A Case of Multiple Blunt Injuries Treated with Emergency Department Thoracotomy and Extracorporeal Life Support

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Learning Objectives: 1) To understand the indications for thoracotomy during resuscitation of trauma patients in the emergency department and 2) to appreciate the role of extracorporeal life support in the management of posttraumatic acute respiratory failure.

Abstract

A 7-year-old girl was run over on her chest and abdomen by a tank truck. She sustained cardiac arrest in the emergency department due to hemorrhagic shock and bilateral tension hemopneumothorax, despite no apparent thoracic surface injury. Resuscitation was achieved with emergency department thoracotomy and internal cardiac massage. The patient was also noted to have brain concussion, mandibular fracture, and dorsal degloving injury. Laparotomy revealed hepatic and mesenteric injuries, intestinal lacerations, and pancreatic transection. Once bleeding was controlled, a distal pancreatectomy was performed. Massive intrabronchial bleeding from left bronchial and pulmonary injuries was controlled by a bronchial balloon tamponade technique. Respiratory insufficiency caused by bilateral pulmonary contusions and a left intrabronchial clot was managed by conventional ventilation strategies. However, the respiratory index deteriorated, and extracorporeal life support (ECLS) was begun on the second hospital day. After 18 days of ECLS, pulmonary function was recovered and periodic suctioning successfully removed clots in the left lower lobular bronchus with further improvement in oxygenation. The patient was extubated on the 30th hospital day and suffered posttraumatic epilepsy, which became well controlled with antiepileptic agents. She eventually returned to her elementary school activities in 6 months.

We describe the assessment and treatment of this 7-year-old patient following a motor vehicle incident resulting in severe blunt trauma and cardiopulmonary arrest, who survived and fully recovered a rare scenario of pediatric multiple injuries. In particular, the application of emergency department thoracotomy and ECLS played a critical role in supporting this child with multisystem trauma.

The value of emergency department thoracotomy for blunt trauma has been questioned because of its poor prognosis; however, the technique could be beneficial for pediatric patients who demonstrate "salvageability" on arrival. The pliability of a child's chest wall may result in heart and pulmonary damage without overlying injury, in which case resuscitative thoracotomy may reveal reparable internal injury.

The management of severe pulmonary contusions is extremely challenging when complicated with bronchial injury in multisystem trauma patients. The adjunctive use of extracorporeal life support (ECLS) for lethal acute respiratory failure has played a critical role in supporting such patients.

In this case report, we describe a child with multiple blunt injuries, including brain concussion, mandibular fracture, severe bilateral pulmonary contusions, injury of the left main bronchus, blunt cardiac injury, liver injury, pancreatic transection, mesenteric injuries, intestinal lacerations, and a dorsal degloving injury. The patient was resuscitated successfully with emergency department thoracotomy and managed on ECLS for 2 weeks for posttraumatic acute respiratory failure.

Case Report

A 7-year-old girl was run over on her chest and abdomen by a tank truck. External bleeding was not noted at the scene. She was lethargic and brought to our hospital by an emergency medical team. On arrival, during the primary survey, she sustained a witnessed cardiac arrest. Resuscitation was achieved with tracheal intubation, left thoracotomy, internal cardiac massage, right pleural drainage, and intravenous epinephrine infusion in the emergency department. Tension hemopneumothorax and pulmonary contusions were recognized when the thoracotomy was performed.

After the resuscitation, on an FiO_2 of 1.0, blood gas analysis resulted a $PaCO_2$ of 61.8 mmHg, a PaO_2 of 116.4 mmHg, and pH of 6.97. Since she had demonstrated guarding during earlier abdominal examinations, she underwent laparotomy, which revealed grade IV liver injuries, mesenteric injuries, intestinal lacerations, and a grade III pancreatic transection. Peritoneal bleeding was controlled surgically and distal pancreatectomy was performed. During the operation, increased bronchial bleeding from coagulopathy due to hemorrhage, dilution, and hypothermia was noted. Left bronchial rupture at the division of upper and lower lobe bronchus was diagnosed by fiberoptic bronchoscopy. Since a size-appropriate double-lumen endotracheal tube was not available for isolation of the lung, massive intrabronchial bleeding from the left bronchial and pulmonary injury was controlled by a bronchial balloon tamponade technique using a Fogarty catheter placed in the left main bronchus proximal to the injury for 4 hours (Figure 1). Total bleeding from the time of incident to the end of operation was estimated at 3,000 ml, and resuscitation included the infusion of 2,100 ml of crystalloid and 2,800 ml of blood.

After surgical hemostasis was achieved, the patient was admitted to the intensive care unit. Management of respiratory insufficiency resulting from bilateral pulmonary contusions and a left intrabronchial clot was attempted by increased FiO_2, positive end-expiratory pressure ventilation, pressure-controlled inverse-ratio ventilation, prone ventilation, and permissive hypercapnia. However, a hemopneumopericardium developed, and the patient's subcutaneous and mediastinal emphysema worsened. Although the pericardium was opened and drained through a subxiphoid window and bilateral pleural drainage

Figure 1. Chest radiograph immediately after surgery. Left main bronchus was blocked by balloon catheter, and the left lung showed intrabronchial hemorrhage and atelectasis. Since the left lung was not expanded, the left pleural fluid has not drained sufficiently. In the right lung, pulmonary contusion and overexpansion were observed.

was doubled and secured, her respiratory function deteriorated. On an FiO_2 of 1.0, a respiratory rate of 30 breaths/min, a positive end-expiratory pressure of 15 cm H_2O, and peak inspiratory pressure of 30 cmH_2O, blood gas analysis revealed a $PaCO_2$ of 42.3 mmHg and a PaO_2 of 32.4 mmHg.

Although a pulmonary artery catheter was not inserted to measure transpulmonary shunt, in response to this deteriorating oxygenation, ECLS was initiated on the second hospital day. ECLS flow via the right femoral vein and artery was established at 2.0 L/min, contributing about 50% of cardiac output. The extracorporeal circuit consisted of a centrifugal pump and a hollow-fiber oxygenator (Terumo Corporation, Tokyo, Japan); the entire extracorporeal system was heparin coated. The whole blood activated clotting time was kept between 180 and 220 sec with continuous infusions of heparin sodium, 300 to 400 IU/hr, and nafamostat mesilate, 2.0 to 2.5 mg/hr (Futhan®, Torii Pharmaceutical Co., Ltd, Tokyo, Japan) (a protease inhibitor). The circuit was replaced every 3 days to maintain oxygenative ability of the hollow fibers. During ECLS, ventilatory settings were reduced to an FiO_2 of 0.35, a respiratory rate of 17 breaths/min, a positive end-expiratory pressure of 5 cm H_2O, and tidal volume of 100 ml in order to minimize barotrauma and oxygen toxicity. Meticulous pulmonary toilet and positional drainage of airway secretions were maintained throughout the course of ECLS. Vigorous lavage and suctioning were performed periodically if secretions were copious. Liquid ventilation was not available in our institute. The patient was sedated with continuous infusion of morphine, midazolam, and propofol. Systemic antibiotics were given to prevent surgical wound infection. Central hyperalimentation and enteral feedings via nasogastric tube were provided, and optimization of oxygen delivery by transfusion, selective use of inotropic agents, and careful intravascular volume management was achieved.

After 2 weeks of ECLS, the patient's pulmonary function recovered gradually. Sixteen days into the ECLS course, a bleeding complication was noted as a right hemothorax, and surgical hemostasis and drainage were performed through right thoracotomy. Considering the balance between improved pulmonary function and the added risk of coagulopathy, she was weaned from ECLS over 2 days; ECLS was terminated on the 18th day of its course. Right femoral cannulas were removed and vessels were surgically reconstructed. On the 22nd hospital day, the clot obstructing the left lower lobular bronchus cleared and respiratory function improved drastically. The patient was extubated successfully after 30 days of intensive care therapy and transferred to a general ward. She suffered posttraumatic epilepsy, which was well controlled with antiepileptic agents. She left the hospital for home with full recovery in 4 months after the incident and returned to her elementary school activities in 6 months.

Discussion

Enthusiasm for emergency department thoracotomy has waned over the past several years. The survival of patients receiving emergency department thoracotomy is less than 5%, and the mortality rate is significantly higher when it is performed for blunt injury.[1] Therefore, it is reported that thoracotomy is indicated only in select patients who have vital signs at the scene or upon arrival in the emergency department, or if the patient is experiencing witnessed deterioration or cardiac arrest.[2]

Our pediatric patient was awake but agitated at the scene and deteriorated during transport to our hospital. The cardiac arrest was witnessed by a trauma surgeon on arrival at the emergency department, and thoracotomy and internal cardiac massage were performed immediately. Tension hemopneumothorax was not apparent before the arrest despite careful physical examination, done while awaiting the results of imaging studies. The flexibility of a child's chest wall might result in organ damage without overlying injury, and the mobility of mediastinal structures might predispose a child to tension pneumothorax. In these situations, resuscitative thoracotomy may reveal reparable thoracic injury of lung, heart, aorta, esophagus, or diaphragm, as in this case, in which tension hemopneumothorax and pulmonary contusions were found. Left thoracotomy also allows immediate access for clamp occlusion of thoracic aorta if it were indicated for uncontrolled peritoneal bleeding. Although median sternotomy is another option to allow superior exposure to the mediastinum, we prioritized the immediate access through left anterolateral thoracotomy using simple instruments for resuscitation.

The technique of balloon tamponade (using the Fogarty catheter) to control endobronchial bleeding has been reported previously.[3] In our case, this technique was effective for hemostasis and one-lung ventilation. However, this blockage resulted in left endobronchial occlusion with clotted blood, which, together with severe pulmonary contusion, led to severe respiratory failure. During the postoperative course, ECLS was initiated since conventional ventilatory support was failing.

Accepted criteria for ECLS include patients with potentially lethal respiratory failure with a transpulmonary shunt greater than 30%, who are unresponsive to conventional management and whose primary condition is reversible.[4–6] The therapeutic principle of ECLS is to ensure adequate oxygenation by partially replacing pulmonary gas exchange. The lungs are not exposed to potential barotrauma and volutrauma from

mechanical ventilation or to oxygen toxicity from exposure to toxic FiO_2 levels. Therefore, the lung is better able to heal during this period of rest and support. Furthermore, ECLS allows a margin of minutes for broncho-alveolar lavage, which is particularly useful in a small pediatric airway.

Hill et al reported the first adult case of trauma managed successfully with prolonged ECLS in 1972.[7] A subsequent National Institutes of Health-sponsored randomized, multicenter, prospective trial failed to demonstrate improvement of survival in adults with acute respiratory distress syndrome managed with ECLS.[8] However, technology has changed considerably, and more recent studies in adults suggest better survival.[5,9] An adult with multiple injuries successfully treated with open heart massage in the operating room and ECLS was reported.[6] However, to our knowledge, survival and full recovery of a child with multiple injuries treated with combination of emergency department thoracotomy and ECLS have not been reported previously. In a retrospective review of pediatric blunt trauma patients, Steiner et al[10] reported survival in 4 of 6 cases treated with ECLS for respiratory failure. Although significant conclusions cannot be drawn from a limited experience, ECLS may prove useful in the treatment of posttraumatic acute respiratory failure. Further evaluation will be necessary to determine selection criteria for this invasive technique.

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References

1. Branney SW, Moore EE, Feldhaus KM, Wolf RE. Critical analysis of two decades of experience with postinjury emergency department thoracotomy in a regional trauma center. *J Trauma* 1988; 45(1):87–94.
2. Powell MA, McMahon D, Peitzman AB. Thoracic injury. In Peitzman AB, Rhodes M, Schwab CW, Yealy DM, eds. *The Trauma Manual.* Philadelphia, Lippincott-Raven Publishers, 1998, pp 199–225.
3. Kshettry VR, Bassett HF. The Fogarty balloon technique for the control of endobronchial bleeding. *Thorax* 1983; 38(8):640.
4. Germann P, Ullrich R, Donner A, et al. Extracorporeal lung assist (ELA) in adults: indications and application. *Acta Anaesthesiol Scand* Suppl 1997; 111:132–5.
5. Michaels AJ, Schriener RJ, Kolla S, et al. Extracorporeal life support in pulmonary failure after trauma. *J Trauma* 1999; 46(4):638–45.
6. Sasadeusz KJ, Long WB III, Kemalyan N, et al. Successful treatment of a patient with multiple injuries using extracorporeal membrane oxygenation and inhaled nitric oxide. *J Trauma* 2000; 49:1126–8.
7. Hill JD, O'Brien TG, Murray JJ, et al. Prolonged extracorporeal oxygenation for acute post-traumatic respiratory failure (shock-lung syndrome): use of the Bramson membrane lung. *N Engl J Med* 1972; 286(12):629–34.
8. Zapol WM, Snider MT, Hill JG, et al. Extracorporeal membrane oxygenation in severe acute respiratory failure: a randomized prospective study. *JAMA* 1979; 242(20):2193–6.
9. Anderson H 3rd, Shapiro MB, Delius RE, et al. Extracorporeal life support for respiratory failure after multiple trauma. *J Trauma* 1993; 37(2):266–72.
10. Steiner RB, Adolph VR, Heaton JF, et al. Pediatric extracorporeal membrane oxygenation in posttraumatic respiratory failure. *J Pediatr Surg* 1991; 26(9):1011–5.