ECMO For Pediatric Cardiac Arrest Caused by Bronchial Rupture and Severe Lung Injury: a Case Report About a Life-threatening Rescue at an Adult ECMO Center

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Case report

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Abstract

Background

Bronchial rupture in children is a rare but dangerous complication after chest trauma that has been associated with increased mortality. Veno-venous (V-V) extracorporeal membrane oxygenation (ECMO) is reported as one of the treatments for this life-threatening complication.

Case presentation

A 4-year-old boy who suffered from bronchial rupture and traumatic wet lung complicated by cardiac arrest after chest trauma was admitted to an adult ECMO center. He had two cardiac arrests—one before and one during the operation. The total duration of cardiac arrest was 30 minutes. V-V ECMO was initiated because of severe hypoxia and carbon dioxide retention during the operation. ECMO was performed for 6 days, and mechanical ventilation lasted 11 days. On the 31st day after the operation, he recovered completely and discharged without neurological deficit.

Conclusion

V-V ECMO can be considered for support in children with severe acute respiratory failure after bronchial rupture. In an emergency, V-V ECMO can be carried out effectively in a qualified and experienced adult ECMO center. But the application of ECMO in children is different from that in adults and requires more refined management.

Introduction

Bronchial rupture is a rare and life-threatening injury, especially in children, that can lead to varying degrees of pneumothorax, atelectasis, and even death in severe cases. Early treatment has an important impact on the prognosis of traumatic bronchial rupture in children. V-V ECMO can improve oxygenation and ventilation, may play a role as an additional treatment for severe but reversible acute respiratory failures. We present the case of a 4-year-old boy with cardiac arrest caused by bronchial rupture after chest trauma who was rescued successfully through V-V ECMO.

Case Presentation

A 4-year-old boy (height, 100 centimeters; weight, 16 kilograms) was hit in the chest by a car. He was conscious and complained of chest tightness. Upon arrival to the local hospital after 18 minutes, he was semiconscious and cyanotic, and breath sounds were not heard in the right hemithorax, and his vital signs were unstable: heart rate (HR) of 162 beats per minute (bpm), blood pressure (Bp) of 102/56 mm Hg, respiratory rate (RR) of 32 times per minute, and oxygen saturation (S\text{p}O\text{2}) of 70%. 30 milligrams of propofol intravenously for sedation, and then emergency endotracheal tube above the carina was performed. Chest computerized tomography (CT) showed right pneumothorax with lung compression of
90%, and the left clavicle was fractured (Figure 1). A chest tube was positioned in the right thoracic cavity and a breathing balloon was used for ventilation, and then his vital signs were as follow: HR of 155 bpm, Bp of 97/50 mm Hg, RR of 22 times per minute, and S\textsubscript{p}O\textsubscript{2} of 98%. 24 minutes later, he was admitted to the emergency department of our hospital for further treatment. The results of blood gas analysis were as follows: pH, 7.12; carbon dioxide partial pressure (P\textsubscript{a}CO\textsubscript{2}), 76 mm Hg; oxygen partial pressure (P\textsubscript{a}O\textsubscript{2}), 68 mm Hg. Bronchoscopy indicated that the right middle lobe bronchus was ruptured. Transthoracic echocardiography ruled out associated blunt cardiac injury. Emergency exploratory thoracotomy and the right middle or right middle and lower lobectomy were planned. The patient went into sudden cardiac arrest after being sent to the operating room (S\textsubscript{p}O\textsubscript{2}, 76%; End-tidal carbon dioxide partial pressure (P\textsubscript{e}CO\textsubscript{2}), 46 mm Hg). After 12 minutes of cardiopulmonary resuscitation he regained his spontaneous heart rhythm. He didn't regain consciousness. Mainstem intubation of the left bronchus under direct fiberoptic guidance to ventilate the left lung. Pressure control ventilation (fraction of inspiration O\textsubscript{2} was 100%, peak pressure was 32 cm H\textsubscript{2}O, tidal volume was 45 milliliters). HR of 145 bpm, Bp of 92/48 mm Hg (0.05 µg/kg/min norepinephrine), RR of 20 times per minute, and S\textsubscript{p}O\textsubscript{2} of 70%. Blood gas analysis results at this time were as follows: pH, 6.87; PaCO\textsubscript{2}, 114 mm Hg; PaO\textsubscript{2}, 46 mm Hg; plasma lactic acid (Lac), 6.7 mmol/L; K+, 3.2 mmol/L; Hemoglobin 7.3 g/dl; Ca++ 1.21 mmol/L. Sudden cardiac arrest occurred due to severe respiratory acidosis, so we decided to initiate V-V ECMO. Our hospital is an adult ECMO center, and it is 300 km away from our nearest pediatric ECMO center, approximately a 3.5-hour drive. The child was at death's door, therefore, we decided to use the smaller adult ECMO tubes. ECMO was initiated via percutaneous in the left femoral vein and incision in the right internal jugular vein (MAQUET 2050, Cardiopulmonary GmbH BE-PLS, Germany; the left femoral vein: 15 Fr/5 mm single-stage drainage cannula, MAQUET, Germany; the right internal jugular vein: 14 Fr/ZX 4.7 return cannula, Changzhou Kangxin Medical Equipment Co., Ltd., China). The blood flow was 1.7 L/min, sweep gas was 1.5 L/min, FiO\textsubscript{2} was 100%. Cardiac arrest occurred again after ECMO, so we gave him cardiopulmonary resuscitation immediately. Blood gas analysis results at this time were as follows: pH, 6.84; P\textsubscript{a}CO\textsubscript{2}, 72 mm Hg; P\textsubscript{a}O\textsubscript{2}, 61 mm Hg; Lac, 9.7 mmol/L; K+, 9.8 mmol/L; Hemoglobin 7.3 g/dl; Ca++ 1.21 mmol/L. Soda bicarb (5%, 32 ml), insulin (2 U) added to glucose injection (10%, 100 ml), and calcium chloride injection (3%, 0.1 g) were given at once. Spontaneous sinus rhythm was restored after 18 minutes. An exploratory thoracotomy was performed successfully, the root of the right middle lobe bronchus was found to be ruptured (Figure 2), and a branch of the right middle lobe artery was ruptured. Right middle lobectomy and right middle bronchoplasty were performed. He was admitted to the intensive care unit (ICU) after the operation. Mechanical ventilation and ECMO was continued, we adjusted the ventilator parameters: FiO\textsubscript{2} was set at 30%, positive end expiratory pressure (PEEP) was set at 10 cm H\textsubscript{2}O, the respiratory rate was set at 12 times/minute and the tidal volume was set at 6 mL/kg. Oxygen saturation was between 98% and 100%. Along with mild hypothermia for brain protection (34-36 celsius degree for 30 hours), piperacillin sodium and tazobactam injection for the prevention of infection, methylprednisolone injection (16 mg q12h) to reduce pulmonary exudation, and norepinephrine 0.15 µg/kg/min to maintain blood pressure. On postoperative day 2, he became conscious and was able to act on command. Due to the traumatic wet lung on the left and secondary pulmonary infection, ECMO was withdrawn on the 6th day after the
operation, with a total ECMO time of 137 hours. On postoperative day 11, mechanical ventilation was withdrawn. On postoperative day 12, chest CT showed a mass of high-density shadow in the upper lobe of the left lung with cavitation, considered a large traumatic pseudocyst (Figure 3). He left the ICU on postoperative day 16. He was discharged from the hospital on postoperative day 31 without neurological deficit. He is able to communicate and play normally. The timeline of the treatment process is shown in Figure 4.

Discussion And Conclusion

Traumatic bronchial rupture in children is often caused by blunt chest trauma, which is rare but often life-threatening [1, 2]. A review of the literature on tracheobronchial ruptures[3] concluded motor vehicle accidents were the most frequent mechanism of injury (59%) and the injury occurred within 2 cm of the carina in 76% of patients, and 43% occurred within the first 2 cm of the right main bronchus.

The cricoid cartilage and tracheal carina are fixed anatomically, with two lungs hanging on either side; when the chest is compressed forward and backward, the lungs are pushed sideways, and the two bronchi near the carina produce shear force, leading to bronchial rupture. When the chest wall is squeezed suddenly, the glottic reflex is closed, the thorax shrinks, and the internal pressure of the bronchus increases sharply. If the pressure exceeds the tolerance limit of the bronchus, the bronchus ruptures. The bronchus walls are weak in children, who often hold their breath at the moment they are injured due to startling; this can increase the airway pressure and the relative movement of the bronchus and lung, which is a special feature of traumatic bronchus rupture in children.

Children with bronchial rupture should be treated as soon as possible after diagnosis. Early surgery can quickly restore the continuity of the bronchi, terminate the pneumothorax, preserve lung tissue as much as possible, and restore lung function. Surgical repair should be performed according to the degree of bronchial rupture. In severe cases, lobectomy is required. ECMO can be used to provide pulmonary support after blunt chest trauma. Severe trauma injuries are considered to be a contraindication for ECMO because of the risk of unstoppable bleeding or intracranial hemorrhage. Fortenberry and others[4] first proposed that ECMO could be used to provide support for post-traumatic respiratory failure or acute respiratory distress syndrome in children. In adult patients, V-V ECMO can be used for supportive treatment of intrabronchial hemorrhage [5] and auxiliary measures for surgical repair after iatrogenic [6] or traumatic bronchial rupture [7].

In this patient, after chest trauma, the right middle lobe bronchus was ruptured, traumatic wet lung was observed on the left lung, and severe acute respiratory distress syndrome appeared. The patient was still suffering from hypoxia after inserting chest tube and mechanical ventilation, thus ECMO assistance was performed. He recovered well with the assistance of ECMO. It has been previously reported that children are treated by specialized pediatric ECMO centers. The success of this rescue shows that the adult ECMO centers can also provide pulmonary support for children in an emergency. Ballouhey and others[8] reported that they successfully rescued several children with traumatic bilateral bronchial rupture by ECMO. They
believed that ECMO should be implemented as soon as possible after chest deflation and mechanical ventilation in children with severe bronchial rupture. ECMO can be started before surgery, when instability occurs during thoracic surgery or when mechanical ventilation is expected to be difficult. ECMO can also be established after surgical repair to prevent continuous ventilatory difficulties or barotrauma. ECMO was started after cardiac arrest in this patient. We considered that it may be possible to avoid the first cardiac arrest if ECMO had been performed when the oxygenation index was first found to be extremely low. When ECMO was running, the boy suffered cardiac arrest again due to severe hyperkalaemia and acidosis. 400 milliliters red blood cell were going to be prefilled into the ECMO tube; however, afterwards, it turned out that an 800 milliliters stock red blood cells were used which resulted in hyperkalaemia. Studies have shown that the longer the storage time of red blood cell, the higher the concentration of K+ and lactic acid[9]. In children, prefilled with a large volume of stored red blood cell directly can cause low pH and high K+ and lactic acid concentrations, which increase myocardial irritability, reduce the ventricular fibrillation threshold, and can cause myocardial weakness, hypotension, and ventricular fibrillation. If cardiac arrest occurs immediately after the initiation of ECMO, hyperkalaemia needs to be ruled out, and it is very important to do blood gas analysis and treat hyperkalaemia in a timely manner. Furthermore, in pediatric patients, the use of red blood cells cleaned by a blood recovery machine or a fresh red blood cell for prefilling should be considered. ECMO played a vital role in the successful treatment of bronchial rupture in this boy. However, there are also many lessons to be learned in the implementation process. The application of ECMO in children is different from that in adults and requires more refined management.

V-V ECMO can be considered for support in children with severe acute respiratory failure after bronchial rupture. In an emergency, V-V ECMO can be carried out effectively in a qualified and experienced adult ECMO center.

**Abbreviations**

V-V: Veno-venous

ECMO: Extracorporeal membrane oxygenation

HR: Heart rate

Bpm: Beats per minute

Bp: Blood pressure

RR: Respiratory rate

S\textsubscript{p}O\textsubscript{2}: Oxygen saturation

CT: Chest computerized tomography
\( P_{a\text{CO}_2} \): Carbon dioxide partial pressure

\( P_{a\text{O}_2} \): Oxygen partial pressure

\( P_{et\text{CO}_2} \): End-tidal carbon dioxide partial pressure

Lac: Lactic acid

ICU: Intensive care unit

PEEP: Positive end expiratory pressure

**Declarations**

**Ethics approval and consent to participate**

Not applicable.

**Consent for publication**

The patient's parent provided written consent to use clinical information for scientific publications.

**Availability of data and materials**

The datasets used and/or analysed during the current study are available from the corresponding author on request.

**Competing interests**

The authors declare that they have no competing interests.

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**Authors' contributions**

SZ-concept, XC-writing of manuscript, WC-critical revision of article, YW-data collection, LZ-data collection, MZ-preparing figures. All authors read and approved the final manuscript.

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Not applicable.

**References**
1. Ballouhey, Q., Fesseau, R., Benouaich, V., et al. Management of blunt tracheobronchial trauma in the pediatric age group. *Eur J Trauma Emerg Surg*, 2013. 39(2): p. 167-71.

2. Oosthuizen, J.C., Paediatric blunt laryngeal trauma: a review. *Int J Otolaryngol*, 2011. 2011: p. 183047.

3. Andy, C.K., Sean M.O’B., Frank, C.D. Blunt tracheobronchial injuries: treatment and outcomes. *Ann Thorac Surg*, 2001. 71(6): 2059-65.

4. Fortenberry, J.D., Meier, A.H., Pettignano, R., et al. Extracorporeal life support for posttraumatic acute respiratory distress syndrome at a children’s medical center. *J Pediatr Surg*, 2003. 38(8): p. 1221-26.

5. Yuan, K.C., J.F. Fang, and M.F. Chen. Treatment of endobronchial hemorrhage after blunt chest trauma with extracorporeal membrane oxygenation (ECMO). *J Trauma*, 2008. 65(5): p. 1151-4.

6. Korvenoja, P., Pitkänen, O., Berg, E., et al. Veno-venous extracorporeal membrane oxygenation in surgery for bronchial repair. *Ann Thorac Surg*, 2008. 86(4): p. 1348-9.

7. Enomoto, Y., Watanabe, H., Nakao, S., et al. Complete thoracic tracheal transection caused by blunt trauma. *J Trauma*, 2011. 71(5): p. 1478.

8. Ballouhey, Q., Fesseau, R., Benouaich, V., et al. Benefits of extracorporeal membrane oxygenation for major blunt tracheobronchial trauma in the paediatric age group. *Eur J Cardiothorac Surg*, 2013. 43(4): p. 864-5.

9. Sumpelmann, R., Schürholz, T., Thorns, E., et al. Acid-base, electrolyte and metabolite concentrations in packed red blood cells for major transfusion in infants. *Paediatr Anaesth*, 2001. 11(2): p. 169-73.

**Figures**
Chest CT(6.12) showed right pneumothorax and right lung compression 90% (blue arrow) and left traumatic wet lung (white arrow).

**Figure 1**

See image above for figure legend.
Intraoperative findings. The root of the right middle lobe bronchus was disconnected (black arrow).

Figure 2

See image above for figure legend.
Chest CT(6.24) showed a mass of high-density shadow in the upper lobe of the left lung with cavitation (green arrow).

Figure 3

See image above for figure legend.
The timeline of the entire treatment process.

Figure 4

See image above for figure legend.

Supplementary Files

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