

Extracorporeal Membrane Oxygenation Therapy in Children with Acute Fulminant Myocarditis

HQ ZHOU, B CHEN, BT NING, HY ZHANG

Abstract

Objective: Acute fulminant myocarditis is a serious and rapidly progressive condition, when aggressive medical support is ineffective, extracorporeal membrane oxygenation (ECMO) support is considered the most effective option in adult. In order to observe the clinical effect and nursing of ECMO in children with acute fulminant myocarditis, we performed the following study. **Methods and patients:** Seven children with acute fulminant myocarditis, who were hospitalised at the Children's Hospital Intensive Care Unit, School of Medicine, Zhejiang University and received ECMO adjuvant therapy from February 2009 to July 2014, were analysed. **Results:** Six of seven patients were successfully weaned from ECMO treatment after 40-142 hours and discharged from the hospital; one patient died because of continued cardiac dysfunction and multiple organ failure. The total survival rate was 85.71% (6/7). The heart rate, blood pressure, and oxygen saturation significantly improved after initiating ECMO. During ECMO, wound haemorrhage was the most common complication result in 85.71% (6/7). Acute renal failure and haemorrhage secondary to haemolysis was observed in one patient, and hyperglycaemia happened in one patient. During the follow-up period lasting for 3 months to 5 years and 3 months, cardiac function recovered normally in the six surviving children. **Conclusion:** Clinical ECMO application provides effective support for the treatment of acute fulminant myocarditis in children. Timely intervention, thorough assessment and close monitoring based on nursing care, and complication prevention are the keys to ensuring successful ECMO treatment.

Key words

Acute fulminant myocarditis, Children, Extracorporeal membrane oxygenation (ECMO)

Pediatric Intensive Care Unit, Children's Hospital, School of Medicine, Zhejiang University, Hangzhou 310003, China

HQ ZHOU (周紅琴) MD
BT NING (寧鉞濤) PhD, MD

Rehabilitation Department, Hangzhou Hospital of Zhejiang CAPR, Hangzhou 310003, China

B CHEN (陳波) MD
HY ZHANG (張海燕) MD

*HQ Zhou and B Chen contributed equally to the paper.

Correspondence to: Dr BT NING

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Acute fulminant myocarditis is a rapidly progressive life threatening condition, and can be refractory to maximal supportive therapies including mechanical ventilation and vasoactive medications. For these conditions, veno-arterial (VA) extracorporeal membrane oxygenation (ECMO) is an effective option for cardiopulmonary support,¹⁻⁴ in which blood is drawn from central venous cannula by a centrifugal pump and then undergo gaseous exchange through the membrane oxygenator, before oxygenated blood is pumped back to aorta. The high flow extracorporeal circuit can provide full heart lung support for conditions of low cardiac output and severe respiratory failure ensuring effective oxygen delivery to all vital organs.⁵⁻⁸ During the ECMO

support, mechanical ventilation and inotropic medications can be stopped or minimised so as to avoid further barotrauma and myocardial damage, and active treatment focusing on primary disease can be offered which are crucial for heart and lung recovery. VA ECMO is shown to be effective in treating refractory acute fulminant myocarditis in children. In our study, we reviewed seven cases with good clinical outcome.

Methods and Patients

Case Information

This study was approved by the Ethics Committee of the Children’s Hospital of Zhejiang University School of Medicine. Informed written consent was obtained from the parents of the patients, which was documented in the hospital’s computerised records.

Seven children with acute fulminant myocarditis who were hospitalised at the Children’s Hospital Intensive Care Unit, School of Medicine, Zhejiang University and received ECMO adjuvant therapy from February 2009 to July 2014 were evaluated. Three males and four females aged 6 to 14 years (median 10 years) and weighing 20-62 kg (mean 32.9 kg) were included. The ECMO therapeutic duration ranged from 40 to 142 hours (mean 88.1 hours). Among the seven cases, four had severe circulatory failure and three developed cardiac arrest. Three of seven patients received cardiopulmonary resuscitation (CPR) and had ECMO established simultaneously (E-CPR). All patients were administered large doses of vasoactive drugs including adrenaline (0.2-1 µg/kg · min), dopamine (10-15 µg/kg · min), and/or dobutamine (10-20 µg/kg · min) prior to ECMO initiation.

Treatment

A Maquet ECMO Kit (MAQUET, Rastatt, Germany) was used in all patients and included centrifugal pumps, a membrane oxygenator, air-oxygen mixing device, oxygen saturation probe, and circulation line. All patients underwent veno-arterial (V-A) ECMO. Heparin at 1 mg/kg was administered intravenously 3 minutes prior to ECMO cannulation and continued after ECMO was established at a dose maintaining the activated clotting time (ACT) between 180 and 220 seconds. During ECMO therapy, the vasoactive medication was gradually reduced and discontinued. Ventilation support was provided using the synchronised intermittent mandatory ventilation (SIMV) mode with a 30%-45% FiO₂, 10-15 breaths/min respiratory rate, 50% of the tidal volume, and 4-5 cmH₂O positive end expiratory pressure (PEEP). The auxiliary flow was adjusted between 50 and 150 ml/min·kg according to haemodynamic indicators; to maintain the venous oxygen saturation above 65%. The air-oxygen FiO₂ was maintained at 40%-60% to generate an arterial oxygen saturation over 95%. The circulatory and respiratory condition was assessed daily during ECMO treatment using echocardiography, chest radiography, blood gas analysis, and the haemodynamic index. When the cardiac function improved adequately, the auxiliary flow was gradually reduced while the vasoactive drug dose was increased and the ACT time was extended. Once the auxiliary flow was decreased to 10%-20% of the maximum, ECMO was discontinued. Once a smooth circular breathing pattern was observed for approximately 30 minutes, the intubation tube was removed, the cervical vessels were ligated, and the femoral artery and vein were repaired.

Table 1 Patient clinical characteristics before and after establishing ECMO

Parameter	Children patient 1		Children patient 2		Children patient 3		Children patient 4		Children patient 5		Children patient 6		Children patient 7	
	Before	After												
Heart rate (bpm)	160	100	40	85	15	72	160	80	170	90	160	94	142	98
SBP (mmHg)	65	110	60	95	45	85	60	90	55	100	60	96	77	120
CVP (cmH ₂ O)	10	8	12	10	13	9	10	10	14	8	10	7	11	8
SPO ₂ (%)	65	>95	55	>95	35	>95	75	>95	70	>95	75	>95	85	>95

CVP: central venous pressure; SPO₂: percutaneous oxygen saturation; SBP: systolic blood pressure

Results

The heart rate, blood pressure, and oxygen saturation significantly improved 30 minutes after initiating ECMO (Table 1).

During ECMO, wound haemorrhage occurred in five patients; acute renal failure and haemorrhage secondary to haemolysis in one patient; and hyperglycaemia in one (Table 2).

The mean ECMO duration was 88.1 hours (40-142 hours). Six patients were successfully weaned from ECMO and survived to hospital discharge, resulting in an 85.71% (6/7) survival rate. One patient died because of continued cardiac dysfunction and multiple organ failure, which prevented removal of ECMO and ventilation supports, and finally her parents decided to abort the ECMO therapy. During the follow-up period lasting 3 months to 5 years and 3 months, cardiac function normalised in the six surviving children. The remaining organ functions were normal, and the patients possessed normal learning ability and behaviour (Table 2).

Discussion

Care of the Nervous System

Hypoxia, acidosis, and low perfusion may cause brain damage in children; therefore, the nervous system required

close examination before initiating ECMO. To maintain patient compatibility with ECMO, early and deep sedation while initiating ventilator support were needed. Patients were kept supine disposition and the head was kept centrally in the bed to improve venous return to minimise cerebral oedema. The pupillary light reflex and Glasgow Coma Scale (GCS) were performed hourly, and 48 hours' head hypothermia therapy for brain protection was performed for the E-CPR patients. All seven patients were administered both sedative and analgesic agents, midazolam 1-5 µg/kg-min and fentanyl 3-8 µg/kg-h initially. Once patients were stable, sedative and analgesic drugs were discontinued. After hospital discharge, the six surviving patients were followed for 3 months to 5 years and 3 months; their cardiac function fully recovered with no abnormal function in other organs, and their daily activities were normal.

Care of Respiratory System

Infection can reduce patient survival and is a common cause of death; therefore, a good ventilator associated pneumonia (VAP) prevention strategy should be in practice. Patients were regularly examined, including thoracic auscultation each time, and chest radiography was performed daily during ECMO. Because systemic anticoagulants were administered, endotracheal tube suction was performed gently, and closed circuit suction tubes were used to prevent infection and injury. Suction was performed

Table 2 Clinical demographics in the six surviving pediatric patients with acute fulminant myocarditis treated with ECMO

#	Sex	Age (years)	Weight (kg)	Diagnosis	Model	Duration (h)	Complications	Outcomes	Sequel
1	Male	10	32	AFM, serious circulation failure	Left femoral vein-right femoral artery	140	Suture bleeding	Survival	No
2	Male	10	30	AFM, cardiac arrest	Right femoral vein-right femoral artery, E-CPR	40	Suture bleeding	Survival	No
3	Female	9	25	AFM, cardiac arrest	Right femoral vein-right femoral artery, E-CPR	55	Suture bleeding Haemolytic renal failure	Death	
4	Female	9	28	AFM, cardiac arrest	Right jugular vein-right cephalic artery, E-CPR	142	Hyperglycaemia	Survival	No
5	Female	13	33	AFM, serious circulation failure	Right femoral vein-right cephalic artery	72	Suture bleeding	Survival	No
6	Female	6	20	AFM, serious circulation failure, ventricular flutter	Right jugular vein-right cephalic artery	96	Suture bleeding	Survival	No
7	Male	14	62	AFM, serious circulation failure	Right jugular vein-right cephalic artery	72	Suture bleeding	Survival	No

AFM: acute fulminant myocarditis; E-CPR: simultaneous ECMO and CPR

as needed to prevent infection and haemorrhage as follows: The bed end was raised 30–45 degrees. The endotracheal tube air chamber pressure was checked. The oral cavity was cleaned. Oral secretions were removed, and the body position was changed every 2 hours. This maintained patient comfort, skin integrity, and promoted airway clearance, thus preventing ventilator-associated pneumonia (VAP).⁹ During ECMO, lung protection ventilation strategy was adopted to avoid pulmonary damage caused by pressure and high oxygen concentration.¹⁰ No symptoms of pneumonia or pulmonary damage were observed in any of the children.

Care of Circulatory System

Circulatory function was determined based on the following parameters: warmth in peripheral limbs, peripheral mucus membrane colour (red, grey, piebald), urine output, capillary refilling time, and peripheral oedema. All patients were compared according to extremity oxygen saturation, continuous invasive blood pressure, peripheral limb warmth, and peripheral mucus membrane colour observed every 8 hours. Intravenous fluid intake and output were recorded hourly. During the initial 3 days of ECMO treatment, one patient showed repeated hypotension and haemorrhagic discharge within the endotracheal tube. Pulmonary oedema was suspected, and vasoactive drugs, crystalloid and colloid fluids were adjusted accordingly. Fluid intake was regulated according to the urine volume. By day 4 of ECMO therapy, the blood pressure stabilised.

ECMO Pipeline Management

The ECMO pipelines were secured and maintained unobstructed to ensure successful treatment. The carotid artery/vein and femoral artery/vein catheterisations were performed routinely. The pipeline was covered and secured with an elastic bandage, and a gauze pad was placed between the tubes to prevent skin irritation. Patient comfort was maintained throughout, and sedation was administered early to prevent agitation and tube dislodgement. The catheter interface was monitored hourly for tightness, and the ECMO tubing was monitored for dislodgement. The patient body temperature and the ECMO tank temperature were monitored for consistency and maintained at 36.5–37.5°C. The oxygenator was examined for bubbles and plasma leakage, and the pre-pump circuit pressure was maintained at not less than -30 mmHg and post-pump not higher than 300 mmHg. During fluid replacement within the ECMO tubing and venous lines, bubbles were prevented from entering to prevent air embolism.

Observation and Treatment of Complications

The most common and serious ECMO complication is haemorrhage,³ and much of the patient's blood resides in vitro during ECMO and contacts non-physiologic surfaces that may induce clotting. As a result, heparin was administered and adjusted to maintain the activated clotting time (ACT) between 180 and 220 seconds, which was monitored every 4 hours; in addition, the catheter site was observed for haemorrhage, as well as other physical parameters: bilateral pupils, decompression fluid and urine colour, and body skin colour. Skin puncture was minimised to avoid haemorrhage. Notably, six of the patients had wound haemorrhage, which was effectively controlled after adjusting heparin dose, administering blood transfusions, and treating symptoms as needed. The tubing may damage red blood cells resulting in haemolysis or thrombosis, and the colour between each lung membrane and pipeline junction was observed. Commonly we select the size of femoral arterial cannula according to the patient weight, using 12F cannula for 10–15 kg, 14F cannula for 15–20 kg, 16F cannula for 20–30 kg and 18F for 30–40 kg patients. If the weight was less than 25 kg, we mostly choose right jugular vein-right cephalic artery for catheterisation to avoid lower limb ischemia. To evaluate the distal reperfusion line, the colour, temperature, swelling in the catheterised limbs and dorsal pedal arterial pulse were observed hourly. The urine volume, colour, and haemoglobinuria were also observed hourly. Haemoglobinuria was observed in one patient, and the membrane lung was immediately replaced and urine was alkalinised to correct kidney function.

Conclusion

Clinical ECMO application is a novel option for providing paediatric respiratory and circulatory support, and it provides effective support for the treatment of acute fulminant myocarditis in children when maximal conventional support is inadequate. Correct treatment timing, thorough assessment with good nursing support, and complication prevention are the keys to ensuring successful ECMO treatment.

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Declaration of Interest

There are none.

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