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Extracorporeal life support for the neonatal cardiac patient: Outcomes and new directions

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ABSTRACT

Extracorporeal life support is an important therapy for neonates with life-threatening cardiopulmonary failure. Utilization of extracorporeal life support in neonates with congenital heart disease has increased dramatically during the past three decades. Despite increased usage, overall survival in these patients has changed very little and extracorporeal life support-related morbidity, including bleeding, neurologic injury, and renal failure, remains a major problem. Although survival is lower and neurologic complications are higher in premature infants than term infants, cardiac extracorporeal life support including extracorporeal cardiopulmonary resuscitation is effective in preventing death in many of these high-risk patients. Miniaturized ventricular assist devices and compact integrated extracorporeal life support systems are being developed to provide additional therapeutic options for neonates.

Extracorporeal life support (ECLS) has become a critically important supportive therapy for neonates with life-threatening heart failure. Defined broadly as the use of an extracorporeal system to provide partial or full cardiopulmonary support, ECLS may be used to support neonates with refractory cardiac and/or pulmonary failure as a bridge to recovery, surgical intervention, or transplantation. Although recent advances in biotechnology have led to the development of miniaturized paracorporeal and implantable ventricular assist devices (VAD) that may be useful in providing medium- and long-term ECLS for young patients,[1] extracorporeal membrane oxygenation (ECMO) remains, by far, the most widely employed form of ECLS during the neonatal period.[2] The clinical versatility of ECMO and the breadth of clinical experience with this form of supportive therapy have led to expanded indications and increased utilization.

Trends in neonatal cardiac ECLS

Over 5000 cases of neonatal cardiac ECMO have been reported to the Extracorporeal Life Support Organization (ELSO) international registry. Categorically, neonatal cardiac ECMO represents 9.2% of the total cases. The use of ECMO for primarily pulmonary indications has declined dramatically during the last 20 years, whereas the use of ECMO to support neonates with predominately cardiac failure has steadily climbed.[3] Only 16 cases of neonatal cardiac ECMO were reported to the ELSO registry in 1987, representing 2.4% of non-ECPR neonatal ECMO runs. The number of reported neonatal cardiac cases was 370 and represented 31.2% of all non-ECPR neonatal runs in 2012.[2,4] This greater than 20-fold increase in the utilization of ECMO is due to an increase in the number of centers performing ECMO, greater clinical familiarity, and expanded indications for mechanical

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circulatory support in neonates with life-threatening heart failure. The proportional shift away from non-cardiac to cardiac ECMO is primarily related to the development of improved adjuvant medical therapies for respiratory failure, such as exogenous surfactant, high-frequency oscillatory ventilation, and inhaled nitric oxide,[5] which enable critically ill newborns to be supported without incurring the additional risks associated with ECMO.

Neonatal cardiac ECMO survival has changed over time with a 40% cumulative rate of survival to hospital discharge or transfer.[4] The reported survival rate was 69% prior to 1987. By 1994, survival had decreased to 34% despite significantly increased utilization. The survival rate has been steadily increasing since 1994, with 48% of neonatal cardiac ECMO patients surviving to hospital discharge in 2012 (Fig) The remarkably high rate of survival observed during the late 1980s was likely due to more conservative patient selection criteria during the initial clinical experience with ECMO. The gradual trend of improved neonatal cardiac ECMO survival observed during the past 20 years likely reflects improvements in ECLS equipment and patient management strategies that have improved overall patient safety despite increased utilization in higher-risk patients. Additional factors, such as time to initiation of support, patient selection, and the availability of additional forms of mechanical cardiac support, have undoubtedly contributed to improved survival in the contemporary era.

Indications for neonatal cardiac ECLS

The primary indication for mechanical circulatory support in neonates is inadequate cardiac output and end-organ injury that is refractory to optimal medical therapy. ECMO may be used for preoperative stabilization, failure to separate from cardiopulmonary bypass, post-cardiotomy low cardiac output states, and as a bridge to transplantation. Single-ventricle heart disease, once considered a relative contraindication to ECMO, now represents the most common underlying diagnosis in neonates who require cardiac ECMO. Additional indications for mechanical cardiopulmonary support include cardiomyopathy, myocarditis, pulmonary hypertension, intractable dysrhythmia, cardiac arrest, and low cardiac output states unrelated to structural heart disease (Table).

Preoperative stabilization

In 1970, Baffes et al.[6] published what has been credited as the first series describing prolonged extracorporeal circulatory support for infants with congenital heart disease. ECMO may be used to provide initial stabilization in neonates who present with refractory hypoxemia and/or severe cardiogenic shock, who might otherwise not survive to operative repair of structural heart disease. When used to stabilize patients with evidence of shock and end-organ damage, ECMO enhances end-organ perfusion, reverses acidosis, and may facilitate recovery of cardiac function. Most neonates with ductal-dependent cyanotic heart disease (e.g., Tetralogy of Fallot with pulmonary atresia) or isolated parallel circulations respond well to prostaglandin infusion to establish or maintain ductal patency or a balloon atrial septostomy to increase mixing at the atrial level. However, ECMO may be necessary to stabilize patients who present in a delayed manner with hypoxic shock that is refractory to pharmacological restoration of pulmonary

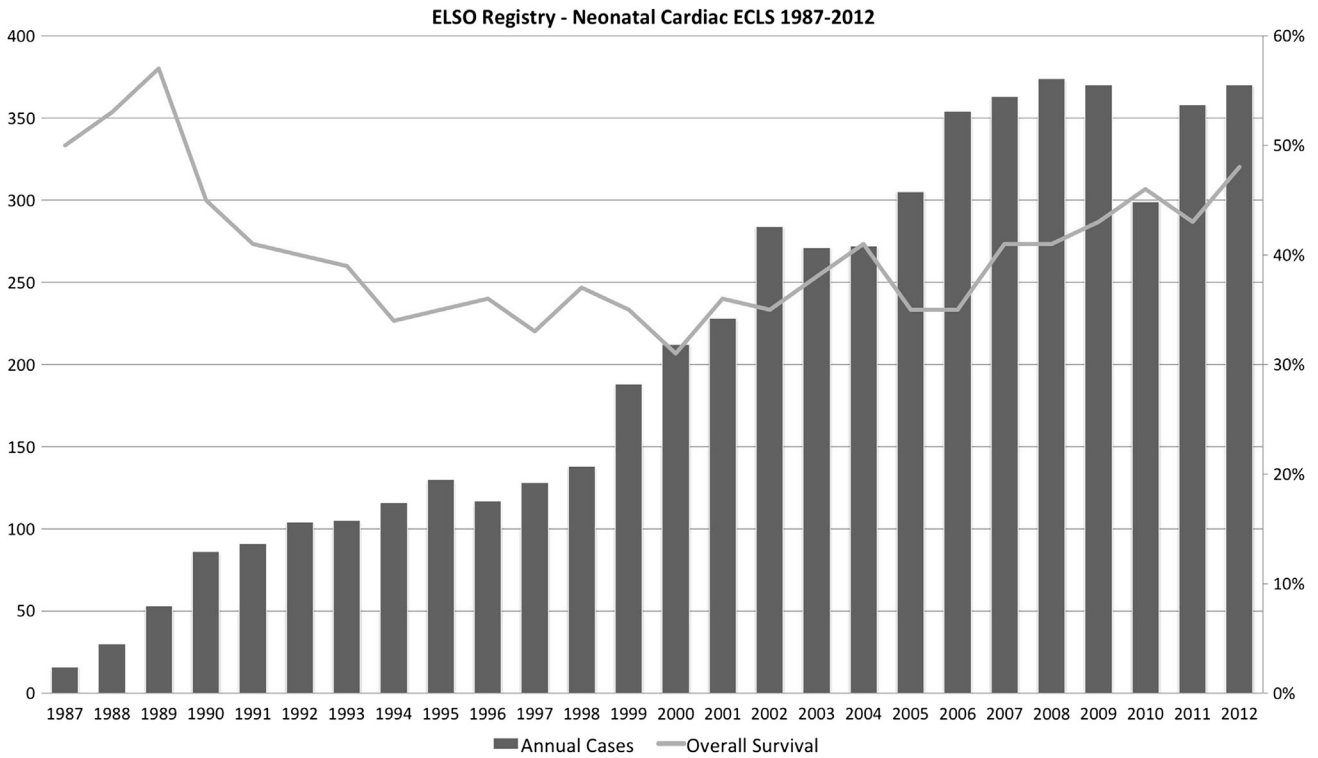

Fig – Neonatal Cardiac ECLS Trends in Utilization and Survival 1987-2012.