Definitive femur fracture management while on extracorporeal membrane oxygenation for trauma related respiratory failure

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Abstract
Ongoing surgical intervention in the setting of salvage extracorporeal membrane oxygenation (ECMO) has not been previously described. We describe successful performance of long bone surgical fixation in the setting of polytrauma while on salvage ECMO therapy.

Keywords: extracorporeal membrane oxygenation; acute respiratory distress syndrome; traumatic lung injury

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Introduction
Repeated case reports have described successful use of extracorporeal membrane oxygenation (ECMO) for polytrauma patients with acute respiratory failure refractory to optimal ventilator management (1–4). As comfort with indications, contraindications and management of patients on ECMO improves, the restrictions for ongoing care while waiting for respiratory recovery are being examined. We present the successful performance of internal reduction and fixation of long bone fractures while on ECMO support with subsequent ECMO decannulation, extubation, and survival to discharge home.

Case
Our patient is a 27 year-old male found unresponsive 35 feet from the site where he was struck by a motor vehicle while riding his bicycle. Upon arrival in the trauma bay his heart rate was 108 beats/min, blood pressure 86/47 mmHg, and Glasgow Coma Score of 7. He was promptly intubated for airway protection. He subsequently became bradycardic and hypotensive, and two rounds of ACLS were performed due to pulseless electrical activity with return of spontaneous circulation. After stabilization, his injuries were assessed and included a left occipital condyle fracture, grade two liver laceration, grade one left renal laceration, large left pneumothorax, T5 vertebral body nondisplaced fracture, nondisplaced inferior sternal fracture, left clavicle fracture, left scapular body fracture, left 7–10 rib fractures with pulmonary lacerations, and right segmental femur 90 degree fracture (Fig. 1). No intrathoracic vascular injury or intracranial injury was identified, and a focused assessment with sonography for trauma (FAST) scan was negative. A left-sided chest tube was placed in the trauma bay as well as administration of three units of packed red blood cells and 5 liters of crystalloid. Upon arrival to the Surgical Intensive Care Unit, he underwent external traction pinning of the femur fracture.

No intervention was necessary for the liver or renal laceration. He had minimal output from his chest tube with a small air leak. Progressively worsening respiratory insufficiency contraindicated early surgical management of his femur fracture. By hospital day 6, his progressively worsening hypoxia refractory required salvage interventions, including a trial of airway pressure release ventilation (APRV), inhaled epoprostenol (20,000 μunits), inhaled nitric oxide (40 ppm), additional chest tube
placement for progressive pneumothorax, and paralytic therapy. Chest x-ray (Fig. 2) and clinical picture were consistent with severe adult respiratory distress syndrome (ARDS). Arterial blood gas was: pH 7.21, pCO2 77.4, pO2 41.5, HCO3 30.8, saturating 72%. Bi-level ventilation settings at this time were: high/low PEEP 30 cm/0 H2O, PEEP high/low time 5.4/0.6 seconds (frequency: 10 releases per minute), and FiO2 100%. Due to failure of maximal ventilator therapy, he was considered for salvage femoral-femoral veno-veno ECMO. Following heparinization (7,500 units of IV, approximately 80 u/kg bolus), percutaneous femoral-femoral veno-veno ECMO was initiated with a 23 F inflow cannula positioned in the lower inferior vena cava and a 23 F cannula at the level of the right atrium using a Medtronic Biomedicus BP-80 pump and tubing circuit (Minneapolis, MN, USA) and a Maquet Quadrox D oxygenator (Wayne, NJ, USA). Cannula placement in the internal jugular was contraindicated due to the inability to definitively rule-out a cervical spine injury. Initial flows were 4.2 liters/min on 100% oxygen. This resulted in an improvement and stabilization in his oxygenation and respiratory acidosis. Intravenous heparin anticoagulation was maintained with a target partial thromboplastin time (PTT) of 40–60 seconds. Due to his tenuous pulmonary status, his operative right femur fracture had not been definitively addressed and his femur was maintained in strict traction. To facilitate his ongoing care and minimize the risk of ongoing release of inflammatory mediators which increase risk of fat emboli, ongoing ARDS, renal failure and multiple organ failure, the decision was made to proceed to definitive surgical repair with open reduction and internal fixation while on ECMO therapy to allow possible improvement of his pulmonary function by removing skeletal traction and definitively stabilizing the femur fracture. While still on ECMO, heparin was held to allow his PTT to normalize and the procedure was performed in an uncomplicated manner (Fig. 3). The heparin was restarted 24 hours later. There were no visible clots/thrombus in the

Fig. 1. X-ray of right femur at time of admission demonstrating the complex fracture.

Fig. 2. Chest x-ray demonstrating severe bilateral pulmonary infiltrates consistent with adult respiratory distress syndrome.

Fig. 3. Intraoperative x-ray of right leg obtained after successful internal stabilization of femur fracture.
system and circuit inflow/outflow blood gases showed no change in oxygenator efficiency. Estimated blood loss was 400 cc, and he required no blood product during the procedure. The procedure was successfully performed with continuous ECMO system monitoring by an intraoperative perfusionist and supplemental cardiac anesthesia support with a protocol similar to our institutional guidelines for the management of patients requiring noncardiac surgery who are supported with mechanical ventricular assist devices (5). Care was taken not to disrupt the medial femoral access during the procedure. Conventional open-reduction and internal fixation, via a lateral incision, was successful and uneventful.

Postoperatively, after a total of 10 days of ECMO support, flows and oxygenation support were gradually weaned and he was successfully decannulated (Fig. 4). He was extubated 8 days later and transferred to a rehabilitation facility on post-trauma day 40. He has since returned home, on room air, and is ambulating without assistance.

Discussion
ECMO has been accepted as a salvage therapy for refractory failure secondary to ARDS (6). It has been successfully utilized in traumatic lung injuries resulting in ARDS; however, there has been some hesitation in this population given the presumed need for systemic anticoagulation to prevent circuit thrombosis (7). However, recent case reports identify successful management of heparin-free ECMO in the setting of clinical inability to anticoagulate secondary to traumatic brain injuries (8). Our experience demonstrates that the range of treatment options on extracorporeal support is still being expanded, emphasizing that many contraindications for ECMO are relative and each patient's clinical picture needs to be evaluated individually in the context of the experience of the team and resources available.

The parameters of ongoing definitive care in patients with polytrauma on ECMO have not been established. In our case, we demonstrated that continuation of operative care may be appropriate and can continue when improvement and cardiopulmonary stability have been accomplished with ECMO support. This concept is consistent with the prioritization of the injured or sick patient in which airway, breathing, and circulatory needs take priority. This is a strategy that we have been successful with in other similar catastrophic clinical situations – such as severe necrotizing soft tissue infections complicated by severe cardiopulmonary shock (9, 10). The decision to proceed with further non-life threatening injury management should be made while taking into account the likelihood of successful decannulation and overall outcomes. This can be very difficult at times and probably should reflect the inherent chances of meaningful survival independent of the extent of respiratory failure and the need for ECMO. The risk factors for survival in adults requiring ECMO for respiratory failure are variable, complex, and varying by precipitating cause of respiratory failure (11). These findings are clearly difficult to apply to an adult polytrauma patient. Nevertheless, the most significant known predictor of survival prior to initiation of ECMO in adults has been found to be the APACHE II score (12).

Fig. 4. Chest x-ray following successful ECMO decannulation prior to extubation.

Early definitive treatment of femur fractures versus delayed treatment was demonstrated to have potentially beneficial results in regards to minimizing ongoing pulmonary complications, respiratory failure, overall mortality, and hospital length of stay in a recent systematic review of treatment in polytrauma patients (13, 14). Unfortunately, early surgical stabilization is not always possible in patients who are critical ill, too unstable for transport or a major surgical procedure. In these patients, much like ours, the concept of ‘damage control orthopedics’ with external fixation with traction can be applied (15). The decision to pursue early total orthopedic care in a critically ill patient is subjective and may reflect the experience of the team combined with the ongoing needs and status of the patient. The severe refractory respiratory failure, hypoxemia, and hypercarbia in our patient clearly contraindicated any nonacute interventions – including even some basic nursing care, such as even turning for routine skin care – a task that was further challenged by his external fixation and traction. Based upon these principles of definitive therapy for orthopedic injuries, we elected to pursue open-reduction and internal-fixation of his femur fracture, once stable on ECMO. Pulmonary support with ECMO also provided the additional benefit of reducing the associated risk of a catastrophic fat embolism, a known complication of femur fracture.
management, in an already respiratory compromised patient (16). Overall, the goal was to definitively stabilize his leg to assist in his overall care – a goal, we believe we safely and appropriately accomplished as demonstrated by our good outcome.

**Conclusion**

The management of noncritical surgical needs of a stable patient on ECMO should not be contraindicated based on the presence of ECMO support alone. ECMO, much like other forms of critical care life-support, can serve as a valuable tool in the stabilization and management of polytrauma patients. With integrated multidisciplinary Teamwork, patients can undergo safe and definitive surgical intervention of their orthopedic injury with the goal of facilitating their overall recovery.

**References**