Review Article
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Care Management for Patients with Covid-19 Receiving Extracorporeal Membrane Oxygenation (ECMO): A Narrative Review

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ABSTRACT

Extracorporeal membrane oxygenation (ECMO) is recommended in individuals experiencing COVID-19 with refractory hypoxemia and no response to mechanical ventilation (MV). The support should be given according to predetermined protocols and care management of these patients are under the responsibility of a specialized multiprofessional team. The present review provides information to the multiple health professionals about care and treatment of COVID-19 patients on ECMO.

Keywords: *Extracorporeal Membrane Oxygenation, COVID-19, Hypoxia, Mechanical Ventilation*

Introduction

Patients under serious conditions experiencing COVID-19 usually develop respiratory failure and acute respiratory distress syndrome (ARDS). Since there is a high mortality rate for patients receiving mechanical ventilation, the use of extracorporeal membrane oxygenation (ECMO) in some serious ARDS cases may decrease those rates (Bartlett *et al*., 2020; Badulak *et al*., 2021).

The World Health Organization (WHO) recommends the use of extracorporeal membrane oxygenation in patients experiencing COVID-19 with refractory hypoxemia and no response to mechanical ventilation (MV). The support should be promptly started as soon as the patient meets all eligibility criteria to ECMO [1]. Extracorporeal membrane oxygenation is a salvage therapy for these patients, and the veno-venous (VV) support can be considered (Henry, 2020; Alshahrani *et al*., 2018).

ECMO is a valuable therapeutic option for patients with acute lung failure, each case should be analyzed, according to different factors, such as financial, professional resources, government and hospital policies (Bartlett *et al*., 2020). The VV ECMO is the choice for patients experiencing COVID-19, and venoarterial (VA) ECMO may also be considered if COVID-19 is associated with serious heart failure. ECMO should be used in patients with favorable prognosis for such a support (Shekar *et al*., 2020). In this narrative review provides important information to the multiple health professionals about care and treatment of COVID-19 patients on extracorporeal membrane oxygenation.

Patient Selection

The patient undergoing support should be chosen based on a rigorous and extremely fair selection, always considering the possibility of making it even more restrict (Badulak *et al*., 2021).

Indication

Specific criteria for ECMO initiation:

PaO_2: FiO_2 < 50 mmHg > 3 hours;

PaO_2: FiO_2 < 80mmHg > 6 hours;

arterial pH <7.15 due to respiratory acidosis with PaCO2 > 60 mmHg.

Contraindications

There are no absolute contraindications for the support; the risks and benefits are individually assessed for each patient; However, there are conditions that may be considered as a relative contraindication (Bartlett *et al*., 2020); [2].

High mechanical ventilation settings ≥ 10 days (may not be applicable to some specific patients);

Serious neurological injury;

Prolonged cardiac arrest;

Multiple comorbidities or multiple organ dysfunction.

Cannulation

The cannulation of patients with COVID-19 should be performed preferably in an isolated place of the hospital. During the procedure, the patient must be sedated, and neuromuscular blocking agents should be given. Lastly, it is recommended use of x-ray, vascular ultrasound, and echocardiography (transthoracic or transesophageal) to help with the cannulation. The cannulas used have different sizes, according to the patient's weight and optimum blood flow (Table 1) (Shekar *et al*., 2020; Broccoli *et al*., 2018).

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Table 1: Cannulas according to the patient's weight.

Patient's weight	Circuit's diameter	Blood stream	Arterial cannula	Venous cannula	VVDL cannula
Up to 5 Kg	¼	1 l/min	8 to 14 Fr	10 to 15 Fr	12 to 15 Fr
5 to 10 Kg	¼	1.2 l/min	12 to 17 Fr	15 to 21 Fr	15 Fr
10 to 15 Kg	03-Aug	1.8 l/min	17 to 19 Fr	17 to 21 Fr	15 to 18 Fr
15 to 45 Kg	03-Aug	4.5 l/min	17 to 23 Fr	17 to 23 Fr	
45 to 90 Kg	03-Aug	5.5 l/min	17 to 23 Fr	17 to 23 Fr	
>90 Kg	03-Aug	6.5 l/min	17 to 23 Fr	17 to 23 Fr	
VVDL - veno-venous double lumen					

ECMO Configurations

VV ECMO:

- It is recommended the use of a multi-stage, large-size drainage cannula (23 Fr for adults) or a single-stage cannula from 19 to 23 Fr.
- As for the cannulation site, it is recommended a jugular-femoral configuration.

VA ECMO:

- In the VA modality, it is recommended to use the femoro-femoral configuration, with backflow cannula in the distal portion of the limb, in order to prevent ischemia.

Anticoagulation

Due to the hypercoagulable state of patients receiving ECMO, the anticoagulation parameters should be kept within an upper limit from the normal values. It is strictly recommended to avoid flows lower than 2000 ml/min due to an increased risk of thrombogenic episodes in the circuit [3].

Table 2: Heparin infusion based on aPTT.

Anticoagulation			
aPTT (sec)	Relatedness	Heparin dosage	New control
<70	<2	Increase by 20%	4 hours
71 – 85	2.1 – 2.4	Increase by 10%	4 hours
86 – 105	2.5 – 3.0	Continue at same rate	4 hours
106 – 120	3.1 – 3.5	Decrease by 10%	4 hours
>120	>3.5	Decrease by 20%	4 hours
aPTT - activated partial thromboplastin time			

50 to 100 IU/kg of unfractionated heparin (UFH) bolus is used to perform the cannulation. The initial monitoring is carried out using the activated clotting time (ACT); when ACT is decreased to 300 sec values, the heparin infusion is therefore started, with a dosage from 7.5 to 20 IU/kg/h. ACT should be

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kept within a 180 to 220 seconds range throughout the period the patient continues receiving the ECMO support. After the ACT values become steady, the heparin infusion should be guided based on the activated partial thromboplastin time (aPTT) (Table 2) (Broccoli *et al*., 2018; Chaves *et al*., 2019) [3].

Mechanical Ventilation

COVID-19 pandemic imposed huge challenges to the management of mechanical ventilation due to inflammatory storm, angiotensin-converting enzyme 2 (ACE2) regulation failure and immune response. Clinically, the disease is translated into pneumonia/ARDS associated with inflammatory damage due to edema, changes in hypoxic vasoconstriction reflex, and tissue hypoxia (Bartlett *et al*., 2020).

The main focus of the MV in ARDS is to provide the proper gas exchange, therefore decreasing the risk of injuries. Incorrect management of mechanical ventilation may lead to ventilator-induced lung injury (VILI), in addition to inadequate diaphragm muscle effort, that can be poor (P0.1 - inspiratory pressure generated in 100 ms < 2.0 cmH20) or excessive (P0.1 > 4.0 cmH20), which may lead to diaphragm atrophy or myotrauma, respectively. The monitoring of both the respiratory drive and patient effort is crucial to minimize the patient self-inflected lung injury (P-SILI) during spontaneous breathing (Abrams *et al*., 2020) [4].

ECMO is commonly indicated in cases of serious hypoxemia or hypercapnic acidosis refractory to conventional ventilator management strategies. A highly protective ventilation strategy may be used in patients receiving ECMO since the device membrane can maintain the oxygen and carbon dioxide rates within the desired values (Bartlett *et al*., 2020; Abrams *et al*., 2020)

Reduced lung volumes are recommended, a predicted tidal volume (Vt) of 4 ml/kg is associated with lower mortality, reduces pulmonary inflammation, and has the potential to increase days without ventilation in patients with PaO_2 / FiO_2 ≤150. However, they increase the atelectasis areas, leading to increased unbalance of the ventilation/perfusion ratio. Therefore, elevated positive end-expiratory pressure (PEEP) values are usually recommended; however, this PEEP should be enough to sustain the alveolar recruitment without causing hyperdistension (Badulak, 2020). Patients should be assessed individually, considering the heart and hemodynamic limitations. The positive airway pressure affects the pre- and post-load of both the right ventricle (RV) and left ventricle (LV). Patients receiving ECMO who are experiencing RV failure may be adversely affected due to the high positive end-expiratory pressure levels, while patients experiencing LV failure may benefit from the high PEEP levels, therefore reducing the probability of pulmonary edema. The highly protective strategy may also decrease the plateau pressure (Pplat), driving pressure (ΔP), mechanical power, and respiratory rate (RR). (Abrams *et al*., 2020; Badulak, 2020) [4].

After the ECMO is connected, the patient remains sedated and curarized for the initial adjustments in the ventilation parameters and PEEP titration. During the period the patients receive the controlled mechanical ventilation, it is possible to maintain the inspiratory time and expiratory time ratio (I:E), which can be reversed in 2:1, in order to optimize the gas exchange (Table 3). As the patient experiences hemodynamic improvement and recovers from hypoxemia and acidosis, the sedation levels may be reduced and the I:E ratio should be maintained as close as possible to the physiological one, which is approximately 1:2 (Table 4) (Abrams *et al*., 2020; Badulak, 2020) [4].

Table 3: Initial ventilation parameters for patients receiving ECMO.

Initial ventilation parameters
Tidal volume = 3 to 4 ml/kg of the predicted weight
Plateau pressure ≤ 28 cmH2O
ΔP ≤ 10 cmH20
Respiratory rate = 5 - 10 ipm
FiO_2 in the ECMO membrane = 100%
FiO_2 in the mechanical ventilator = 50%
PEEP = 10 - 15 cmH20 or titration by the lowest ΔP
I:E ratio = 2:1 in the first 24h-48h (*only during the controlled cycle)
ΔP – Driving Pressure; FiO2 – fraction of inspired oxygen; PEEP – positive end-expiratory pressure; I:E ratio - inspiratory:expiratory ratio

Table 4: Ventilation monitoring for patients with COVID-19 in the controlled mechanical ventilation modality and spontaneous MV modality.

Controlled ventilation	Spontaneous ventilation
Tidal volume = 3 to 4 ml/kg of the predicted weight	Vt = 4 to 6 ml/kg of the predicted weight
Lowest FiO_2 possible for SpO_2 between 92% and 96% or for the desired PaO_2	Lowest FiO_2 possible for SpO_2 between 92% and 96% or for the desired PaO_2
Plateau pressure ≤ 28 cmH20	Peak pressure < 25 cmH20
Driving Pressure ≤ 10 cmH20	Transpulmonary ΔP = 10 to 12 cmH20
---	Esophageal ΔP = 4 to 8 cmH20
Respiratory rate = 5 to 10 irpm	Respiratory rate ≤ 25 irpm
PEEP 10 to 15 and/or titration to the lowest ΔP	PEEP 10 to 15 and/or titration to the lowest ΔP
I:E ratio = 1:2	---
---	P0.1 = 2.0 to 4.0 cmH20
Vt - tidal volume; FiO_2 – fraction of inspired oxygen; ΔP – Driving Pressure; SpO2 – oxygen saturation; PaO_2 – partial pressure of oxygen; PEEP – positive end-expiratory pressure; I:E ratio - inspiratory:expiratory ratio; P0.1 – airway occlusion pressure	

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The ECMO ventilation and gas management should be conducted by a specialist professional, and the decisions are made by a multidisciplinary team. The ventilation strategy is complementary and should be in line with the oxygenation and CO2 removal strategies through the membrane. Therefore, the actions have to be concomitantly planned, executed, and monitored. For example, during the ECMO weaning, if the blood flow deviated to the device is reduced, it will lead to limited gas exchange as a result of the arterialization blood flow decrease and, at that moment, the ventilation strategy should gradually return to more physiological parameters [4].

Nursing Management

The nurse is exclusively accountable for the direct care of individuals receiving ECMO [5]. In light of the nurse's perception of the care required, it is important to establish specific nursing care interventions according to the priority health needs of the patient (Silva *et al*., 2020; do Nascimento Pereira *et al*., 2017).

Clinical approach is the tool that provides systematized, reflexive, and humanized care, promoting specific care; the systematization of nursing care (SNC) is at the nurse's discretion, and through it, it is possible to operationalize and document the nursing process, fostering the health promotion, prevention, recovery, and rehabilitation, whenever the nursing interventions are applicable throughout this process (Ferreira *et al*., 2016; Oliveira *et al*., 2017) [6].

The main nursing intervention in patients receiving ECMO refer to the monitoring of hemodynamic parameters, bleeding prevention and/or control care, change of position, neurological, ventilation, gas, and diuresis volume follow up and monitoring, glucose control, and observation of patient clinical changes. (Board 1) (Chaica *et al*., 2020; Martorelli *et al*., 2019).

Board 1: Nursing interventions and diagnoses in patients receiving ECMO.

Nursing diagnosis	Nursing intervention
Risk of bleeding	-Observe and take note of the presence of bleeding in mucosae, urinary and intestine eliminations, exudation in punch sites, and presence of petechiae; -Observe the presence of hematoma, take note of the size in cm and site; -Observe and take note of how much bleeding was drained; -Monitor the clotting screen (PT, aPTT, fibrinogen, platelet count); -Monitor blood pressure trends and hemodynamic parameters.
Decreased cardiac output	-Observe and take note of the presence of sweating, cold and sticky skin, pallor, agitation, tachycardia or bradycardia, and hypotension; - Check blood pressure, heart rate, temperature, and O_2 saturation every 2 hours.

Impaired spontaneous ventilation	-Observe signs of worsening of respiratory status (peripheral cyanosis, use of accessory muscles, thoracic retraction, breathing with pursed lips, restlessness and noisy breathing).
Risk of infection	- Observe and take note of signs of bacteremia: temperature changes; - Use isolation precaution measures according to the protocol from the hospital infection control; - Check if there are signs of infection at the ECMO cannulation sites; - Perform oral hygiene with gauze and filtered water in patients receiving MV; - Replace continuous infusion tubes and burettes every 96 hours; - Replace the valve connector every 96 hours; - Perform bed cleaning concomitantly; - Maintain patients receiving MV with the head of bed elevated to 30º-45; - Observe and take note of the presence of hyperemia, heat, pain, and edema at sites with invasive accessories; - Replace the central catheter insertion bandage, cleaning it with saline solution 0.9% and alcohol-based chlorhexidine at the insertion site, taking note of the aspect and using an sterile film to cover it (every 7 days).
Risk of injured skin integrity	- Observe if there are signs of pressure or irritation on the skin; - Observe if there is hyperthermia, malnutrition, deep sedation, and edema that may favor the onset of lesions; - Use pressure redistribution devices; - Make bandages.
Inefficient peripheral tissue perfusion	- Assess peripheral wrists, capillary perfusion, temperature, and color of extremities; - Monitor the pulmonary/arterial capillary pressure and central/right atrial venous pressure; - Improve the perfusion of limbs with a heating system, if required.
Risk of bedsores	- Perform/stimulate position change every 2 hours.
Excessive fluid volume	- Take note of fluid ingestion and elimination in a balance sheet.
Self-care deficit Bathing/Hygiene	- Bathing should be made on bed, with a dedicated towel.
Risk for unstable blood glucose	Observe, take note, in case of any signs of hypoglycemia: sweating, pallor, agitation, anxiety, irritability, nausea.

Blood Component Replacement Therapy

Due to several factors, blood component replacement in patients receiving ECMO is often required. 8 In some cases the transfusion is applied to maintain the clinical stability; however, a rigorous assessment of the real needs of the patient should be performed (Table 5) (Romano *et al*., 2017; Shekar *et al*., 2020).

Table 5: Hemoderivative transfusion.

	Reference Value	Replacement
INR	2-2.5	FFP 10 – 20 mL/Kg
Platelets	>50,000	Platelet concentrate 1IU/10Kg
Fibrinogen	>100	Cryoprecipitate 1U/5Kg
Hb	>7-8	Red blood packed cell 20ml/kg

INR – international normalized ratio;
FFP – fresh frozen plasma; Hb – hemoglobin

Continuous Renal Replacement Therapy

Patients receiving ECMO often develop acute kidney injure (AKI) and volume overload. The incidence of AKI and respective complications in these individuals increase the hospital mortality rates (Lee *et al*., 201). In patients experiencing COVID-19, there is not a clear consensus about AKI; however, the cause may be attributed to multiple factors associated, such as hemodynamic changes, inflammatory response, hypercoagulability, and cytotoxicity due to SARS-CoV-2 (Costa *et al*., 2021). The continuous renal replacement therapy (CRRT) is commonly used to compensate this clinical condition. CRRT is the safest and most reliable option for patients receiving ECMO and the most used configurations are conventional filtration, continuous hemofiltration, and CRRT machine (Seczyńska *et al*., 2021; Poveda *et al*., 2018).

Conventional Filtration and Continuous Hemofiltration

The hemofilter is used for conventional ultrafiltration, with the purpose of removing volume from patients, and may also be used as a continuous hemodialysis, with the purpose of removing fluids and solutes. The specific configuration is implemented from the line that delivers blood to the hemofilter, which is connected to the ECMO circuit in the post-pump; the blood returns from the hemofilter to the venous portion in the pre-pump position. When the hemodialysis is performed, the dialysis solution is implemented, and the infusion is made in the opposite direction to the blood flow in the hemofilter. To monitor the hemofilter output volumes and in cases of dialysis solution infusion, continuous infusion pumps are required in order to control the volume input and output (Fig. 1) (Broccoli *et al*., 2018; Poveda *et al*., 2018).

CRRT Machine with ECMO Circuit

It can be performed through a venous access, but it is often used only when the patient has a previous vascular access. However, the use of this modality depends on the discretion of the clinical staff. In sites where it is possible to use a CRRT therapy machine, the connection is made through the venous line of the post-pump circuit, with the blood flow returning to the pre-pump access. (Fig. 2) or, yet a CRRT machine flow input configuration through the post-pump access returning to the pre-membrane position (Fig. 3) (Poveda *et al*., 2018).

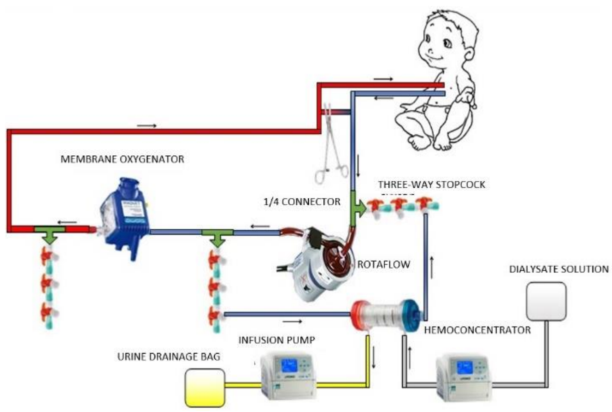

Figure 1: ECMO configuration, showing the hemofilter output and input access points, as well as the infusion pump for dialysis solution and volume removal.

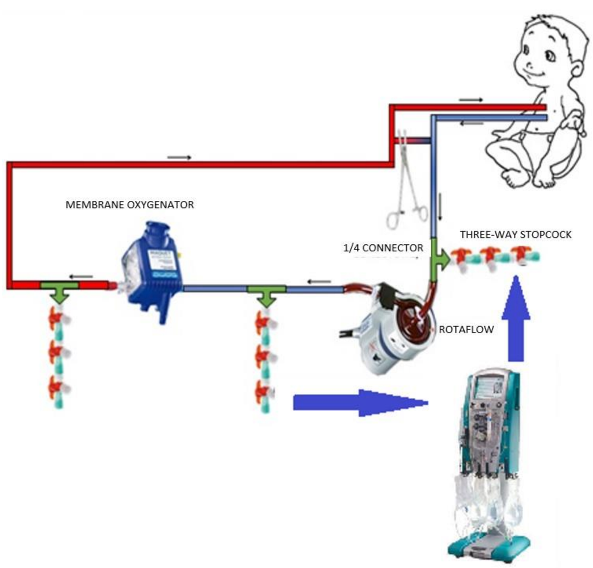

Figure 2: ECMO configuration, showing the CRRT machine output and input access points, with access in a post-pump pathway and return through the pre-pump.

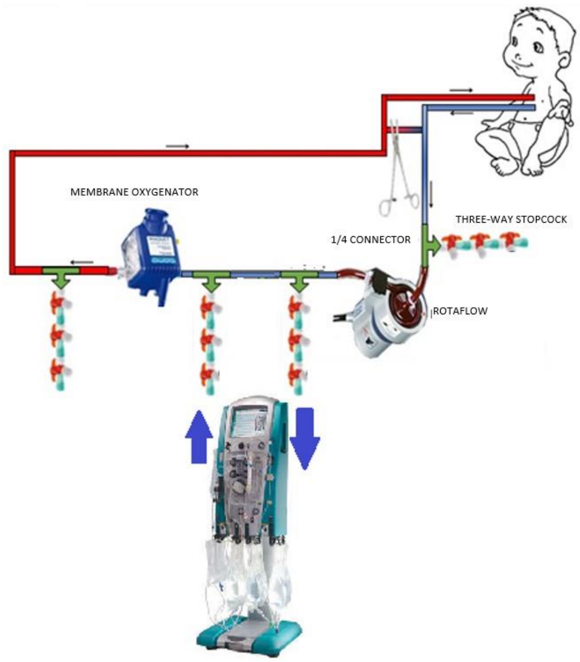

Figure 3: ECMO configuration, showing the CRRT machine output and input access points, with access in a post-pump pathway and return through the pre-membrane.

Prone Position During ECMO

The prone position helps treating the pulmonary side effects of patients receiving ECMO, and may be safely performed whenever needed, from a therapeutic point of view (Kimmoun *et al*., 2013). Prone position a patient leads to positive oxygenation effects and helps reducing pulmonary lesions induced by protective mechanical ventilation (Guervilly *et al*., 2019). The prone procedure in individuals receiving VV ECMO for periods exceeding 12 hours results in increased alveolar recruitment, respiratory compliance, PaO_2/FiO_2 ratio, and may influence the survival of these patients (Dalmedico *et al*., 2019).

Patients may be proned to 180º once every 24 hours, for the suggested period from 8 to 12 hours. They should be manually positioned by a team of 4-5 professionals, which should consist in a physician, a nurse, a physiotherapist, a nursing technician, and perfusionist. The lines and tuber should be carefully handled, following the sagittal plane (Kipping *et al*., 2013).

Transportation Of Patients Receiving ECMO

There are situations in which it is required to remove the patient to another place, whether to other hospital areas, such a surgical center and for imaging, or to transfer them to another reference site (Broccoli *et al*., 2018).

If the patient needs to be transferred to another hospital, it is important to check the distance between the places and the geography of the route since these factors have influence and determine the type of vehicle to be used. It is worth noting that, regardless of the vehicle chosen, all of them should have the appropriate electrical apparatus for the ECMO circuit and remaining equipment required during the transfer (Table 6) [7].

Table 6: Types of vehicles used according to the distance and capacity of personnel allocation.

	Ambulance	Helicopter	Aircraft
Space for the team	4-5 members	3-5 members	>4 members
Distance traveled	Up to 400 km	Up to 650 km	Any distance

Personnel

It is crucial the presence of a multiprofessional team that had received the appropriate training to transport patients receiving ECMO [7]. Therefore, the team should consist in:

- Cardiothoracic surgeon (responsible for the cannulation)
- Physician with experience in ECMO
- Perfusionist
- Nurse
- Nursing technician
- Physiotherapist

Materials and Equipment for The Transportation

- Centrifugal pump
- Membrane oxygenator
- Hand crank
- Heater /cooler machine
- Oxygen tank
- Saline solution 0.9% (1000 ml)
- Heparin infusion pump
- Anticoagulation monitoring equipment
- Tubing clamp forceps (Henry, 2020)

Whenever the patients needs to be transported, it will be required to check the battery level of the equipment and if a hand crank is available, as well as if the latter is working properly. Also, the oxygenator output device should be occluded throughout the patient transportation (Broccoli *et al*., 2018).

The oxygen tank is directly connected to the membrane oxygenator and the blender disconnected. The transportation is made with a multi-parameter monitor for a continuous assessment of heart rate, arterial blood pressure, and pulse oximetry. The pressure monitors and hemodialysis filtration solutions should be disconnected (Broccoli *et al*., 2018). The following EPIs are required: long-sleeve apron, medical gloves, protection goggles, and/or face shields, face mask, and medical cap [8].

ECMO Complications

ECMO has several advantages, but can also lead to different complications since it is an invasive, highly complex and specific device (Nakasato *et al*., 2018). Basically, there are 2 types of complications: clinical and mechanical; those related to clinical outcomes are most frequent ones observed, like vascular, neurological, renal, hemorrhagic, and infectious outcomes (Board 2) (Cheng *et al*., 2014; Broccoli *et al*., 2018).

Board 2: Clinical complications.

Complications	
Bleeding	Hemorrhagic disorders are frequent in patients receiving ECMO, and the cannulation and suture sites are the most affected. Intracranial hemorrhage is one of the most serious complications in patients, and may occur in the first 24 hours of care. Gastrointestinal bleeding is rarely observed, but can be caused by gastritis or trauma when inserting the nasogastric tube and worsened by anticoagulation.
Vascular complications	Limb ischemia, fasciotomy, lower limb amputation, thrombosis in the superior vena cava, and thrombosis in the jugular vein.
Hemolysis	Turbulence in the circuit's blood flow and sudden changes in oncotic pressure may contribute to cell lysis. Excessive circuit stream, improper venous drainage, and hyperthermia (>40°C) are factors that may lead to hemolysis.
Thrombocytopenia	It occurs due to the adhesion of platelets on the circuit and oxygenator surface. The consumption is higher in the first 24 hours after the care is first implemented. Qualitative platelet disorder also occurs. The platelet count should be maintained over 50,000.
Seizures	Hypertensive episodes, heart rate oscillations, and blood flow reduction from the circuit may indicate seizures.
Systemic arterial hypertension	It often occurs when ECMO is starting, but also throughout the care, being secondary to factors such as pain, agitation, hypervolemy, acidosis, hypercarbia, hypoxia, and seizures.
Hypovolemia	It may occur with hypotension, decreased central venous pressure and access

	pressure, and reduced circuit stream. The volemic adjustment is important when care is initiated and tends to become steady after the first 24 hours.
Infection	The connection between the patient and the external surface for long periods is the main risk factor of infections.
Renal Failure	Oliguria is often observed in the first 24 to 48 hours after the care is first implemented. Hypotension and hypoxemia before ECMO is implemented, as well as the lack of pulse flow during the process are the main factors involved in the renal failure onset.
Hemodynamic deterioration	Cardiac tamponade, hemothorax, pneumothorax, and hemorrhage may cause hemodynamic decompensation of the patient. Hypoxemia, peripheral hypoperfusion, hypotension, reduced pulse curve amplitude, and decreased circuit venous return with increased negative pressure are the main clinical changes observed.
Cardiac Arrest	In VV ECMO, the resuscitation maneuvers should be immediately started and, in case of failure, the care may be converted to VA ECMO.

The mechanical complications are not so frequent, but if they occur, their consequences can be catastrophic. The mechanical complications more commonly observed include clotting formation, cannula displacement, embolism, rupture of connectors, circuits bending, oxygenator failure, and improper pump function (Board 3) (Broccoli *et al*., 2018).

Board 3: Mechanical complications.

Complications	
Thrombosis	There is no way to stop the formation of small clots in the circuit, even with a strict anticoagulation control. Clots in the circuit venous pathway do not represent risks, but should be monitored since they can grow and cause displacements.
Cannulae	Small cannulae may restrict the circuit stream. The cannula insertion may cause other complications, like vascular lesions. Other complications include improper cannula positioning or displacement, which may result in accidental decannulation.
Tubes and connections	Tubes and connections can become dry, which leads to rupture, leakage, and disconnection of the components.
Loss of circuit stream	The most common causes are hypovolemia, increased intrathoracic pressure, obstruction or bad positioning of cannulae and tubes.
Centrifugal pump failure	In this case, the manual backup should be used until the pump is replaced.
Oxygenator failure	Failure indications: decreased pO2 after oxygenator, increased pCO2 after oxygenator and patient, increased transmembrane gradient, presence of air in the blood phase of the

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	oxygenator, presence of blood solution leaking from the air output device, increased hemolysis, and consumption coagulopathy.
Embolism	In case of opening or rupture of venous pathway connectors, air may enter into the circuit. Small amounts of air in the venous pathway are eliminated in the deaeration chamber of the oxygenator; however, large amounts of air may pass through the oxygenator and, as a consequence, to the patient.
Heater /cooler machine	Malfunctioning may lead to hyperthermia or hypothermia. Another complication, which is less frequent, is the leakage between the blood and liquid phases, that can occur due to the heating circuit corrosion.

Weaning of ECMO

VV ECMO:

It is necessary to check the oxygen once a day so as to assess the patient gas exchanges. The test is made by increasing the mechanical ventilator FiO_2 to 100% and, after 30 minutes, perform the arterial blood gas collection. If the patient pO2 presents values over 150 – 200 mmHg, it suggests improved pulmonary function, therefore, the care weaning can be started (Broccoli *et al*., 2018).

The VV ECMO weaning starts by gradually reducing care until reaching 30 – 40 ml/kg/min, of gas flow and oxygen concentration, reaching the minimum parameters of 0.05 – 0.1 LPM sweep and 21% FiO_2 (Broccoli *et al*., 2018). ECMO FiO_2 should be reduced from 100% to 60%, then 30%, and 21%; each step should take from 5-10 minutes, with monitoring of clinical and laboratory parameters. The weaning may be stopped if the patient experiences instability (Vasques *et al*., 2019).

Subsequently, the autonomy test should be applied, which checks if it is possible to remove the support. To perform it, the ECMO sweep should be 0 L/min, or the gas tube should be disconnected and pinched, and the ventilation patterns must be configured as follows: Tidal volume ≤6-8 ml/Kg, PPLAT ≤ 30 cmH2O, PEEP ≤16 cmH2O, FiO_2 ≤ 50%, pH > 7.30 and SatO2 > 88%, or adjusted as required. If the gas exchange is adequate during 2 to 4 hours, the patient can have the cannula removed. 6 It is worth noting that, during the decannulation, heparin should be disconnected from 30 to 60 minutes before the procedure [9].

VA ECMO:

VA ECMO is used if, in addition to pulmonary impairment, heart failure is concurrently diagnosed. Its weaning should be gradually and relatively fast, with reduction of 5 to 10 ml/kg rate per hour, in order to minimize the venous blood shunting in the arterial path created by the circuit. When reaching at least

20 to 30 ml/kg/min, the blender gas stream is disconnected and the clamping is performed. If the patient has normal clinical and laboratory parameters, the decannulation is realized (Broccoli *et al*., 2018).

Clinical Practice for Other Health Professionals

Nutrition Support

Nutrition therapy for critically ill patients is difficult due to hemodynamic instability. The hypotensive state leads to compromised splanchnic perfusion, which is a prerequisite for the possible start of nutritional support. On the other hand, ECMO can provide favorable circulatory support, which reduces the risk of gastrointestinal hypoperfusion and mesenteric ischemia. Thus, the nutritional management of the patient in ECMO should follow the same guidelines as other critical patients (Farías *et al*., 2015; Broccoli *et al*., 2018).

Nutritional support can be started when the patient presents hemodynamic stability, which usually occurs after the first 6 to 12 hours the start of ECMO assistance (Farías *et al*., 2015; Broccoli *et al*., 2018). Early enteral feeding of low-dose (trophic) nutrition therapy is recommended. The enteral nutrition (EN) is important to regulates gastrointestinal motility, in addition is generally well tolerated by most patients; serious adverse events is not reported, such as intestinal ischemia, gastrointestinal bleeding or other complications. Enteral nutrition intolerance is common in clinical practice, and can be demonstrated by residual gastric volume (> 500 ml), vomiting and abdominal distension, in these cases, total parenteral nutrition (TPN) is considered (Rocha *et al*., 2020; Toh *et al*., 2021).

Oral Healthcare

The presence of oral healthcare professionals for critically ill patients is important. Efficient oral hygiene is able to reduce bacterial colonization and minimize the risk of Ventilator-associated pneumonia. The oral microbiota remains in balance for about 48 hours after admission in ICU; however, the composition of the microbiota is vulnerable to change. Thus, it is necessary implementing oral hygiene to reduce bacterial oropharyngeal colonization and dental plaque (Lima *et al*., 2021).

In the context of COVID-19, oral health and care for critically ill patients has been even more necessary due to imbalance of the oral microbiota and immunosuppress developed for SARS-CoV-2 infection. This situation can allow secondary viral and fungal infections, such as herpes simplex virus (HSV-1) (Furtado *et al*., 2021; dos Santos Júnior *et al*., 2020).

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Psychological Monitoring

Psychological care is linked to the effectiveness of physical treatment and must be given priority. Thus, the inclusion of the psychologist in the intensive care team aims to add to their knowledge so that they can promote ample support for the life of the patient and their family (Ferreira and Mendes, 2013).

The ICU team must be ready to attend the demands of patients and their families. It is important to emphasize that the actions within an ICU must be performed by an entire multidisciplinary team with the objective of contemplating the humanization of the environment and care; guarantee the necessary information, as well as the suppression of pain, privacy, comfort, individualization, embracing emotions, assistance to the family and the choice and effectiveness of treatment (Ferreira and Mendes, 2013).

Conclusion

The careful patient selection, appropriate management and experience of the multidisciplinary team are factors affecting the efficacy of ECMO support in the COVID-19 pandemic. Therefore, all decisions should be made following established protocols to provide a favorable outcome for the patient.

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