Adult Extracorporeal Life Support for Acute Respiratory Failure

Essay

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List of Abbreviations

ACT	Activated clotting time
ANZ ECMO	The Australia and New Zealand Extracorporeal Membrane Oxygenation
aPTT	Partial thromboplastin time
ARDS	Adult respiratory distress syndrome
ARF	Acute respiratory failure
BCDL	Bicaval dual lumen
CESAR	Center for Advanced Studies and Systems
CVP	Central venous pressure
DO_2	Oxygen delivery
ECBF	Extracorporeal blood flow
$ECCO_2R$	extracorporeal CO_2 removal
ECLS	Extracorporeal life support
ELSO	Extracorporeal Life Support Organization
F_DO_2	Fraction of delivered oxygen
FiO_2	Fraction of inspired oxygen
HIT	Heparin induced thrombocytopenia
IVC	Inferior vena cava
LDH	Lactate dehydrogenase
MO	Membrane oxygenator
OLT	Orthotopic liver transplantation

$PaCO_2$	Partial pressure of carbon dioxide
PaO_2	The partial pressure of oxygen
PEEP	Positive end expiratory pressure
PMP	Polymethylpentene
PVC	Polyvinylchloride
$PvCO_2$	Pump venous carbon dioxide of blood
RCT	Randomized controlled trial
RPMs	Revolutions per minute
RRT	Renal replacement therapy
SaO_2	Arterial saturation of oxygen
SVC	Superior vena cava
TEE	Trans esophageal echocardiography
UNOS	The United Network of Organ Sharing
VA ECMO	Veno-artetrial Extra corporeal membrane oxygenation
VO_2	Venous oxygen
VILI	Ventilator-induced lung injury

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Aim of the Work

The aim of the work is to highlight indications, the device technique and role of extracorporeal life support (ECLS), and Extracorporeal membrane oxygenation (ECMO) in management of acute respiratory failure and future of use of (ECMO).

Introduction

Extracorporeal life support (ECLS) systems are mechanical devices designed to support the failing heart or lungs temporarily. They definitly differ from cardiopulmonary bypass systems used in the operating room for very short-term support during surgery in both their configuration and intent. The term ECMO (Extracorporeal membrane oxygenation) is often used interchangeably with ECLS, as we will use it here, although it denotes a form of ECLS in which the primary purpose is to provide blood oxygenation. There are two types with two anatomic approaches that are used to implement ECMO: veno-arterial (VA) and veno-venous (VV). Virtually all applications are variations on these approaches ***(Extracorporeal Life Support Organization, 2014).***

ECMO is briefly a form of mechanical assist therapy that employs an extracorporeal blood circuit including an oxygenator and a pump. To perform standard respiratory ECMO, two vascular accesses are established, one for removal of venous blood and the other for infusion of oxygenated blood When blood is returned to the venous side of the circulation, the procedure is known as venovenous ECMO (VV ECMO), which provides gas exchange but cannot give cardiac support. When blood is returned to the arterial side of the circulation, this is called venoarterial ECMO (VA ECMO), and it can be employed for both gas exchange and cardiac support. Both types are associated with many risks, VA ECMO is associated with the potential risk of major limb vessel occlusion by the arterial cannula, as well as arterial embolism and refractory cannula site bleeding. The common reasons for selecting VA ECMO in ARDS (adult respiratory distress syndrome) patients are pulmonary hypertension, cardiac dysfunction and arrhythmia. VV ECMO will be discussed later ***(Extracorporeal Life Support Organization, 2014).***

ECMO is a high-risk and complex therapy that may be considered for the sickest patients with ARF (acute respiratory failure). Potential indications for the use of ECMO include severe ARF from: severe ARDS, status asthmaticus, bridge to lung transplantation. For sure ECMO should be organized at regional and national levels to provide the maximum care possible in high-volume, dedicated centers, because inappropriate use of ECMO may markedly increase costs of hospital stay and expose individual patients to important risks and hazards. Referral to an expert ECMO center, where ECMO is offered as part of a larger management protocol for ARF, may be associated with improved outcomes ***(Peek et al., 2009).***

Networks of hospitals at the local, regional or interregional level should be created around each ECMO center located in tertiary referral hospitals. Such networks have been successfully organized in the UK ***(NHS, 2014),*** Italy and have been associated with encouraging results for the treatment of the most severe forms of influenza A (H1N1)–associated ARDS ***(Patroniti et al., 2011).*** The feasibility of a network-wide system to evaluate the daily capacity for receiving patients receiving ECMO at individual centers was also demonstrated in Germany ***(Weber-Carstens et al., 2013)*** and in France ***(Pham et al., 2013).***

Organization of ECMO programs on a regional or national level is needed to provide the best, safest, and most efficient care possible to the ECMO population. Local, regional, or interregional networks of hospitals with necessity of presence of mobile ECMO team should ideally be present around each ECMO center; such a system has recently successfully been organized in a few countries ***(NHS, 2014).***

<u>Figure (1):</u> ECMO machine ***(Sidebotham et al., 2009).***

History of adult respiratory ECMO

ECLS was initially developed in the 1950s by John Gibbon as a means of oxygenating blood via a membrane oxygenator during prolonged operations on cardiopulmonary bypass. Given the lack of an open reservoir of blood and extreme anticoagulation required with a traditional cardiopulmonary bypass circuit, ECMO presented a less complex and more sustainable option for treatment of refractory cardiovascular and respiratory failure outside the operating room ***(Gibbon, 1954).***

In 1972, Hill reported the first successful use of ECMO in an adult respiratory failure patient. A 24-year-old man was exposed to traffic accident, admitted to hospital and underwent emergency surgery for multiple fractures and aortic rupture and developed ARDS 4 days later. He recovered after being placed on ECMO for 75 h. This report attracted considerable attention to role of respiratory ECMO, and the first randomized controlled trial (RCT) was conducted in the United States between 1974 and 1977 to investigate ECMO for ARDS. Patients with severe respiratory failure with criteria (either a PaO_2 <50 mmHg for 2 h with FiO_2 of 100% and PEEP >5 cmH_2O or a PaO_2 <50 mmHg for 12 h with FiO_2 >60% and PEEP >5 cmH_2O)

were randomized to conventional treatment group or an ECMO group. It was found that ECMO group patients had better prognosis ***(Zapol et al., 1979).***

In 1986, it was reported that a single-centre observational study of low-frequency positive pressure ventilation with extracorporeal CO_2 removal ($ECCO_2R$) that employed and used the same entry criteria. In this study it was found that the ventilation rate was reduced to a minimum level, with the aim of avoiding lung damage due to repeated expansion and contraction of affected alveoli ***(Schmidt et al., 2015).***

The H1N1 influenza pandemic occurred in 2009, the same year as publication of the Center for Advanced Studies and Systems (CESAR) trial, and The Australia and New Zealand Extracorporeal Membrane Oxygenation (ANZ ECMO) mentioned that Influenza Investigators obtained great and favourable results with ECMO for influenza associated ARDS. According to the Extracorporeal Life Support Organization (ELSO) registry, the average recent survival rate is around 60%–70% for patients undergoing adult respiratory ECMO ***(Pham et al., 2013).***

Extra Corporeal Membrane Oxygenation ECMO Circuit Design

ECMO Cricuit Design

The extracorporeal membrane oxygenation (ECMO) circuit is customized to provide adequate tissue oxygen delivery in patients with severe cardiac and/or respiratory failure for a prolonged period of time (days to weeks). A standard ECMO circuit consists of: (Fig. 2).

1. A mechanical blood pump.
2. Gas exchange device (oxygenator).
3. Vascular canulas.
4. Heat exchanger.
5. Circuit tubing
6. Other components of ECMO

ECMO circuits can vary from simple to complex and may include a variety of blood flow and pressure monitors, continuous oxyhemoglobin saturation monitors, circuit access sites and a bridge connecting the venous access and arterial infusion limbs of the circuit ***(Toomasian et al., 2011).***