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· Extracorporeal Membrane Oxygenation (ECMO)

· Extracorporeal Cardiopulmonary Resuscitation (ECPR)

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Children and adults with severe, life-threatening cardiopulmonary failure represent some of the most challenging patients in modern medicine. When standard therapeutic interventions are inadequate to support these patients, extracorporeal membrane oxygenation (ECMO) may be used to provide temporary hemodynamic and respiratory stabilization. ECMO involves the use of a specialized external blood pump and oxygenator to either replace or partially support the function of a patient's heart and lungs. Since its introduction three decades ago, over 27,000 patients have been supported by ECMO, with over 1,700 supported in 2009 alone. Although initially developed to treat patients with refractory respiratory failure, ECMO has been increasingly used to provide mechanical support for patients with predominately myocardial failure. Advances in ECMO technology have enabled physicians to expand the role of ECMO in caring for critically ill patients. The ECMO program at Seattle Children's Hospital is one of the busiest in the country.

Integration of Technology

Recent advances in the development of blood pump circuits and improved circuit-blood interface biocompatibility have provided clinicians who treat ECMO patients with the opportunity to offer cardiopulmonary support to a wider range of patients and for longer periods of time. A major focus of my clinical research is examining the interaction of advanced ECMO circuit components in specific clinical settings. We have recently shown that postoperative bleeding can be dramatically reduced by using a specially designed ECMO circuit that requires less systemic anticoagulation (Figure 1). Using this type of ECMO circuit enables pediatric cardiac surgeons to more safely transition to ECMO support in the operating room.

Our team is also examining patients who develop renal failure while supported by ECMO. By incorporating newer chronic renal replacement therapy (CRT) equipment into an ECMO circuit, we hope to achieve safer and more efficient hemodialysis and fluid management.

Patients who require only respiratory assistance may be supported by venovenous ECMO, which involves extracorporeal central venous gas exchange. A significant limitation of this strategy is deformation of the single-lumen veno-venous ECMO cannula over time. Seattle Children's Hospital is one of the first American centers to incorporate the new Avalon wire-reinforced venovenous ECMO cannula into our circuit. We are currently examining the safety and efficacy of the new Avalon cannula in neonates with severe respiratory failure.

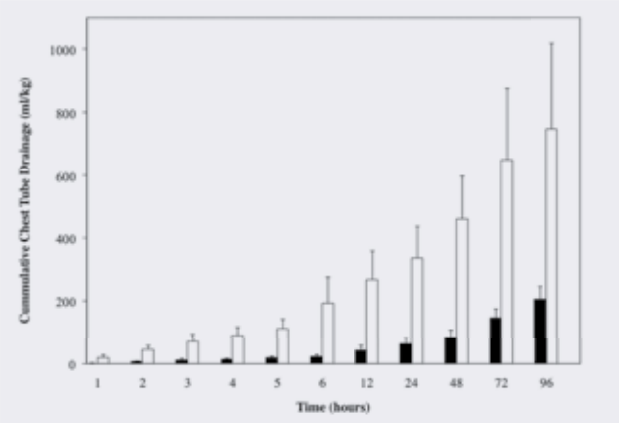

Figure 1: Bleeding is reduced when a specialized ECMO circuit is used during the early postoperative period. (Black Bars represent a specialized ECMO circuit; white bars represent a standard ECMO circuit.)

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Clinical Outcomes

Using data from several international clinical databases, we are examining differences in clinical outcomes related to ECMO in a variety of patient populations. Specifically, we are evaluating the safety of ECMO when used to support patients at extremely low birth weight and gestational age. We are also evaluating the international trend of using centrifugal ECMO pumps to support neonatal patients. Working with our pediatric cardiology colleagues, we are defining predictors of clinical outcome in patients with life-threatening dysrhythmia who may need ECMO support and patients who require percutaneous cardiac catheterization while receiving ECMO support.

ECPR

Extracorporeal Cardiopulmonary Resuscitation (ECPR) is a novel therapeutic strategy that involves the rapid initiation of ECMO support in children who have experienced cardiac arrest requiring cardiopulmonary resuscitation (CPR). Although ECPR is currently only offered at a limited number of medical centers in the United States, it is emerging as an important method of rescuing critically ill children who would otherwise die. Studies have shown that ECPR improves survival from approximately 1% to 38% in appropriately selected patients. However, neurological injury is a well-recognized complication of ECMO, affecting up to 10% of certain patient populations. Furthermore, long-term neurodevelopmental complications are observed in up to 50% of ECMO survivors. The percentage of ECPR survivors who suffer significant neurologic injury is unknown. We are enrolling patients in a prospective trial designed to determine whether neurodevelopmental outcomes are worse in ECPR patients than in ECMO patients in general.

RELATED PUBLICATIONS

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3. McMullan DM, Oppido G, Davies R, Kawahira K, d'Udekem d'Acoz YAC, Penny DJ, Brizard CP. Surgical Strategy for the Bicuspid Aortic Valve: Tricuspidization with leaflet extension versus pulmonary autograft. *J Thorac Cardiovasc Surg* 134:90-98, 2007.
4. McMullan DM, Reddy VM, Gottliebson WH, Silverman NH, Perry SB, Chan F, Hanley FL, Riemer RK. Morphological studies of pulmonary arteriovenous shunting in a lamb model of cavopulmonary anastomosis. *Pediatr Cardiol* 29:706-712, 2007.
5. Oppido G, Davies B, McMullan DM, Cochrane AD, Cheung MM, d'Udekem Y, Brizard CP. Surgical treatment of congenital mitral valve disease: Mid-term results of a repair-orientated policy. *J Thorac Cardiovasc Surg* 135:1313-1321, 2008.
6. McMullan DM. The relative risks of Recombinant Factor VII. *Pediatr Crit Care Med* 10:604-605, 2009.
7. Subramanian S, Clark JD, Jeffries HE, McMullan DM. Novel H1N1 viral cardiomyopathy requiring veno-venous extracorporeal membrane oxygenation. *Pediatr Crit Care Med* 11:714-717, 2010.
8. McMullan DM, Emmert JJ, Morscheck A, Permut LC, Cohen GA. Heparin-bonded cardiopulmonary perfusion circuit reduces postoperative hemorrhage. *Eur J Cardiothorac Surg* 39:392-397, 2011.