Invited lecture/Review

Extracorporeal Oxygenation (ECMO) in Patients with Acute Respiratory Failure

Tadel Kocjančič Špela[1,*]

1. University Medical Center Ljubljana, Slovenia; Faculty of Medicine, University of Ljubljana, Slovenia
* Correspondence: Špela Tadel Kocjančič; spela.kocjancic@gmail.com

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Abstract:
Extracorporeal membrane oxygenation (ECMO) is a method for oxygenation and removal of carbon dioxide in patients with respiratory failure in whom we cannot achieve that with standard methods of invasive mechanical ventilation. The method works as an extracorporeal bypass of blood, which we take from one central vein, then the blood goes through an oxigenator and returns oxygenated and free of carbon dioxide to another central vein. The system is run by a pump with steady non-pulsatile flow. We use two standard ECMO types. For respiratory failure alone we use veno-venous ECMO and for heart failure we use veno-arterial ECMO. We can also combine more types of ECMO according to the patient´s needs. We started using ECMO in 2009, with the number of patients is increasing every year. The majority of patients with the need of ECMO has influenza, pneumococcal pneumonia or infection with Legionella species. We also used ECMO a lot during COVID-19 pandemic. With this new method even the patients who would otherwise (even 10 years ago) die of respiratory failure, have a greater possibility to survive.

Keywords: ECMO – extracorporeal membrane oxygenation, respiratory failure, cannulas, non-pulsatile blood flow

1. Introduction

ECMO means ExtraCorporeal Membrane Oxygenation (extracorporeal life support, extracorporeal lung assist). It is a method for oxygenation and removal of carbon dioxide in patients with respiratory failure in whom we cannot achieve that with standard methods of invasive mechanical ventilation. ECMO is not a treatment and does not correct the underlying pathological insult.

We use two types of ECMO: venovenous (VV ECMO) for respiratory support and venoarterial (VA ECMO) for respiratory and hemodynamic support. We can also combine these two methods according to the patient´s needs.

ECMO was developed in 1970 for respiratory support in acute respiratory failure. It was used for adding O2 and removing CO2, but it was performed with cannulation of femoral artery and vein and limited to 5 days. In 1979, the first randomized trial showed very high complication rates and survival rates no higher than mechanical ventilation alone.

In early 1980s the switch to veno-venous was made, but after that the technology was largely abandoned due to bleeding and poor outcomes (Mosier et al., 2015).

There was a boom of ECMO during the global pandemic of influenza H1N1 in 2009-2010 and again in 2020-2022 during global pandemic od COVID-19.

Several centers reported survival benefits for ARDS secondary to influenza. Two retrospective case-control studies showed lower mortality when transferred to ECMO centers and lower mortality among younger patients who received ECMO (Schmid et al., 2015; Australia Group, 2009; Luyt et al., 2012; Zangrillo et al., 2013; Bednarczyk et al., 2014).

2. VV ECMO circuit

VV ECMO is used in isolated failure of the lungs, unresponsive to optimal ventilatory support and medical treatment. It is used in children and in adults. It consists of large conduit tubing, a blood pump, an oxygenator and additional components which may include a heat exchanger, monitors, and alarms.

Two ECMO cannulas are inserted percutaneously, ultrasound or diascopy guided. Usually they are inserted through the jugular or femoral vein, one for draining deoxygenated blood from the venous system (superior or inferior vena cava) to ECMO circuit, the other one for returning the oxygenated blood to the right atrium. Their size is dependant on the height of the patient. The cannulas are manufactured from biocompatible silicone polyurethane polymer, which may be coated with polymers that may reduce platelet activation and the inflammatory response at the blood-cannula interface (Pavlushkov et al., 2017; Lequier et al., 2013; Kohler et al., 2013).

The cannulas are constructed with a reinforced stainless steel (SS) wire. Wire reinforcement of the cannula walls is used to prevent kinking or collapse. A rigid cannula introducer is made of polyvinylchloride with an embedded SS rod (Pavlushkov et al., 2017; Lequier et al., 2013; Kohler et al., 2013; Beckmann et al., 2011; Medtronic, 2012).

Surface coatings are applied on the cannula to reduce the activation of the clotting; control of blood clotting is mandatory during the extracorporeal life support. The surfaces can be coated with heparin, bivalirudin, or tethered-liquid perfluorocarbon (Leslie et al., 2014; Wyss Institute, 2014; Yang et al., 2012).

A blood pump and an oxygenator can be joined together or separate. For adult respiratory failure the largest size ECMO machine is used which includes large conduit tubing, a blood pump capable of at least 5 L/min, and an oxygenator with rated flow over 5 L/min. A blood pump has a steady non-pulsatile flow (ELSO Guidelines, 2017).

In the absence of lung function, VV access can supply all metabolic oxygen requirements. Patient ′s PaCO2 is controlled by the sweep gas flow (ELSO Guidelines, 2017).

3. Indications and contraindications for veno-venous ECMO

Indication for VV ECMO is potentially reversible acute respiratory insufficiency, which may be hypoxemic, hypercapnic (pH less than 7.0), and ireversible lung damage in patients who have already been accepted for lung tranplantation as a bridge to transplantation (ELSO Guidelines, 2017). Contraindications may be absolute or relative. Absolute contraindications are pre-existing conditions, incompatible with recovery, for example advanced lung disease without possibility for transplantation, other end stage diseases. Relative contraindications are uncontrollable bleeding, very poor prognosis from primary condition, age above 65, advanced septic shock, imunosuppresive treatment (ELSO Guidelines, 2017).

4. Complications

Complications on ECMO are very common and are associated with a significant increase in morbidity and mortality. These complication could be related to the underlining pathology needed ECMO, or of the ECMO condition itself .

Patients on ECMO are very ill patients with respiratory insufficiency, usually with multiple organ disfunction. The complications are common and include complications during insertion of the cannulas, during treatment with ECMO and during decannulation.

Complications due to the insertion of cannulas are hemorrhage, venous spasm, arrhythmias, ruptured blood vessels, pneumothorax. During treatment with ECMO there can be adsorption and sequestration of drugs and blood cells on artificial materials, hemorrhage, blood clots, HIT (heparin induced thrombocytopenia), infections. There can also be neurologic complications, intracranial bleeding, infarction, cerebral edema. It is important to realize that these findings may be a consequence of the condition that prompted ECMO, rather than a complication of the ECMO process (Mateen et al., 2011; Mehta & Ibsen, 2013; Lidegran et al., 2007). These may be partially due to systemic heparinization, thrombocytopenia, coagulopathies, or systolic hypertension.

Complications due to the removal of the cannulas are hemorrhage, venous spasm and ruptured blood vessels.

5. Outcome of patients on veno-venous ECMO

According to the published data, 67% of patients with acute respiratory failure treated with ECMO were weaned off ECMO and 52% survived to hospital discharge (ELSO Guidelines, 2017; Hemmila et al., 2004; Noah et al., 2011; Pham et al., 2013). This was also confirmed by the CESAR study (Peek et al., 2009), which demonstrated that referral to an ECMO center significantly improves recovery and survival from severe ARDS.

6. Conclusion

Introduction of ECMO in the treatment of patients with acute respiratory failure has improved survival of these patients. ECMO use has risen since H1N1 influenza outbreak in 2009 and until now ECMO centres still continue to report high survival rates for patients who are supported with ECMO. It is important to emphasize that that patients, treated with ECMO return to a reasonable quality of life, although after prolonged rehabilitation.

Conflicts of Interest: The author declares no conflict of interest.

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