Successful Use of Extracorporeal Membrane Oxygenation Therapy in Patients With 80% Full Thickness Burns

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Despite advances in burn care, mortality in adult patients with extensive burn injuries remains a concern, particularly in those who develop concurrent acute respiratory distress syndrome (ARDS). In cases of ARDS refractory to conventional treatments, venovenous extracorporeal membrane oxygenation (ECMO) may represent a viable salvage therapy, even in the major burn population. We present the case of a 38-year-old man with full thickness burns to over 80% of his body, who developed severe ARDS 4 days postburn. After failing to respond to deep sedation, paralysis, and proning, ECMO therapy was initiated to maintain oxygenation and ventilation. Over the next 14 days, while the patient was treated with ECMO, he successfully underwent three major operations to debride and allograft approximately 65% of his body surface area, including one in the prone position. ECMO therapy was discontinued on postburn day 18, and the patient had his wounds reconstructed and survived his injuries. To the best of our knowledge, this is the first report of a burn patient with such severe burns requiring surgical intervention that has been treated with ECMO and survived, and the first case of a burn patient on ECMO having surgery in the prone position. They conclude this case serves as a "proof of concept" that ECMO is a potential treatment for appropriately selected major burn patients with ARDS who fail to respond to other therapies.

The use of extracorporeal membrane oxygenation (ECMO) was first described in 1972[1] and was popularized for use in neonates with reversible lung disease in the late 1970s and 1980s.[2] Over the past four decades, the indications for this potentially life-saving technology have continued to expand. Its use in adults with reversible lung disease became more widely accepted during the H1N1 crisis in 2009 and 2010 among patients who failed conventional therapies (eg, lung protective ventilation, paralysis and proning) for severe acute respiratory distress syndrome (ARDS).[3]

Due to the need for anticoagulation to prevent circuit and membrane clotting, the use of ECMO may cause problematic bleeding in certain subpopulations including trauma and burn patients, especially if surgery is required. The first successful use of ECMO to treat respiratory failure in a patient with burn injury and resultant ARDS was reported in 1994.[4] Since that time, a growing body of evidence suggests that with careful patient selection, ECMO can be a useful salvage therapy.[5] We describe here the successful use of ECMO for management of severe ARDS refractory to other treatments in an adult patient with over 80% total body surface area (TBSA) full thickness burns requiring extensive surgical intervention.

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CASE PRESENTATION

A 38-year-old man was admitted to hospital with 82% TBSA burns following a house fire. His burns affected the entire body with the exception of a portion of his scalp, a portion of his right anterior torso, bilateral groins and genitals, and right pretibial area. Excluding the scalp, all were deep partial or full thickness burns. He was transported urgently to the emergency department at the regional burn center with activation of the trauma team, where he was emergently intubated in the emergency department. He was transferred to the intensive care unit (ICU) for co-management by the plastic surgery and critical care teams. In the first 12 hours of his admission, he required massive fluid resuscitation (approximately 16 liters of intravenous fluids) and vasopressors to manage his hypotension and tachycardia; bedside echocardiography demonstrated a severe burn-associated cardiomyopathy. We performed a bedside percutaneous tracheostomy because we feared a lost airway because of a precarious nasotracheal tube. He required escharotomies to his torso and all limbs, and bilateral lower eyelid canthotomies for elevated intraocular pressures. Bronchoscopy showed a grade 2 to 3 inhalational injury, based on the Abbreviated Injury Score.[6] Despite his inhalational injury, his initial ventilator requirements were reasonable for a patient with this extent of burn injury (pressure control mode, inspiratory pressure of 20 cm H_2O, PEEP of 10 cm H_2O, respiratory rate of 24, tidal volumes of 400 to 525 ml, and FiO_2 of 70%).

In the following 12 hours, he required another 8 liters of crystalloid and 5% albumin to maintain his blood pressure,

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urine output and perfusion, based on serum lactate. By 36 hours into his admission, vasopressors were weaned to low doses, his cardiac output improved, and his fluid requirements decreased. We planned to begin early excision and coverage of his burn wounds, using Integra (Integra Life Sciences), a bilayer dermal regeneration template for initial coverage, beginning on postburn day (PBD) #4. Unfortunately, starting late on PBD#3, the patient's respiratory status worsened acutely, with significant increases in his oxygen requirements and climbing airway pressures. This persisted despite deep sedation and paralysis. A chest radiograph demonstrated bilateral patchy infiltrates consistent with ARDS, and P_a/FiO_2 was as low as 43. Prone positioning briefly improved his oxygenation saturation and PaO_2 but over the next 2 hours his FiO_2 requirements returned to 1.0, with oxygen saturation levels in the 1980s and a climbing lactate. It was clear that the patient would die imminently without further intervention. In light of his young age and good health prior to his burn injury, we felt he was a reasonable candidate for salvage therapy with ECMO. After discussion with his wife about the significant risks, venovenous ECMO therapy was initiated.

The cardiovascular surgery team was consulted to urgently cannulate the right internal jugular and femoral veins. Transesophageal echocardiography (TEE) confirmed that both cannula were positioned appropriately in the right atrium and inferior vena cava, respectively. A heparin infusion was initiated to minimize the risk of circuit or membrane thrombosis, with a PTT target of 50 to 60.

With initiation of ECMO, the patient's oxygenation improved rapidly. We were able to adjust the ventilator to safer settings, using a pressure control mode, inspiratory pressure of 20 cm H_2O, PEEP of 10 cm H_2O, respiratory rate of 10, and FiO_2 of 30%. Despite improved oxygenation, the patient's lactate level continued to rise with a profound metabolic acidosis by PBD#5. Repeat TEE showed a worsening cardiomyopathy, with an ejection fraction of 15% to 20%. Initiation of an epinephrine infusion promptly improved cardiac function, and the patient's metabolic status normalized over 24 hours. Bloodwork indicated an acute renal injury with rising creatinine and hyperkalemia, so we initiated continuous renal replacement therapy in-line with the ECMO circuit.

The use of ECMO and CRRT improved the patient's oxygenation and perfusion and allowed us to begin surgical debridement on PBD#6. We chose to limit surgery to the left lower extremity, to determine whether we could safely operate on ECMO without excessive peri- or postoperative bleeding. His heparin infusion was held for 4 hours before and after surgery. We discontinued continuous renal replacement therapy just before transporting the patient to the operating room (OR). Surgery was conducted in the OR, approximately 300 m from the patient's room on the same floor of the hospital. He was transported to the OR with the ECMO circuit connected and operating normally, and the surgery was conducted without disrupting ECMO. We took great care to prevent dislodgement of the cannula during transport and intraoperatively, and our perfusionist team was present at all times to monitor ECMO flows.

To minimize bleeding and decrease operative time, we performed a fascial excision of all burn wounds. In a burn patient with such extensive burns, we would normally debride the wounds and apply Integra immediately, but given the patient's high risk of mortality and hematoma formation, we instead applied cadaveric allograft and secured it with a negative pressure wound therapy (NPWT) dressing. Based on the success of this case, the patient underwent two further debridements while on ECMO. We debrided and allografted both upper extremities on PBD#10, and the majority of the patient's torso on PBD#13. To access both the anterior and posterior trunk without shearing any fresh allograft during position changes, we used a Jackson OR table, which is designed for intraoperative position changes from supine to prone and vice versa. This allowed us to debride the patient's back and flanks, cover with allograft, apply half of the NPWT dressing, and then carefully rotate the patient and table into the supine position to complete the remainder of the case. The turn was performed safely, without any significant reductions in ECMO flows. This is, to the best of our knowledge, the first report in the literature of a burn patient on ECMO being operated on in the prone position.

Following his third debridement, approximately 60% to 65% of the patient's TBSA had been excised and grafted, with only his right lower extremity and face still requiring debridement. As we debrided and allografted his burns, his overall condition stabilized, with improved oxygenation and ventilation and normalized renal function. On PBD#17, venovenous ECMO was discontinued, after a total of approximately 330 hours. For the majority of his time on ECMO, his flows varied between 3.5 and 7 liters/min; but were not so consistently above 4 liters/min that we felt comfortable not anticoagulating him. We debrided and allografted his right lower extremity and face on PBD#19. Several days later, we began the process of replacing his cadaveric allograft with Integra. This was performed in three surgical cases over a 2-week period, with excellent take. The next stage of his reconstruction involved coverage of his neodermis with Meek autografts, as well as sheet grafting of his face and bilateral hands.

DISCUSSION

This case report describes successful use of salvage venovenous ECMO therapy in a major burn patient (>80% TBSA full thickness burns) with ARDS, who would certainly have died without this intervention. Furthermore, we were able to perform extensive surgical intervention while the patient was still on ECMO, including one surgery in which the patient was placed in the prone position. To the best of our knowledge, this is the first time ECMO has been described in a patient with this extent of full thickness burn injury, and the first case of such extensive burn debridement while on ECMO in the prone position.

One of our main concerns around the use of ECMO in this patient requiring extensive surgical debridement and reconstruction was the anticoagulation necessary to prevent ECMO circuit thrombosis. At our institution, we titrate our anticoagulation based on the activated clotting time for the first 24 hours, and then follow the partial thromboplastin time; we set a target of 50 to 60 seconds for this patient. In this case, holding the heparin for four hours preoperatively

and restarting it four hours postoperatively seemed to avoid any dangerous bleeding. The only potential "downside" of a slightly lower PTT target was that the ECMO oxygenator membrane had to be changed once due to slow accumulation of thrombus, but this was done smoothly without incident.

The acute care of this patient is complete; he is now in the rehabilitation stage of his recovery. His wounds are closed, his tracheostomy has been removed, his cognition is excellent, he no longer requires opioids, and he has been discharged from our institution's rehabilitation hospital to his new home. It is important to note several complications that arose during his care. The first and most life-threatening was obviously ARDS, which was likely a result of the severity of his burns, his inhalational injury, and his massive fluid requirements early in his resuscitation. After the application of Integra to all of his wounds (excluding his face), the patient stabilized and was transferred out of the ICU, but developed an acute, severe infectious pancolitis and sepsis that required re-admission to the ICU. Finally, the patient developed a profound weakness that continues to affect his functional recovery, likely due to a combination of critical illness neuropathy (confirmed on nerve conduction studies and electromyography), skeletal muscle atrophy related to his burn and hypermetabolism, and disuse from periods of prolonged sedation and short periods of immobilization after grafting. Fortunately, this shows signs of resolution, with a slow but gradual return of muscle function.

The role of ECMO in the care of burn patients continues to evolve. The Extracorporeal Life Support Organization and National Burn Registries have both shown that burn patients treated with ECMO have survival rates of 43% and 47%, respectively,[7,8] an improvement from earlier systematic reviews.[9] This may suggest that with improved ECMO technologies and more experience, it represents a valuable salvage therapy in ARDS that has not responded to traditional treatment modalities. Our experience with this patient would certainly support its role in even the most severe of burn cases.

CONCLUSION

We believe this case to represent the first report in the burn literature of a patient with such extensive full thickness burns requiring debridement (80%+ TBSA) being initiated and weaned off of ECMO with a successful outcome. Furthermore, this may be the first time that a burn patient has been operated on in the prone position while on ECMO. As such, this case serves as a "proof on concept" for what is possible in even the sickest of burn patients, in a young man who would not otherwise have survived without the appropriate use of this therapy. Although there are a host of physiological and logistical issues involved in its application, we believe further study is warranted to determine the role of ECMO in the care of patients with extensive burns.

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