

Case Report

Ground Transportation of a Pediatric Patient on ECMO Support

David Machin, BSc (Hons), ACP; Richard Scott, ACP; Aimee Hurst, BSc (Hons), ACP

Perfusion Department, Theatres, Glenfield Hospital, Leicester, United Kingdom

Abstract: Extracorporeal membrane oxygenation (ECMO) is a technique for providing cardiac and/or pulmonary support. Many hospitals worldwide practice ECMO at some time, yet few centers are able to offer a portable ECMO service, with the United Kingdom being of no exception. We describe the first reported successful ground transfer of a 22-kg girl with suspected myocarditis, supported by veno-arterial ECMO between two hospitals within the United Kingdom (UK). A modified Falcon

series 2 patient stretcher was used to transport the patient and house the ECMO hardware, consisting of a Levitronix CentriMag pump system, a Hico-variotherm 550 heater/cooler unit, and an oxygen supply. Design limitations and future technical recommendations of the portable ECMO system subsequent to clinical experience are discussed. **Keywords:** extracorporeal membrane oxygenation, Levitronix CentriMag, Hico-variotherm 550, portable ECMO system. *JECT. 2007;39:99–102*

The technique of extracorporeal membrane oxygenation (ECMO) is used to provide cardiac and pulmonary support. This treatment has been used in >23,000 neonatal, 7,000 pediatric, and 2,000 adult patients. There are many hospitals worldwide that practice ECMO at some time, but only 169, including our own institute, are benchmarked by the Extracorporeal Life Support Organization (ELSO) Registry (1). Furthermore, a minority of ECMO centers worldwide offer ECMO transportation as a service, with Cornish et al. (2) and Heulitt et al. (3) in the United States reporting their first ECMO transfer of a neonate in 1986. Currently, in the United Kingdom (UK), there are no established ECMO transport providers.

This report discusses the successful ground transportation of a pediatric patient receiving veno-arterial ECMO for cardiopulmonary support. The patient was transported between a children's hospital and a designated ECMO center within the United Kingdom.

CASE REPORT

Patient History

A 22-kg pediatric girl with a recent history of varicella

was admitted to Alder Hey Children's Hospital, Liverpool, UK, after episodes of vomiting and abdominal pain. A transthoracic ultrasound scan identified dilated cardiomyopathy, which was later thought to be caused by myocarditis. The scan also revealed a large pericardial and right pleural effusion; therefore, the patient was intubated and transferred to the cardiac catheter suite for drainage of both effusions. During the procedure, cardiac arrest occurred, and effective cardiopulmonary resuscitation was performed over a 10-minute period. After stabilization, the patient was admitted to the intensive care unit. Despite increased inotropic drug support, there was progressive deterioration in hemodynamic and pulmonary function; thus, veno-arterial ECMO was initiated.

Static ECMO Circuit Design

ECMO cannulation was achieved through a transthoracic approach through a median sternotomy, using a 25-Fr DLP right-angled venous cannula situated in the right atrium and an 18-Fr elongated one-piece arterial cannula placed in the ascending aorta (Medtronic, Minneapolis, MN). Decompression of the heart was necessary by placement of a 13-Fr DLP left heart vent catheter in the left atrium. The "static" ECMO circuit consisted of a Stockert SIII roller pump (Stockert, Munich, Germany) and a Betta-Tech CU 400 heater/cooler unit (Betta-Tech Controls, Milton Keynes, UK) secured onto a Stockert four-pump base, a Hilite 7000 LT oxygenator (Medos, Stolberg, Germany), and 3/8 in. polyvinyl chloride (PVC) and 1/2 in.

Address correspondence to: David Machin, Senior Perfusionist, Perfusion Department, Theatres, Glenfield Hospital, Groby Road, Leicester, LE39QP, UK. E-mail: machin_david36@hotmail.com

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Tygon HL 65 “raceway” tubing (Saint-Gobain Performance Plastics, Akron, OH). A blood flow rate of 2 L/min and sweep gas rate of 1 L/min with 100% FiO₂ was maintained on the ECMO circuit to provide physiologic biochemical parameters. Systemic anti-coagulation with an unfractionated heparin infusion was used to maintain an activated clotting time (ACT) between 200 and 220 seconds by measurement with an ACT II system machine (Medtronic). Ventilator “rest” settings of positive inspiratory pressure (PIP) 25 cmH₂O, positive end-expiratory pressure (PEEP) 5 cmH₂O, and a respiratory rate of 20 breaths/min were applied.

Three days of ECMO support did not show any significant improvement in heart function, so the decision was made to transfer the patient to a specialist center for further assessment and possible bridge to heart transplantation. Our institute was contacted to assist in the transfer of the patient from Alder Hey Children’s Hospital to Great Ormond Street Hospital for Sick Children (GOSH), London, UK.

Portable ECMO Design

A modified Falcon series 2 patient stretcher trolley (Ferno, West Yorkshire, UK) was used to house the mobile ECMO equipment and transport the patient. A Levitronix CentriMag centrifugal pump console and back-up unit (Levitronix, Kurich, Switzerland), Hico-variotherm 550 heater/cooler unit (Hirtz and Co., Cologne, Germany), and two 680-L oxygen cylinders (to supply the oxygenator and transport ventilator) were located in the

trolley base. A Hilite 7000 LT oxygenator and CentriMag blood pump and drive unit were mounted to the upright struts on the side of the trolley base (Figure 1). The circuit was made up of 3/8 in. PVC tubing, an arterio-venous loop, and two double leuc connectors within the venous line (pre-centrifugal pump) to measure blood pump inlet pressure, enable blood sample analysis, and allow heparin infusion. A spare oxygenator, centrifugal pump and drive unit, 3/8 in. PVC tubing, and polycarbonate tubing connectors were at hand, because of the high level of technical adversity associated with procedures of this nature. A VentiPAC 2D transport ventilator (SIMS pneuPAC, Luton, UK), a Propaq Encore patient monitoring system (Welch Allyn Medical Products, Skaneateles Falls, NY), and drug infusion pumps were mounted on an overbed table attached to the trolley.

The circuit was initially primed with 600 mL of Plasma-lyte A, which was partially exchanged for 1 unit (~280 mL) of patient cross-matched homologous blood, 120 IU unfractionated heparin, 16 mL (8.4%) sodium bicarbonate, and 2 mL (14.7%) calcium chloride. Biochemical analysis was taken from the sanguineous circuit prime to assure acceptable physiologic values before connection of the portable ECMO circuit to the patient.

After patient transfer to the transport trolley, the arterial and venous lines of the “static” ECMO circuit were divided, and patient connection to the portable ECMO circuit was established without any major hemodynamic instability. Blood pump flow rate, oxygenator sweep gas rate, and ventilator settings were maintained at the static

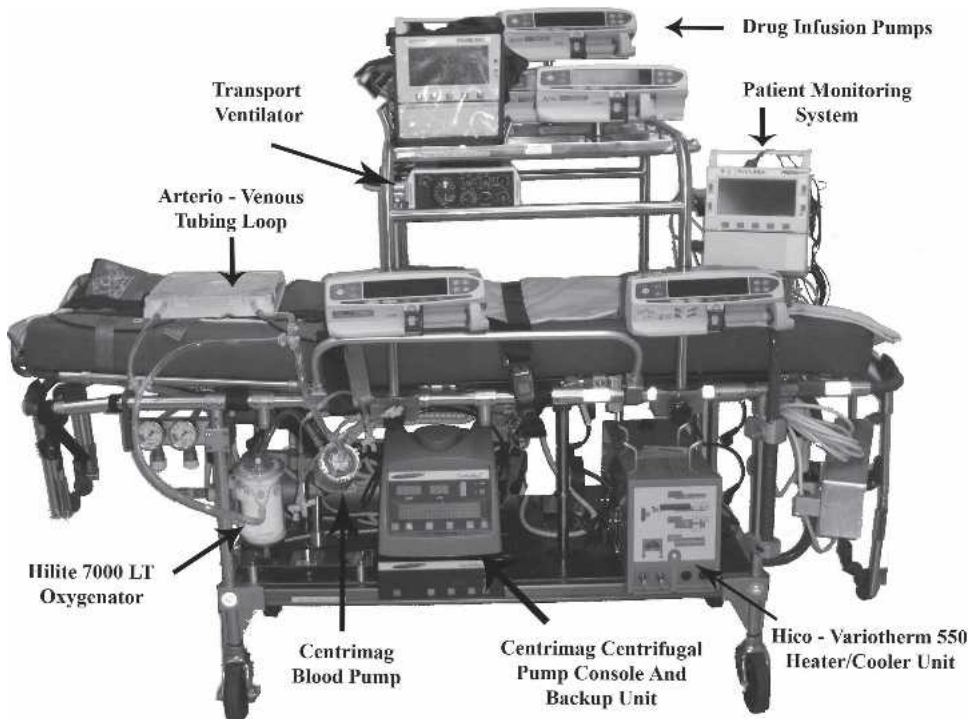


Figure 1. Portable ECMO system for ground transportation at Glenfield Hospital, Leicester, UK.

ECMO parameters. ACT values were targeted at 160–180 seconds using MAX-ACT tubes and an Actalyte Mini ACT machine (Helena Laboratories, Beaumont, TX). The patient was transported uneventfully in a land ambulance (Careflight, Stansted Airport, Essex, UK) fully equipped with ample oxygen (2 × 2300-L oxygen cylinders) and power supply (1.5-kW maximum power output) for portable ECMO support of ~4 hours between Alder Hey and GOSH. On arrival to the Pediatric Intensive Care Unit, the CentriMag blood pump and console of the portable ECMO circuit were attached to a static ECMO cart, and the patient was transferred onto a bed. Over the next few days, cardiac function improved, and the patient was able to make a full recovery.

DISCUSSION

The success of portable ECMO relied on the availability of personnel, appropriate and reliable equipment, adequate transport vehicle specification, sufficient funds, and good communication between the ECMO team and hospitals involved. Our ECMO transport team consisted of an ECMO specialist, ECMO fellow, pediatric intensivist, perfusionist, and ambulance driver/paramedic. In addition, participation of perfusionists, nurses, and medical staff at the referral hospital and receiving ECMO center made transportation more attainable.

The use of a long-term (true membrane) oxygenator and the Levitronix CentriMag blood pump enabled patient support on the same circuit during and after transit. Hence, a reduction in patient exposure to new circuitry will attenuate the inflammatory response, decrease homologous blood product use, and lessen hemodilution (4). The consequences of multiple extracorporeal circuit exposure may have been further reduced by adapting the existing static ECMO circuit for transportation, with sole exchange of the roller pump component for the CentriMag pump.

The design of the CentriMag blood pump provided reliability and extended use because of the elimination of wearable components, i.e., no seals or bearings. The product has European Conformity (CE) mark approval for 14 days of use and thus complies with the relevant European health, safety, and environmental protection legislation. The pump rotor is magnetically levitated and rotated by a series of static (passive) and electro (active) magnets (5). The CentriMag console incorporates an internal battery with availability of a back-up console containing an interchangeable external battery (each providing power for 1 and 3 hours at 3 L/min nominal load, respectively). It features a simple display panel (flow rate, RPM, and system status); low power consumption (120 W); and light weight material (6.6 kg), making it ideal for transport use.

However, battery power could only accommodate the blood pump for a limited period with no active patient temperature control, i.e., no heater/cooler power. The selection of an inverter-equipped ambulance to supply mains AC with a generous power output of 1.5 kW to the ECMO equipment was crucial. Furthermore, the efficiency of the Hico-variotherm 550 heater/cooler device (320 W maximum in comparison to our standard 1-kW Betta-Tech CU 400 heater/cooler) allowed patient temperature to be maintained at 36.5°C nasopharyngeal during ambulance transfer without loss of vehicular power. The relatively low weight (17 kg) and small size (200 × 290 × 440 mm) of the Hico-variotherm also contributed to a reasonably manoeuvrable ECMO trolley.

Attributed to the present design of the portable ECMO trolley, a number of problems and limitations existed. Patient intervention was compromised by the presence of the overbed table, the heater/cooler unit had no battery back-up facility, and accessibility to the oxygenator and blood pump was restricted by their position. Repositioning of the oxygenator and blood pump under the head of the trolley would have afforded easier access and allowed placement of transport ventilator, patient monitor, and infusion pumps in the trolley base. Consequently, the need for an overbed table would be unnecessary.

With an understanding of the technical and design problems observed, the construction of a compact and light weight (~15 kg) ECMO/vital organ support platform for neonatal, pediatric, and adult land and air transportation is currently underway. An ingenious portable device is commercially available, known as the LIFEBRIDGE mechanical circulatory support system (Lifebridge Medizintechnik, Ampfing, Germany); nonetheless, we feel that the features of this system do not conform to our requirements (6). There is a risk of extracorporeal circuit thrombosis within the components of the LIFEBRIDGE during low-dose heparin requirements of ECMO, because a venous reservoir and arterial line filter are present. A facility for patient temperature regulation is also not integrated into the system; an optional heater/cooler unit must be used, therefore restricting the compact design. Finally, the incorporation of a microporous polypropylene oxygenator and a short-term battery back-up facility of ~2 hours (does not include separate battery set) limits the period of support with the LIFEBRIDGE.

This case report, in addition to a previous unreported successful pediatric transfer from our institute to a cardiac transplant center, shows that a safe and effective portable ECMO service can be provided. The application of an appropriate blood pump incorporating a back-up battery supply, the use of a low power-consuming heater/cooler device, and the availability of an ambulance with a sufficient power output facility were pivotal in the provision of ECMO transport.

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REFERENCES

1. Extracorporeal Life Support Organization. ECLS Registry Report, International Summary. Ann Arbor, MI: Extracorporeal Life Support Organization; 2006.
2. Cornish JD, Carter JM, Gerstmann DR, Null DM Jr. ECMO as a means of stabilizing and transporting high risk neonates. *ASAIO Trans.* 1991;37:564–68.
3. Heulitt MJ, Taylor BJ, Faulkner SC, et al. Inter-hospital transport of neonatal patients on extracorporeal membrane oxygenation: Mobile ECMO. *Pediatrics.* 1995;95:562–66.
4. Dickes MS, Buckley KW, Glogowski KR, Raff GW, Geiss DM. Conversion from extracorporeal membrane oxygenation to total cardiopulmonary bypass: A simplified method. *J Extra Corpor Technol.* 2003;35:196–99.
5. Mueller JP, Kuenzli A, Reuthebuch O, et al. The CentriMag: A new optimized centrifugal pump with levitating impeller. *Heart Surg Forum.* 2004;7:E477–80.
6. Mehlhorn U, Brieske M, Fischer UM, et al. LIFEBRIDGE: A portable, modular, rapidly available “plug-and-play” mechanical circulatory support system. *Ann Thorac Surg.* 2005;80:1887–92.