Nursing Care and ECMO

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Preface

Extracorporeal membrane oxygenation (ECMO) is growing rapidly and is now considered in the treatment of all patients with severe respiratory or cardiac failure. Health-care workers of all disciplines are in need of a dedicated book that will help them through the management of these patients, explaining the principles of safe and successful practice. This book is especially focused on the unique aspects of nursing care of ECMO patients. It provides a comprehensive overview of the physiopathology and indications, setting up of the device, monitoring ECMO and the patient, troubleshooting, ethical aspects, and rehabilitation. Nurses, but also physiotherapists, perfusionists, and all other key members of the ECMO team, will find herein the basics required to better understand the technology and ultimate care of the patient.

The future of this activity promises to be especially exciting.

Paris, France   Alain Combes

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Chapter 1
ECMO: Definitions and Principles

Charles-Henri David, Alicia Mirabel, Anne-Clémence Jehanno, and Guillaume Lebreton

1.1 Introduction

Directly based on the principle of cardiopulmonary bypass (CPB), short-term circulatory support was developed to supplement heart and/or respiratory failure. Circulatory support is represented by two techniques closely related in their implantation but whose objectives are different. Extracorporeal membrane oxygenation (ECMO) aims to supplement failing lungs, while extracorporeal life support (ECLS) aims to support heart failure. ECMO will primarily affect oxygenation and decarboxylation of blood, while ECLS has a circulatory and a respiratory effect. By extension, the acronym ECMO is used for all short-term circulatory support techniques (under 1 month). To distinguish the two types of assistance, cannulation sites will be identified. Venoarterial ECMO (ECMO-VA) is used to discuss about ECLS (heart failure or cardiopulmonary failure) and venovenous ECMO (ECMO-VV) to discuss about ECLS (respiratory failure only).

The main difference from the commonly used CPB is that ECMO has no cardiotomy reservoir to store the blood. ECMO is therefore a closed circuit. This detail is important because this system is more dependent on the preload and afterload than CBP. The other difference is that CBP will be used over several hours while ECMO may be used for several days or weeks.

In 1953, the first heart–lung machine was used in humans [5]. In 1972, the first successful use of ECMO outside the operating room was reported [2]. Initially developed for neonatal and paediatric use, these technologies have gradually been

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applied to adults, with disappointing initial results. A multicentre study evaluating its interest in respiratory failure found no difference from the control group [11]. Despite this, many other studies have shown that this technique could provide a benefit in terms of survival. With improvement in its components—especially the centrifugal pump with a reduction in haemolysis and the new oxygenator—a renewed interest in ECMO emerged [6, 10].

Recently, we have seen a renewed interest in ECMO in the risk of developing ARDS (acute respiratory distress syndrome) during the pandemic H_1N_1 viral pneumonia [3]. Although its use is discussed, the fact remains that ECMO saves lives where conventional treatments have failed [8].

Currently, the main indication for ECMO is cardiogenic shock with organ dysfunction (at least two organ dysfunctions in addition to the heart) and/or the need to rapidly increase doses of inotropes (especially if the patient is away from a centre with a circulatory support programme) and/or rapidly reversible cardiac dysfunction (in short, a patient who cannot wait more than a few hours or with significantly faster recovery potential: myocarditis, drug poisoning, deep hypothermia) [4, 7].

ECMO is a means and not an end. This is a bridge to one or more therapeutic orientations.

- A bridge to decision—if the diagnosis is uncertain, it can save the patient's life while investigations continue. This can eventually lead to a deadlock and a therapeutic stop.
- A bridge to functional recovery—in myocarditis, for example.
- A bridge to surgical repair of the culprit lesion.
- A bridge to heart or lung transplantation when no recovery is possible.
- A bridge to long-term mechanical support.

1.2 Principles

ECMO is currently the only emergency treatment able to support temporary cardiorespiratory failure. The basic principle of ECMO is to collect the patient's venous blood into a pump connected to an oxygenator and restore the oxygenated and decarboxylated blood to the patient. In both ECMO-VA and ECMO-VV, the patient's blood is drained via a cannula inserted into a large vein. In ECMO-VA, blood is reinjected through an arterial cannula, while in ECMO-VV, blood is reinjected through a venous cannula.

ECMO is not a cure. It can stabilise a patient in a very serious condition to allow teams to evaluate and/or make a diagnosis and to take a decision. It can provide partial or complete support, and ensures gas exchange and a satisfactory infusion to the patient to protect vital organs. One can see ECMO as a bridge to a decision.

Monitoring of ECMO is done exclusively in intensive care and close to thoracic and vascular cardiac surgery.

1.2.1 Equipment

The ECMO system is similar to that of an operating theatre CBP console, but miniaturised and simplified to enable it to be easily used outside the operating room. An ECMO circuit is composed of a pump, an oxygenator, a heat exchanger, cannulas and a set of tubes for connecting the patient to the machine. According to the patient's needs, assistance will focus on the heart and/or the lungs. In case of ECMO-VA, a venous cannula and an arterial cannula will be needed. In case of respiratory support, only two venous cannulas (or a venous cannula having an output and an input) will be used. Conventionally, the venous blood is drained from the patient from a large calibre vein such as the femoral vein through a pump and is then oxygenated and decarboxylated through a membrane (Fig. 1.1). Then the blood flows back into the patient's circulation.

1.2.1.1 Cannulas

The choice of cannulas is fundamental for the ECMO to work optimally with as little complication as possible. There are a multitude of cannulas classified according to their internal diameter (in Fr, where 1 Fr = 1/3 mm), their length (mm) and their surface treatment.

They feature a contoured tip to facilitate penetration into the vessels (especially for the percutaneous approach), metal coils to strengthen the cannula and

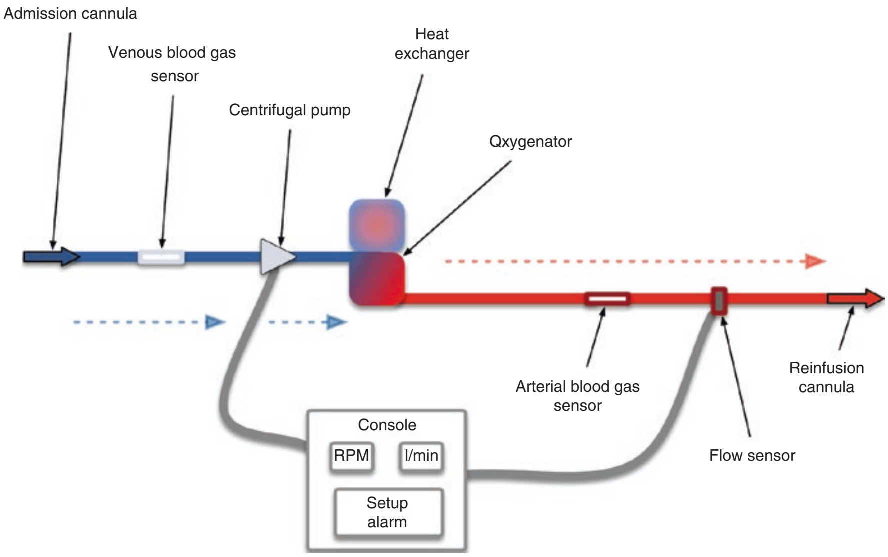

Fig. 1.1 Schematic representation of an ECMO-VA

a rigid proximal portion with a connection fitting with the tubing. The term 'admission cannula' is used for venous drainage cannula and 'reinfusion cannula' for the cannula which carries oxygenated blood from the pump to the patient (inserted either in an artery or a vein, depending on which type of ECMO is used). Venous cannulas are usually wider and longer than arterial cannulas.

1.2.1.2 Pump

In ECMO, we use centrifugal pumps. These are non-occlusive pumps which operate on the principle of entraining blood into the pump by means of a vortexing action of spinning impeller blades or rotating cones. The impellers or cones are magnetically coupled with an electric motor and, when rotated rapidly, generate a pressure differential that causes the movement of blood. The flow rate is calculated (by ultrasonic sensor) in L/min. The console allows the display and setting of various parameters of ECMO (flow, high- and low-flow alarms).

The centrifugal pump generates less haemolysis than other types of pump, and the pump stops in case of air embolism in the circuit; the rate depends mostly on input (blood volume and the choice of cannula size) and output pressure (vascular resistance). Centrifugal pumps are non-occlusive, which means that the blood can move in one direction or the other. Therefore, there can be a backflow with the patient's blood going back to the pump. This is seen most often when the ECMO rates are low and the pressure generated by the patient's heart is more important. There is an anti-backflow system on pumps, but regular monitoring is essential, and the golden rule is to clamp the arterial line whenever the pump is not running. All pumps are equipped with an emergency hand crank to compensate for a pump-operating failure.

1.2.1.3 Circuits

The circuit is composed of PVC tubes with an internal diameter of 3/8 inch (9.525 mm) packaged sterilely with a debubbling pocket. The circuit has a surface treatment in order to reduce clotting.

1.2.1.4 Oxygenators

The blood passes through polypropylene fibres that allow gas exchange to provide oxygenation and decarboxylation. The oxygenator reproduces the alveolar capillary function. Modern oxygenators are composed of multiple hollow fibres of <0.5 mm diameter, coated with a hydrophobic polymer (polymethylpentene), allowing the passage of gas (partial pressure gradient) but not liquid (Fig. 1.2). The gas flows

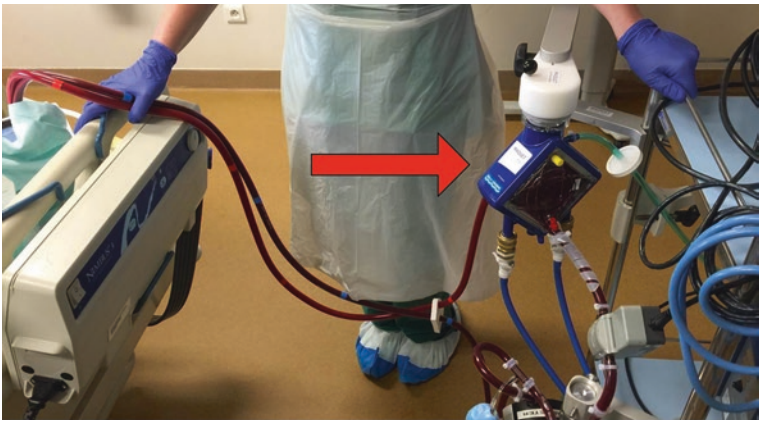

Fig. 1.2 Modern oxygenators

inside the fibres, and the liquid is on the outside. Compared with a healthy lung, transfer capacities with the membrane (artificial lung) are more than ten times lower (3000 vs. 200–250 mL/min). These transfers of O_2 and CO_2 capacity are determined by the exchange surface and the pore diameter of the fibres. These elements are not editable at the bedside to modify these exchanges; the action focuses on the flow of liquid (pump rate) and gas intake.

1.2.1.5 Heat Exchanger

This is a miniaturised thermal unit that can heat patient blood by convection. The thermal unit can heat up the patient's blood during the passage of the latter through the oxygenator: hot water circulates around the oxygenator and thus indirectly warms the patient's blood. The introduction and removal of the device is performed by the perfusionist.

1.2.2 Description of Techniques, Indications and Complications

1.2.2.1 ECMO-VA and ECLS

The most frequent indication for ECMO-VA is represented by all the causes of refractory cardiogenic shock to all medical treatments (Table 1.1). In these cases, there is an inability of the heart to pump to ensure adequate blood flow, leading to tissue hypoxia by stagnation in the absence of hypovolemia which can cause organ failure.