90 mmHg	37 (73%)	24 (89%)	7 (64%)	3 (43%)	2 (50%)	1 (50%)
DM	19 (37%)	11 (41%)	2 (18%)	4 (57%)	1 (25%)	1 (50%)
HCVD	21 (41%)	14 (52%)	2 (18%)	4 (57%)	1 (25%)	0
Renal insufficiency	16 (31%)	10 (37%)	4 (36%)	1 (14%)	1 (25%)	0
ASA classification 4 or 5	33 (65%)	21 (77%)	6(55%)	1 (14%)	4 (100%)	1 (50%)
Predicted mortality rate by euroSCORE (%)	49.4 ± 29.5	56.3 ± 29.5	36.9 ± 29.3	44.8 ± 29.3	48.4 ± 25.8	44.1 ± 45.4

CABG, coronary artery bypass grafting; HTx, heart transplantation; BMI, body mass index; SBP, systolic blood pressure; LVEF, left-ventricular ejection fraction; NYHA: New York Heart Association; DM, diabetes mellitus; HCVD, hypertensive cardiovascular disease, ASA, American society anaethesiologists, euroSCORE, European system for cardiac operative risk evaluation. The valvular surgery include: mitral valvular replacement: 4, mitral valvular repair: 2, mitral valvular repair + tricuspid valvular annuloplasty: 1, aortic valvular replacement: 2, mitral and aortic valvular replacement: 2. The CABG + valvular surgery include: CABG + mitral valvular replacement: 2, CABG + mitral valvular repair: 3, CABG + aortic valvular replacement: 2. Renal insufficiency was defined as: serum creatinine >1.2 mg dl^{-1}.

[a] Including embolectomy of pulmonary artery (n = 1), and ASD repair (n = 1).

[b] The LVEF and NYHA were recorded according to the donated heart.

patients are summarised in Table 1. The patients were divided into five subgroups with relation to their indication for cardiac surgery.

2.5. Statistical analysis

All statistical analyses were performed using SPSS software version 12 (SPSS Inc., Chicago, IL, USA). Categorical variables are expressed as percentages and were evaluated with χ^2 or Fisher's exact tests. Continuous variables are expressed as mean ± standard deviation and were evaluated using Student's t-test. Stepwise logistic regression analysis was used to determine the independent predictors of weaning rate and 1-year mortality. Survival was calculated according to the Kaplan–Meier method.

3. Results

Table 2 shows the outcome of ECMO support. Mean duration of ECMO support was 7.5 ± 6.7 days. Twenty-seven (53%) patients were successfully weaned off the support. Three patients were weaned off after heart transplantation and all were alive in the 1-year OPD follow-up. Seventeen were released from our hospital. Ten patients died in hospital after weaning from ECMO. Six died of late pulmonary infection and four died of refractory congestive heart failure. The main causes of mortality in patients after weaning from ECMO support were pulmonary infections, and the post-ECMO hospital days range from 9 to 81 days, with an average of 34.0 days. At the 1-year OPD follow-up, 15 patients had survived. One patient died of severe infection and another died of sudden cardiac arrest. Fig. 1 shows the Kaplan–Meier curve for 1-year survival. In the 24 patients who could not be weaned from ECMO, 83% (20/24 patients) died of severe heart failure with acidosis-induced multiple organ failure. Long-term ventricular assistance devices are not popular in our country and none were used for these 24 patients.

Overall complications are shown in Table 3. Acute renal failure and femoral bleeding over the cannulation site were the most common. Acute renal failure occurred in 38 (75%) patients and all patients with renal failure required

Table 2
General data and outcomes of the different ECMO groups.

	Total	CABG	Valvular surgery	CABG + valvular surgery	HTx	Others
Number	51	27	11	7	4	2
Pumping time (min)	188 ± 75	173 ± 75	188 ± 45	263 ± 88	205 ± 42	108 ± 57
Operation time (min)	407 ± 131	392 ± 135	417 ± 95	540 ± 114	293 ± 79	315 ± 21
Cross-clamp time (min)	32.0 ± 36.6	4.6 ± 13.4	52.3 ± 28.2	48.9 ± 3.5	108.5 ± 15.9	50.0 ± 18.4
ECMO duration (day)	7.5 ± 6.7	7.8 ± 7.6	7.0 ± 4.6	6.1 ± 4.7	10.3 ± 10.9	3.3 ± 1.6
ICU stay (days)	18.4 ± 15.2	18.4 ± 13.4	12.8 ± 11.2	21 ± 21.8	36.5 ± 15.8	4.5 ± 2.1
Hospital stay (days)	26.1 ± 22.0	23.8 ± 18.1	26.4 ± 27.0	30.0 ± 25.9	44.5 ± 23.7	4.5 ± 2.1
Post-ECMO hospital stay (days)	18.1 ± 23.0	15.4 ± 19.7	18.7 ± 27.0	23.7 ± 28.4	34.2 ± 26.7	0
Weaning from ECMO	27 (53%)	12 (44%)	7 (63%)	4 (57%)	4 (100%)	0
Bridge to transplant	3 (5.9%)	3 (11%)	0	0	0	0
30-Day mortality	25 (49%)	15 (55%)	5 (45%)	3 (43%)	1 (25%)	2 (100%)
Hospital mortality	34 (67%)	20 (74%)	6 (54%)	4 (57%)	2 (50%)	2 (100%)
1-Year mortality	36 (71%)	20 (74%)	7 (63%)	4 (57%)	3 (75%)	2 (100%)

CABG, coronary artery bypass grafting; HTx, heart transplantation. Pumping time is defined as the time during extracorporeal circulation support. Operation time is defined as the time between anaesthetic induction and emergence. Cross-clamp time is defined as the time between aortic clamp and release.

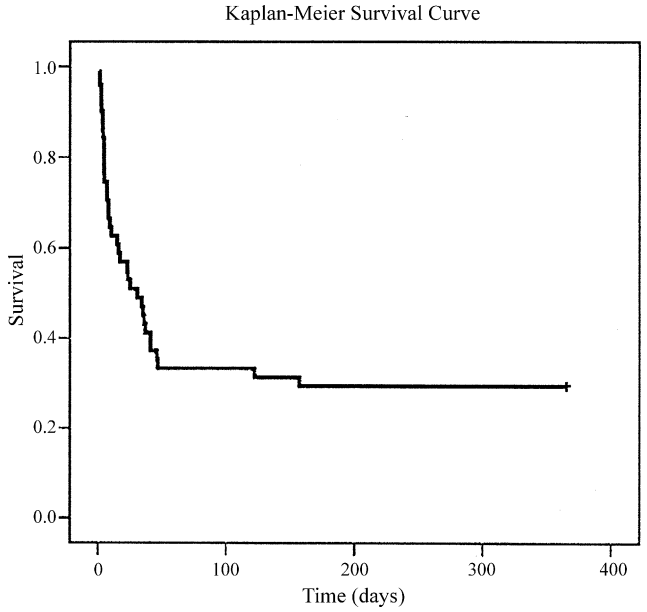

Fig. 1. After a follow-up period of 1 year, all of the discharged patients were followed-up in the OPD. The total 1-year survival rate was 29% (15/51).

Table 3
Overall complications of ECMO.

Complications	No.	%
Acute renal failure	38	75
Femoral bleeding	20	39
Haematuria	17	33
Gastrointestinal bleeding	13	25
Pulmonary infection	11	22
Compartment syndrome	5	9.8
ARDS	5	9.8
Limb ischaemia	3	5.9
Leg amputation	2	3.9
Neurologic complications	3	5.9
Catheter-related infection	3	5.9
Pancreatitis	1	2.0

ARDS, acute respiratory distress syndrome. Acute renal failure is defined as 25% or 50% increase in the creatinine level if the patient has a normal baseline creatinine value or an increase of 1–2 mg dl^{-1} if the baseline creatinine value is abnormal. Pulmonary infection is defined as sepsis with positive sputum culture. Compartment syndrome is defined as swelling of limbs with intra-compartmental pressure >20 mmHg. Neurologic complications include stroke or intracranial haemorrhage. Pancreatitis is defined as both elevated serum amylase and lipase levels.

continuous venovenous haemofiltration. In our early experience, a bleeding tendency such as haematuria, gastrointestinal bleeding or surgical wound oozing, was always noted. Thus, systemic heparinisation was not initiated in the first two postoperative days. The heparin dosage was prescribed according to ACT, which was optimally kept between 140 and 160 s. Limb ischaemia was observed in three patients. Two of these three patients needed amputation of the distal lower limbs and were still alive at the 1-year follow-up. Therefore, distal limb perfusion was optimised with a 6-mm PTFE T-graft anastomosed end to side to the common femoral artery to maintain both central arterial blood flow and distal limb perfusion [12]. Late vascular complications, such as stenosis or pseudoaneurysm, were not noted in our patients. The incidence of bacteraemia was 34%.

Table 4 shows the risk factors for mortality, especially the arterial blood gas data just before ECMO implantation and 24 h after ECMO use. Serum albumin level, lowest platelet count, initial partial pressure of the ECMO venous tube, cardiac index measured through a Swan–Ganz catheter and arterial gas data 24 h after ECMO all reached statistical significance.

The predictors of failure to withdraw ECMO are shown in Table 5. Pre-ECMO predictors include left-ventricular ejection fraction (LVEF) <40%, initial pH <7.2 and preoperative systolic blood pressure (SBP) <90 mmHg, while peri-ECMO predictors include saturation of ECMO venous tube (SvO_2) <65% and a lactate level 24 h after ECMO more than 8.0 mmol l^{-1}.

4. Discussion

Cardiogenic shock is a major complication after cardiac surgical intervention, especially in those with preoperative heart failure or cardiogenic shock [7–10]. In our centre, ECMO therapy is a valuable option for the treatment of severe heart failure with low output syndrome and haemodynamic collapse. Severe cardiac dysfunction with haemodynamic compromise is undoubtedly an indication for V-A ECMO, especially when the heart failure is thought reversible, in cases such as myocarditis, cardiac trauma, acute myocardial infarction after revascularisation and postcardiotomy syndrome. In those with myocarditis, ECMO provides haemodynamic support until the immune reaction subsides. In those with cardiac trauma or myocardial infarction after revascularisation, the myocardial muscle is stunned and the cardiac dysfunction is thought to be temporary. Cardiac dysfunction might contribute to the effect of the cardioplegia solution in postcardiotomy syndrome. Clinically, no standard principles were defined for ECMO use. Unless absolutely contraindicated, we used ECMO early to prevent deterioration of vital organs, especially the brain. In addition, large-dose inotropes were used to increase cardiac loading but resulted in poor perfusion of other vital organs. In our case, dopamine and dobutamine were both kept below 10 $\mu g\,kg^{-1}\,min^{-1}$. IABPs were all used based on the hypothesis of additional pulsatile flow, reduction of afterload and better coronary flow [9,13].

In our early cases of ECMO use, the Seldinger procedure was used for insertion of the ECMO tubes under emergent conditions. Bleeding around the puncture site was always a major complication, especially when platelet inhibitors had been administered. In these 51 cases, we used a cut-down procedure with a T-graft to the femoral artery and the Seldinger procedure for the femoral vein. This could minimise blood loss and decrease the incidence of limb ischaemia. The incidence of limb ischaemia in our group was 5.9%. This is relatively low compared with that found in other studies [7–10]. Moreover, once the ECMO could be withdrawn, stenosis of the punctured vessels could be avoided. We routinely prescribed vancomycin to prevent catheter-related infection. Third- or fourth-generation cephalosporins were prescribed if Gram-negative bacterial infection was suspected.

Table 4
Parameters between the survivor and nonsurvivor groups.

Parameter	Survivors (n = 17)	Nonsurvivors (n = 34)	P
Preoperation			
Preoperative albumin (g dl^{-1})	3.53 ± 0.65	2.89 ± 0.54	<0.001
T. $bilirubin_{0d}$[a] (mg dl^{-1})	1.08 ± 0.53	1.72 ± 1.47	0.08
Post-CPB/pre-ECMO			
Urine output during operation (ml kg^{-1} h^{-1})	2.27 ± 1.49	1.38 ± 2.05	0.12
pH_{0h}[b]	7.31 ± 0.10	7.28 ± 0.15	0.50
$PaO_{2\ 0h}$[b] (mmHg)	122 ± 66	118 ± 58	0.79
$HCO_{3\ 0h}$[b] (mmol l^{-1})	21.8 ± 3.61	19.2 ± 6.1	0.11
$Lactate_{0h}$[b] (mmol l^{-1})	2.56 ± 1.85	5.53 ± 4.77	0.01
$Haematocrit_{0h}$[b] (%)	33.0 ± 6.6	30.9 ± 7.1	0.33
$Postoperative\ albumin_{0h}$[b] (g dl^{-1})	3.22 ± 0.49	2.45 ± 0.66	<0.001
$C.O._{0h}$[b] (l min^{-1})	4.0 ± 0.9	2.8 ± 0.7	<0.001
$C.I._{0h}$[b] (l min^{-1} m^{-2})	2.4 ± 0.5	1.6 ± 0.4	<0.001
24 h post-ECMO			
pH_{24h}[b]	7.47 ± 0.10	7.27 ± 0.21	<0.001
$PaO_{2\ 24h}$[b] (mmHg)	138 ± 50	96 ± 49	0.63
$HCO_{3\ 24h}$[b] (mmol l^{-1})	22.8 ± 4.3	16.5 ± 6.0	<0.001
$Lactate_{24h}$[b] (mmol l^{-1})	3.33 ± 2.19	11.43 ± 4.80	<0.001
$Haematocrit_{24h}$[b] (%)	31.7 ± 3.7	27.7 ± 5.5	0.127
SvO_2 of $ECMO_{24h}$[b] (%)	75.1 ± 5.6	59.3 ± 8.9	<0.001
PvO_2 of $ECMO_{24h}$[b] (mmHg)	47.5 ± 8.7	35.4 ± 6.8	<0.001
3 days post-ECMO			
T. $bilirubin_{3d}$[a] (mg dl^{-1})	6.30 ± 5.15	9.26 ± 5.71	0.07
Lowest $platelet_{3d}$[a] (10^3 μl^{-1})	99 ± 21	70 ± 46	0.004
Transfused RBC_{3d}[a] (U = 250 ml)	17.6 ± 15.7	28.6 ± 17.9	0.36
Transfused SD $platelet_{3d}$[a] (U = 250 ml)	4.9 ± 4.5	7.6 ± 7.4	0.17

CPB, cardiopulmonary bypass; SvO_2, saturation of venous oxygen; PvO_2, partial pressure of venous oxygen; RBC, red blood cells; SD, single donor, C.O., cardiac output, C.I., cardiac index.

[a] 0d indicates data obtained before ECMO implantation, while 3d indicates data obtained 3 days after ECMO use.

[b] 0h indicates data obtained before ECMO implantation, while 24h indicates data obtained 24 h after ECMO use.

In our data, many parameters are used as the predictors of mortality. As shown in Table 4, the pre-ECMO pH and lactate levels did not reach statistical significance, whereas some studies proved pre-ECMO pH and lactate levels are related to a high mortality rate [10,14,15]. Instead, we analysed the arterial blood gas data after ECMO support for 24 h. We found that if acidosis persisted for 24 h after ECMO implantation, the mortality rate would increase. In addition, we also found the platelet count and albumin level play an important role for mortality prediction. The saturation and oxygen pressure of the ECMO venous tube (SvO_2 and PvO_2) could be used to evaluate the systemic hypoxic status. Low SvO_2 and PvO_2 after 24-h ECMO support reflect inadequate systemic perfusion, which can lead to multiple organ failure and mortality. Of course, the cardiac output and index (C.O. and C.I.) obtained through a Swan–Ganz catheter could directly represent cardiac function and be a predictor of mortality.

Table 5 shows the hazard ratio of prognostic factors for failure to wean from ECMO support. Risk factors include LVEF <40%, pH <7.2, preoperative SBP <90 mmHg, SvO_2 of ECMO venous tube and lactate level >8.0 mmol l^{-1}. These risk factors hint that ECMO should be employed early once postcardiotomy cardiogenic shock is suspected. Recent studies report in-hospital survival rates with the use of

Table 5
Risk factors of failing to withdraw ECMO.

Risk factor	Odds ratio	95% Confidence interval of the difference
Preoperation		
LVEF <40%	12.34	3.01–72.02
CHF stage C or D	1.81	0.51–9.53
Preoperative SBP <90 (mmHg)	12.002	2.40–59.95
Post-CPB/pre-ECMO		
Perioperative U/O <1 (ml kg^{-1} h^{-1})	1.18	0.20–6.95
pH_{0h} <7.2	8.797	1.55–49.79
$Lactate_{0h}$ > 2.5	1.117	0.21–5.82
C.I. <1.8	1.871	0.33–10.53
24 h post-ECMO		
SvO_2 of $ECMO_{24h}$ <65%	1.8	0.13–24.52
pH_{24h} <7.4	1.368	0.19–9.73
$HCO_{3\ 24h}$ <20	2.742	0.28–26.88
$Lactate_{24h}$ >8.0	14.28	6.42–67.82
3 days post-ECMO		
T. $bilirubin_{3d}$ >7.5	2.28	1.28–31.89

LVEF, left-ventricle ejection fraction; CHF, congestive heart failure; SBP, systolic blood pressure; CPB, cardiopulmonary bypass; SvO_2, saturation of venous oxygen, C.I., cardiac index.

ECMO ranging from 20% to 50% and mortality rates of 50–70% [7,9]. In our study, there was an acceptable 30-day mortality of 49%; in-hospital mortality was 67% and 1-year mortality was 71%. Right now, we still cannot figure out why pulmonary infection is the main cause of death after weaning ECMO. ECMO itself would induce systemic inflammation response syndrome. The pulmonary parenchyma might be very sensitive to systemic inflammation caused by extracorporeal circulation. Pulmonary complications after cardiopulmonary bypass are mentioned in many basic studies [7–10].

The duration of ECMO support in our patient group was 7.5 ± 6.7 days and thus was longer compared with that seen in other study groups [8,9,13]. That is most likely because of the shortage of donor hearts in our country. The VAD is an alternative, but its cost makes it unpopular. Although the follow-up period was short, it demonstrated that once successfully discharged from the hospital, patients had an acceptable 1-year survival rate. These results justify the use of ECMO, even if only about 30% of the patients survived 1 year after the cardiac surgery.

This article describes a retrospective analysis of our clinical experience. Despite a relatively high mortality rate, we remain confident that the ECMO is a suitable alternative for those with postcardiotomy cardiogenic shock. Of course, good general postoperative care, proper organisation and implementation should be emphasised to prevent the complications of ECMO and to improve the outcomes. Because of the advancement of the ECMO equipment, including oxygenators, biomechanical pumps and heparin-coated tubes, the complications could be overcome. Therefore, the critical patients who are contraindicated for ECMO at present may benefit from ECMO in the future.

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