Vall d'Hebron
University Hospital
Critical Care Department

Pg. Vall d'Hebron, 119-129
08035 Barcelona, Spain
Tel. 34 93 274 62 09
34 93 274 61 42
Fax 34 93 274 60 62

Appendix 1. Vall d'Hebron University Hospital adult ECMO Program standard key points and summary of modifications during COVID-19 pandemic.

VHUH adult ECMO Program

Key points of the program
• Adherence to ELSO guidelines. • Multidisciplinary ICU-led ECMO team. • Concentration of cases in the same unit, regardless of VV/VA. • ECMO team training and retraining based on simulation.

ELSO Center nº 200, with 30-40 venovenous (VV) and venoarterial (VA) adult cases per year. All patients needing either VV or VA ECMO support are concentrated in the general ICU and managed by a specifically trained multidisciplinary ECMO team. An ICU ECMO specialist is on call 24h/365d. The nurse/patient ratio is 1,5/1, so three ECMO-trained ICU nurses take care of two patients. Every member of the team must have completed two ELSO-based courses and 36 hours of practice monitored by an experienced ECMO specialist, who must have given a positive evaluation. Re-training is also provided with a frequency that depends on number of cases per month.

Nine ELSO-based protocols guide the management of patients with ECMO support (VV, VA, ECCOR, ECPR, Transport, Anticoagulation & Bleeding management, Echography, Complications management, Patient Care).

Clinical data of all the ECMO cases are recorded by members of the ECMO team including all the variables needed for covering the ELSO registry.

VHUH adult ECMO management in COVID-19 pandemic:

As a high-volume, ELSO-affiliated ECMO center, the hospital became a referral center for extracorporeal respiratory support during the pandemic in Catalonia, a region with a population of 7.5 million inhabitants. Criteria for ECMO referral during pandemics, and indications and contraindications, are detailed in the table below. Information was delivered to all the potential referral centers. A call was received whenever the physician felt the patient was a candidate for ECMO support. The case was analyzed by the intensivist on call who recorded the available data and either confirmed the indication, suggested modifications in the current treatment with subsequent follow-up, or rejected the indication. An ICU specialist led the cannulation team which also comprised a cardiac surgeon and two specifically trained ICU nurses. Prior to transfer of the patient, all team members performed a briefing exercise during which all the data requested from the referral center were shared (table). On arrival at the primary center, another briefing with the local team before ECMO cannulation was held. Femoro-femoral VV ECMO was the first choice for cannulation aiming to facilitate logistics during transport due to the need for longer tubes and also to keep the team as far as possible from the airway. The roles of the team were redistributed with a standard operation procedure during cannulation and transport to ensure patient safety and reduce team exposure. Cannulations were performed by the intensivist and the cardiac surgeon, members of the ECMO team (normally in parallel, one in the drainage access and the other in the return, due to the presence of life-threatening hypoxemia) with the assistance of the two ECMO-specialist ICU nurses. Another check-list and an extra bag with personal protective equipment (PPE) for all team members were added to the standard bags, with enough equipment to perform cannulation and transport in two stages, leaving time for the team to rest from wearing the PPE if needed and with full-body protection suits for the transport. The reduced group of members of the ECMO team that is usually in charge of retrievals was specifically trained on PPE practices during the first weeks of the pandemic and also a brief specific checklist was done before departure to the primary center. From our setting to the primary center the team used the conventional measures of protection. During the cannulation the PPE included goggles, FFP3-masks, double gloves, and gowns. For the transport back to our center, two of the members responsible for the direct care of the patient in the ambulance changed to a full-body protection to enhance security and facilitate movements in a small place.

Patients were maintained under neuromuscular blockers (NMB) during the first 48 hours to avoid increases of transpulmonary pressure due secondary to a high respiratory drive. After this period, NMB were withdrawn and sedatives were minimized as much as possible.

Gentle ventilation was immediately initiated at arrival to our ICU. An esophageal balloon was placed when possible to monitor transpulmonary pressure. Daily chest x-ray was performed and a CT scan was done if persistent infiltrates or unexpected clinical changes. If stable enough, an angioCT scan was also performed as soon as the patient arrived to our center before coming to the ICU. Fiberbronchoscopy for microbiological surveillance and for clearance of secretions was performed if suspicion of respiratory coinfection, if persistent infiltrates or a decrease of dynamic compliance.

Regarding the anticoagulation and bleeding management, heparin infusion was normally used with titration adjusted to the activated clotting time (ACT) measured each hour with the blood sample taken from the preoxygenator port. We also measure the level of platelets and the coagulation tests, including activated partial thromboplastin time (each 12 hours) and antithrombin III (day of admission and daily if <70%). All the team members are trained to adjust the dose of heparin taking into account all these values and others (calcium levels, body temperature, uremia). The targeted value of ACT in COVID patients was 180-200 seconds, of platelets > 75000 $x10^9$/L and fibrinogen > 1.5 g/L. If bleeding problems occurred, we progressively decrease target until 140 seconds. If bleeding persisted, the heparin infusion was withdrawn and the ECMO flow increased over 4 liters per minute.

Once ultra-protective ventilation was initiated, the ECMO flow was adjusted to maintain SpO_2 over 80% with normal lactate, hemoglobin levels over 10 g/dL and normal cardiac output monitored by echocardiography. Recirculation was monitored by measuring the saturation of the blood entering the circuit (SvO_2). Sweep flow was adjusted to achieve $PaCO_2$ of 35-40 mmHg. Weaning of ECMO was initiated when the chest x-ray cleared and compliance improved. When this occurred, the sweep flow was tapered and respiratory mechanics, SpO_2 and SvO_2 were monitored during at least three hours. If the trial succeeded, the patient was decannulated after withdrawing heparin perfusion, with no administration of protamine.

ECMO referral for patients with SARS-CoV-2 infection. Indications, contraindications, checklist prior to displacement and expansion of ECMO devices during pandemic.

CRITERIA FOR ACTIVATION OF ECMO RETRIEVAL TEAM	- PaO_2/F_IO_2 < 80 mmHg and prone (> 12h) does not increase ratio > 20%. - PaCO2 > 80 mmHg and pH < 7.25 more than 6 hours.	
ABSOLUTE CONTRAINDICATIONS	- Age > 65 years old. - MV with high pressure levels (Pplat > 30 cmH_2O) and F_IO_2 > 0.9 for more than 7 days.	
RELATIVE CONTRAINDICATIONS (2 or more = no indication)	- Age 60-65 years old. - Immunosuppression. - Impossibility of anticoagulation. - BMI > 45 Kg/m^2.	
ITEMS OF CHECKLIST PRIOR TO RETRIEVAL	Jugular and femoral venous diameter, site of central venous catheter, number of platelets, coagulation ratios, volemia status, echocardiography information and prealert for potential use of blood products.	
ECMO DEVICES (Total of 12)	USUAL ECMO MACHINES (5)	EXPANSION (7)
	- 3 CardioHelp© (Getinge). ICU - 1 CardioHelp©. ICU – pediatric ICU - 1 Centrimag© (Abbot). Operating theater.	- 1 CardioHelp© loaned from Getinge. - 2 Novalung© (Xenios-Fresenius) VHUH purchase. - 2 Centrimag© loaned from Abbot. - 1 CardioHelp© loaned from UCI H. Teknon, Barcelona. - 1 Novalung© loaned from UCI H. Sant Pau, Barcelona.