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Resuscitation of Fat Embolism Syndrome With Extracorporeal Membrane Oxygenation

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Abstract: Embolization of marrow fat appears to be an inevitable consequence of long bone fractures. Pulmonary fat embolism (FE) with cardiovascular collapse is associated with a high mortality rate because of acute right ventricular failure and hypoxia. Immediate and appropriate resuscitation is required to prevent sudden death. Although extracorporeal membrane oxygenation (ECMO) has been used for a multitude of applications involving respiratory and circulatory collapse, its full potential as a standard conventional therapy has yet to be exploited. Herein, we describe the successful use of veno-venous (V-V) ECMO in a trauma patient who initially presented with fractures of the right ulna and femur. After surgery, the patient rapidly decompensated despite massive ventilatory support and was placed on ECMO. ECMO support lasted approximately 120 hours followed by an uneventful recovery and discharge 10 days later. **Keywords:** extracorporeal membrane oxygenation, ECMO, fat embolism syndrome, trauma, hypoxia. *JECT. 2004;36:368–370*

Fat embolism syndrome (FES) is a collection of hematological, neurological, circulatory, and respiratory sequelae often associated with orthopedic trauma. Although the clinical incidence can reach 5–10% with multiple bone fractures, the postmortem incidence is thought to be much higher (1–3). The prevalence is approximately 1% among all bone fracture patients (1,4,5). Presentation may be fulminating, with pulmonary and systemic embolization of fat, right ventricular failure, and cardiovascular and respiratory collapse (4,6). More often, the onset is gradual with hypoxia, neurological symptoms, fever, and a petechial rash appearing typically 12–36 hours after injury (4,7). The spectrum of end-organ damage is the result of a variety of manifestations common to other critical illnesses; thus, diagnosis often is made by exclusion or post mortem. Although many therapeutic interventions and prophylactic strategies have been tried with varying success, no set standard is in place for treating such a condition (4).

The use of extracorporeal membrane oxygenation (ECMO) in infants has been much more encouraging than in adults mainly because of resolvable underlying disease and selection criteria. Although adult ECMO has not gained significant momentum as a standard therapeutic modality, there are many applications for its use. Unfortunately, adult ECMO remains a final effort for the treatment of circulatory and/or respiratory failure. Timing is undoubtedly the key to successful outcome, along with stringent recognizable criteria and rapid deployment.

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CASE DESCRIPTION

A 38-year-old male was apparently struck by a 200-lb I-beam and transferred by ambulance to the emergency room. The patient then underwent a series of x-rays and traumagram, which demonstrated a right midshaft femur fracture and an ulnar fracture. The fractures were splinted in the emergency room. The patient was admitted and scheduled for open reduction internal fixation of his right ulna and an intramedullary nailing of his femur under general anesthesia to be performed the next morning.

The patient had an uneventful surgery and was extubated in the operating room before being transferred to the postanesthesia care unit. While there, the patient had an acute onset of respiratory distress, which required reintubation, placement of a pulmonary arterial catheter, and bilateral chest tubes. Subsequent to hypoxia, pulmonary hypertension, tachycardia, petechial rash, and pyrexia FES was suspected (8). After reintubation, the patient was taken to the intensive care unit and was maintained overnight with varying ventilatory strategies. Milrinone also was initiated to help lower the pulmonary hypertension and provide inotropic support. At a maximum positive end-expiratory pressure (PEEP) of 30 cmH_2O, the patient was still unable to maintain adequate tissue oxygenation despite a cardiac index that ranged from 2.2 to 3.8 L/min./m^2. The patient further received a bedside celiotomy for a potential abdominal compartment syndrome. Despite massive ventilatory support as well as other respiratory and hemodynamic assisting techniques and therapies, the patient remained profoundly hypoxic. At this point, the decision was made to deploy the ECMO team.

CASE MANAGEMENT:

Pre-ECMO parameters:

pH = 7.27
PCO_2 = 46 mmHg
PaO_2 = 39 mmHg
FiO_2 = 1.0
Hct = 44
BSA = 2.2 m^2

Oxygenation Index (mean airway pressure x FiO_2/PaO_2) = 123

***O.I. > 40 may indicate of pulmonary insufficiency**

Ventilator settings = Volumetric diffusive ventilation (VDR®)

Inspiratory time: 4 seconds
Expiratory time: 2 seconds
Rate: 10 breaths per minute
Pulse Frequency: 750 Hertz
Pulse I/E: 2:1
Oscillatory continuous positive airway pressure: 15 cmH_2O
Mean airway pressure: 48 cmH_2O

Chest X-Ray = diffuse infiltrates bilaterally

V-V ECMO was initiated with a 21-Fr. cannulae percutaneously accessing the right femoral vein for drainage and a 21-Fr. cannulae percutaneously accessing the left femoral vein for flow. The Carmeda™-coated circuit consisted of a Medtronic 4500 oxygenator, ECMOtherm heat exchanger, and straight-line silicone venous bladder. The circuit was primed with approximately 1500 mL of leukocyte-depleted blood. Hardware consisted of a Jostra roller pump with Terumo CDI 500 arterial and venous blood gas monitoring. Pump flow ranged from 1.5 to 3.0 L/min with a half inch raceway, and the sweep gas flow ranged from 1.0 to 4.0 L/min. Heparin dose ranged from 2 to 15 units/kg/h, with the ACT ranging from 182 to 240 seconds. The ECMO run was uneventful and lasted approximately 120 hours. The patient was discharged approximately 10 days after ECMO termination and had an uneventful recovery.

Post-ECMO Parameters

pH = 7.36
PCO_2 = 43 mmHg
PaO_2 = 104 mmHg
FiO_2 = 0.55
Hct = 31
BSA = 2.2 m^2

Oxygenation index (mean airway pressure × FiO_2/PaO_2) = 8

Ventilator settings = pressure regulated volume control (PRVC)
Rate: 20 breaths per minute
Tidal volume: 500 mL
PEEP: 12 cmH_2O
Pressure Support: 20 cmH_2O
Inspiratory time: 1.0 second
Mean airway pressure: 15 cmH_2O

Chest X-Ray = moderately aerated with some consolidation in right lower lobe.

DISCUSSION

FES has a high mortality rate and presents a unique challenge for any medical center performing orthopedic trauma surgery, particularly when an ECMO team is unavailable (9,10). Furthermore, the increased postmortem incidence with FES may be the result of the unavailability of ECMO centers. Although a typical ECMO set-up was used, as demonstrated by Figure 1, we anticipate making improvements to blunt the inflammatory impact of this therapy and potentially broaden its availability to a larger patient population. Our future hopes are to investigate the new microporous membrane oxygenators that are intended for long-term use to improve efficiency and timeliness of delivery. By reducing the circuit size and using a centrifugal pump with a small footprint, it may be possible to develop a system that could be pole mounted and stationed on a patients bed. This would greatly facilitate transport and maneuverability. Although we have begun to implement some circuit-coating technology, our goal is to move towards a tip to tip set-up, as we have been unable to demonstrate clinical benefit from a biocompatibility and/or inflammatory perspective.

With numerous cardiac cases being performed off-pump, there is no better time for perfusionists to use their experience and expertise to expand into other facets of extracorporeal technology outside the surgical setting. Al-

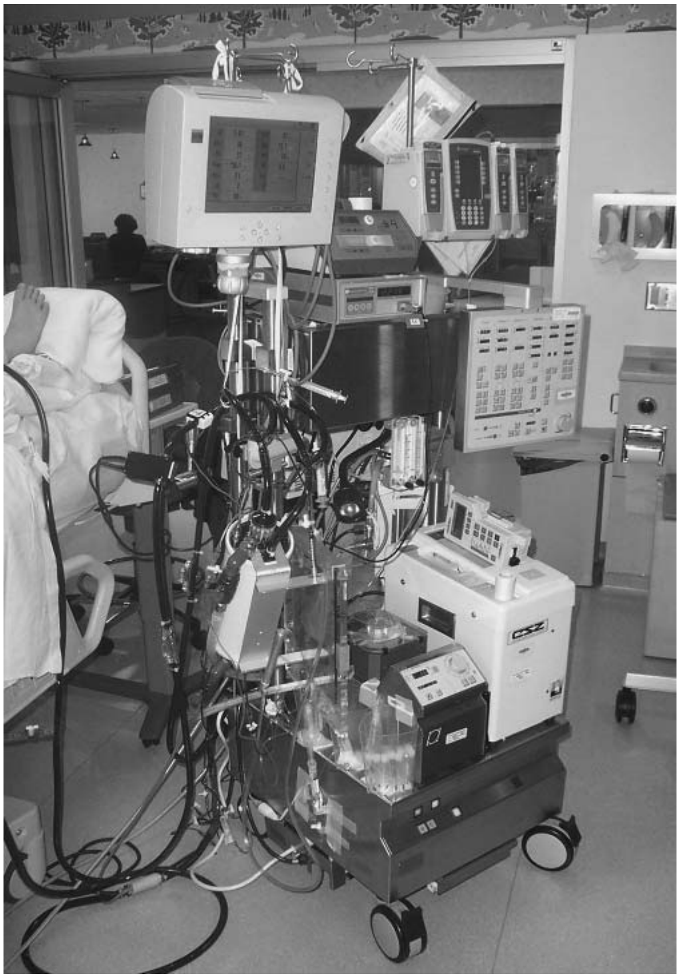

Figure 1. ECMO system.

though the data acquisition related to ECMO have greatly improved, in part because of the Extracorporeal Life Support Organization, the current ECMO circuitry is nearly identical to the original 20-year old design (11). This is truly an area that has yet to be fully exploited, and perfusionists remain pivotal to its developmental proliferation and therapeutic expansion.

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