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Venoarterial versus venovenous ECMO for neonatal respiratory failure

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ABSTRACT

Extracorporeal membrane oxygenation (ECMO) continues to be an important rescue therapy for newborns with a variety of causes of cardio-respiratory failure unresponsive to high-frequency ventilation, surfactant replacement, and inhaled nitric oxide. There are approximately 800 neonatal respiratory ECMO cases reported annually to the Extracorporeal Life Support Organization; venoarterial ECMO has been used in approximately 72% with a cumulative survival of 71% and venovenous has been used in 28% with a survival of 84%. Congenital diaphragmatic hernia is now the most common indication for ECMO. This article reviews the development of the two types of extracorporeal support, venoarterial and venovenous ECMO, and discusses the advantages of each method, the current selection criteria, the procedure, and the clinical management of neonates on ECMO.

Introduction

Extracorporeal membrane oxygenation (ECMO) has been used for several decades as a lifesaving therapy for newborns with respiratory and cardiac failure refractory to maximal medical therapy with outstanding results. It is currently used in the treatment of neonates with a wide variety of reversible cardio-respiratory problems, including meconium aspiration syndrome (MAS), persistent pulmonary hypertension of the neonate (PPHN), congenital diaphragmatic hernia (CDH), sepsis/pneumonia, respiratory distress syndrome (RDS), air leak syndrome, and cardiac anomalies. This article reviews the development of the two types of extracorporeal support, venoarterial (VA) and venovenous (VV) ECMO, and discusses the advantages of each method, the current selection criteria, the procedure, and the clinical management of neonates on VA and VV ECMO.

History of venoarterial and venovenous ECMO

The first successful use of extracorporeal support in a newborn was reported by Dr. Robert Bartlett in 1976.[1] Subsequent data suggested that ECMO provided improved survival when compared with historical controls[2,3]; however, only two small trials with adaptive designs were performed in the United

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States prior to the widespread use of ECMO.[4,5] The UK Collaborative ECMO Trial published in 1996 confirmed that ECMO significantly reduced mortality when compared with standard medical care (32% versus 59%, relative risk = 0.55; 95% confidence interval: 0.36–0.80) with improved survival in all diagnostic categories.[6]

The Extracorporeal Life Support Organization (ELSO), established in 1989, maintains a patient registry, collecting data from more than 200 ECMO centers around the world. ELSO Registry data as of July 2013 include 27,000 newborns placed on ECMO for respiratory support.[7] Approximately 800 neonatal respiratory cases are performed annually with a cumulative survival of 75%. Review of the neonatal ELSO Registry data demonstrates ongoing demographic changes. ECMO use for neonatal respiratory failure has declined over the last two decades, likely related to the increasing use of high-frequency ventilation, surfactant replacement, and inhaled nitric oxide.[8–10] There have also been significant changes in the diagnostic categories receiving ECMO. Dramatic decreases in the use of ECMO for respiratory distress syndrome and sepsis/pneumonia have occurred. There has also been a downward trend in the use of ECMO for meconium aspiration syndrome; it is no longer the most common indication for ECMO. In recent years, congenital diaphragmatic hernia has become the most common indication for ECMO; however, the survival rate continues to decline for this and other diagnostic categories. Qureshi et al.[11] documented a doubling in neonatal respiratory ECMO mortality from 18.5% in 1990 to 34% in 2010. Most ECMO centers are treating fewer patients annually; however, the length of bypass is longer and survival is lower. These changes challenge ECMO centers to maintain their expertise with a complex technology in the face of lower patient volumes.

ECMO requires the diversion of blood from a systemic vessel to the extracorporeal circuit and back to a major blood vessel. VA ECMO, with ligation of the right carotid artery and internal jugular vein, served as the primary mode of support for both cardiac and respiratory failure until the development of the double-lumen VV catheter.[12] VV ECMO utilizing the double-lumen VV catheter in the right internal jugular vein made single-site venovenous support possible. A multicenter trial published in 1993 compared 135 VA neonatal patients to 108 VV patients and concluded that in newborns with adequate cardiac function, VV ECMO, using the double-lumen catheter, provides similar survival results without ligation of the carotid artery.[13] Survival was higher and the length of bypass shorter in the VV group, while neurologic complications were increased in the VA group. The likely explanation for these differences was that the VA patients were more critically ill. Other complications occurred at similar rates except for kinking of the double-lumen VV catheter.

Comparison of venovenous and venoarterial ECMO

VV ECMO provides an alternative means of extracorporeal support for patients with severe respiratory failure who do not require cardiac support. VV ECMO and VA ECMO differ significantly and each has its advantages and disadvantages (Table 1). Both VV and VA share major risks inherent to extracorporeal support, including instrumentation, systemic anticoagulation, and long-term perfusion. However, VV ECMO has several safety advantages over VA support. Most important is the avoidance of carotid artery ligation. Other advantages include shorter cannulation time, avoidance of ischemic lung injury seen in VA bypass, and the use of lungs as a filter for thromboemboli arising from the ECMO circuit, rather than direct access to the systemic and cerebral circulation on VA bypass. The primary disadvantage of VV bypass is that it does not provide direct circulatory support. In addition, oxygen delivery achievable with VV bypass may be inadequate because of recirculation, the mixing of oxygenated ECMO-return blood with desaturated systemic venous blood. With significant hypotension or increased metabolic rate as seen in septic patients, VV bypass may be inadequate. Despite not providing cardiac support, VV ECMO has advantages for the heart including the maintenance of right ventricular preload, pulmonary blood flow, and left ventricular output. In VA ECMO, right ventricular preload and pulmonary blood flow are both reduced while left ventricular afterload is increased. This increase in left ventricular afterload, together with hypoxic coronary perfusion from the desaturated blood from the left ventricle, can result in "cardiac stun" seen in some VA ECMO patients.[14] Echocardiographic studies in VV ECMO patients demonstrate normal cardiac function.[15] VV may improve cardiac function by increasing the mixed venous saturation in the pulmonary arteries, resulting in decreased pulmonary vascular resistance and right ventricular afterload. In addition, myocardial performance may improve by avoiding increased left ventricular afterload seen in VA ECMO, resulting in increased oxygen delivery to the coronary arteries. Another advantage of VV bypass is that pulsatile blood flow is preserved, which has benefits on organ perfusion.

To date, more than 65% of the 27,000 neonatal ECMO patients reported to the ELSO Registry have received

Table 1 – Comparison of venoarterial and venovenous ECMO.

Venoarterial	Venovenous
Advantages	*Advantages*
Direct cardiac support	Spares carotid artery
Excellent oxygen delivery	Pulsatile blood flow
Rapid stabilization	Normal pulmonary blood flow
	Myocardial perfusion with oxygenated blood
	Emboli to pulmonary circulation
Disadvantages	*Disadvantages*
Carotid artery ligation	No direct cardiac support
Nonpulsatile blood flow	Recirculation
Potential for cerebral hyperoxia	Lower oxygen delivery
Lower myocardial oxygen delivery	
Emboli to systemic circulation	