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# Extracorporeal membrane oxygenation in severe respiratory failure resulting from burns and smoke inhalation injury

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ABSTRACT

Extracorporeal membrane oxygenation (ECMO) is one of the most frequent forms of extracorporeal life support (ECLS) and can be used as rescue therapy in patients with severe respiratory failure resulting from burns and/or smoke inhalation injury. Experience and literature on this treatment option is still very limited, consequently results are varied. We report a retrospective analysis of our experience with veno-venous (VV) ECMO in burn patients. All five patients, three male and two female (age: 28-37 years) had flame type burns and smoke inhalation injury. Their Murray scores ranged between 3.25 and 3.75, and their revised Baux scores between 62 and 102. The mean pre-ECMO conventional ventilation time was 7.4 days (3-13). The mean ECMO duration was 18 days (8-35). Three patients were cannulated with dual lumen, two with separate cannulae. One oxygenator had to be changed due to technical issues and two patients needed two parallel oxygenators. Four patients had renal replacement therapy. All patients needed vasoconstrictor support, antibiotics and packed red blood cells (5-62 units). Three had steroid treatment. All five patients were successfully weaned from ECMO. One patient died later from multi-organ failure in the ICU, the other four patients survived. VV-ECMO is a useful rescue intervention in patients with burns related severe respiratory failure. Patients in our institution benefit from having both burns and ECMO centres with major expertise in the field under one roof. The results from this small cohort are encouraging, although more cases are needed to draw more robust conclusions.



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## 1. Introduction

Pulmonary injury resulting from burns and/or acute smoke inhalation presents with multifaceted pathophysiology. The profound inflammation of airways with pulmonary shunting as well as augmented micro-vascular pressure gradient often results in hypoxemic respiratory failure [1–3]. Acute lung injury (ALI) as a result of smoke inhalation contributes significantly to the overall morbidity and mortality of fire victims. Thirty years ago, Shirani et al. [4] described additive effects on mortality in patients with burns and inhalation injury. The authors reported increased mortality of burn patients of approximately 20% with smoke inhalation, up to 40% from pneumonia, and up to 60% if both were present (at the midrange of age and burn size) [4,5].

Extracorporeal membrane oxygenation (ECMO) is a relatively new technology that emerged about 50 years ago and today is routinely used in specialized centres for neonatal, pediatric, and adult respiratory and cardiac failure [7]. It was used for the first time in a burn patient in 1994 [6]. ECMO can be used in veno-venous configuration (VV-ECMO) to provide adequate extracorporeal gas exchange in isolated refractory respiratory failure of numerous causes, or in veno-arterial configuration (VA-ECMO), when support for cardiac and/or circulatory support is required [8]. The overall goal of ECMO in patients with severe respiratory failure is to achieve adequate gas exchange, and to allow a reduced intensity of mechanical ventilation, thereby decreasing the potentially deleterious effects of ventilator-induced lung injury prior to recovery. Consequently, ECMO may be considered the definitive rescue therapy for refractory life-threatening hypoxemia, since pulmonary gas exchange is not required [5,9].

The use of ECMO in neonatal respiratory failure has been established for decades and is supported by randomized trials [10]. Use in adult respiratory failure is more controversial given poor outcomes in early randomized trials [11,12]. The CESAR trial from 2009 [13] and various case series have shown improved outcomes with survival rates between 75% and 85% in patients with refractory respiratory failure who were referred to an ECMO centre [14,15]. To date, only a few studies assessing ECMO in the field of burn and/or acute smoke inhalation injury have been published. This retrospective study reports our experience with five patients requiring ECMO for severe hypoxemic respiratory failure post-burn and smoke inhalation injury.

## 2. Material and methods

The respiratory ECMO service at Wythenshawe Hospital was founded on December 1st, 2011. All patients with burn and/or smoke inhalation injury who were ever treated on ECMO were retrospectively reviewed up to June 30th, 2017. Where appropriate, telephone enquiries were carried out about the post-intensive care course. Data was safely stored in the hospital's ECMO database. This was an internal audit and service review that did not require ethical approval, as determined by the National Health Service health research authority decision tool (www.hra-decisiontools.org.uk/research).

For drainage and return lines either the right internal jugular veins were cannulated using size 27Fr– 31Fr AVALON ELITE® Bi-Caval Dual Lumen (Avalon Laboratories, Maquet, Germany) cannulae or either separate bi-femoral, or separate right femoral vein drainage cannulae (size 23Fr, length 38 cm or 55 cm) (Venous HLS Cannula, Bioline Coating, Maquet, Germany) with right internal jugular vein return (Art. HLS cannula, Bioline Coating, Maquet, Germany; size 21Fr) cannulae were inserted. Sorin Vascular Dilator Kits (Sorin Group USA, Arvada, Colorado, USA) was used during cannulations. The type of cannula used was determined by the inserting consultant depending on the individual and situation; e.g. patient size and expected flow requirements as well as vascular access availability to avoid cannula placement through burned tissue. The cannulae were stitched and tubing secured with adhesive dressings.

The ECMO circuits consisted of Levitronix® consoles, CentriMag blood pump (Thoratec Corporation, Pleasanton, CA) with Medos Hilite® 7000 LT, Paragon PMP Adult Midi® 7000L, or Paragon PMP Adult Maxi® 7000L oxygenators, a mechanical gas blender (Sechrist Industries, Anaheim, CA), and Hirtz HICO-Variotherm 550 heater-cooler system (Hirtz & Co. KG, Cologne, Germany).

All patients were anti-coagulated with heparin according to standard departmental protocol aiming to keep the ACT between 160 and 180 s [16]. When patients required debridement, grafting or dressings, the anticoagulation was stopped approximately six hours before and was restarted approximately 12 h after the procedure if there was no bleeding. If bleeding from wounds occurred, the anticoagulation was stopped for as long as needed with no complications seen.

All patients were kept endotracheally intubated and sedated with alfentanil, midazolam and ketamine. Dräger Evita 4 (Drägerwerk AG & Co., Germany) ventilators were used. Lung protective ventilatory settings were applied using pressure control mode (PIP: 20 cm$H_2O$, PEEP: 10 cm$H_2O$, RR: 10/min, 1:1 I:E ratio, $FiO_2 < 0.4$) all along the ECMO runs except during the final 'ECMO trial-off' phases.

ECMO specialist nurses took care of the circuits and intensive care nurses provided the nursing care in the critical care unit. Perfusionists frequently checked the circuits and console functions. Specialist burn medical and nursing staff from the burn intensive care unit provided the daily burn wound care. All patients had broad-spectrum antimicrobial treatment and dedicated hospital consultant microbiologists looked after the antimicrobial management. Daily physiotherapy and dietician review supported the multidisciplinary effort.

ECMO was continued until obvious signs of lung recovery: significant improvement in lung compliance, gas exchange and radiological improvement on regular chest X-rays. All patients had a brief trial period without oxygen sweep flow before decannulation.

## 3. Results

Since the respiratory ECMO service was started, six patients have been referred for VV-ECMO with burns and burn related inhalational injury causing severe respiratory failure. Five patients were suitable for VV-ECMO and received the

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