Initiation of an inter-hospital extracorporeal membrane oxygenation transfer programme for critically ill patients with coronavirus disease 2019: bringing extracorporeal membrane oxygenation support to peripheral hospitals

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Abstract

OBJECTIVES: Extracorporeal membrane oxygenation (ECMO) is a resource-intensive, highly specialized and expensive therapy that is often reserved for high-volume centres. In recent years, we established an inter-hospital ECMO transfer programme that enables ECMO implants in peripheral hospitals. During the pandemic, the programme was expanded to include ECMO support in selected critically ill patients with coronavirus disease 2019 (COVID-19).

METHODS: This retrospective single-centre study reports the technical details and challenges encountered during our initial experience with ECMO implants in peripheral hospitals for patients with COVID-19.
RESULTS: During March and April 2020, our team at the University Hospital of Zurich performed 3 out-of-centre ECMO implants at different peripheral hospitals. The implants were performed without any complications. The patients were transported by ambulance or helicopter. Good preparation and selection of the required supplies are the keys to success. The implant should be performed by a well-trained, seasoned ECMO team, because options are limited in most peripheral hospitals.

CONCLUSIONS: Out-of-centre ECMO implants in well-selected patients with COVID-19 is feasible and safe if a well-established organization is available and if the implantation is done by an experienced and regularly trained team.

Keywords: Extracorporeal membrane oxygenation • COVID-19 • Acute respiratory distress syndrome • Pneumonia

INTRODUCTION

Per the current World Health Organization (WHO) figures of 17 April 2000, the new severe acute respiratory syndrome coronavirus 2 has infected >2 million people worldwide with, to date, 139 378 deaths. In Switzerland, the first case of coronavirus disease 2019 (COVID-19) was confirmed on 25 February 2020. To date, a total of 34 000 cases have been confirmed by the health authority in Switzerland [1]. The WHO has declared the disease a Public Health Emergency of International Concern and released interim guidelines on patient management [2]. The WHO interim guidelines made general recommendations for treatment of acute respiratory distress syndrome (ARDS) in patients with COVID-19, including referring patients with refractory hypoxemia to expert centres capable of providing extracorporeal membrane oxygenation (ECMO) therapy. For patients who are not in a conventional transportable condition, we have established a mobile ECMO service so that ECMO therapy can be offered to peripheral hospitals and patients can be transferred safely to a specialized centre for further treatment.

Management of extracorporeal membrane oxygenation in patients with coronavirus disease 2019

All procedures described in this report were performed in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

During March and April 2020, our team at the University Hospital of Zurich performed 3 out-of-centre ECMO implants at different peripheral hospitals. Two out of the 3 centres were already familiar with the principles of ECMO therapy. All patients were men. The median age was 58 years; the youngest patient was 49 years old. Detailed patient characteristics are described in Table 1. All patients were on mechanical ventilation for about 1 week (5–6 days) before respiratory performance, despite an intermittent prone position and high pressure ventilation, rapidly deteriorated further and ECMO became necessary. The median Horowitz index before the ECMO device was implanted was 87 (range 84–93) under FiO2 1.0 and volatile NO therapy in 2 of the patients. Preoperative computed tomography scans were available from all patients, showing the typical ground-glass opacities, consolidations and bronchovascular thickening already described in detail in the literature [3]. One patient had a pneumothorax, which was successfully relieved by a chest drain. For preoperative assessment and evaluation, we developed a specific evaluation sheet for patients with COVID-19 to collect the personal details; age, height and weight; co-morbidities; length of orotracheal intubation and actual ventilation parameters; haemodynamics including catecholamine use; and infection parameters. The PRedicting dEath for SEverely ARDS on V-V-ECMO score, the Murray score and the Horowitz index were used to assess the indication and the expected outcome. Although resources may be limited during a pandemic, we gave the priority for ECMO treatment to younger patients with minor or no comorbidities. We formulated in-house indications and contraindications for ECMO in patients with COVID-19 that were discussed by an interdisciplinary team before each implant (Table 2) [4]. The patient's

Table 1: Clinical characteristics and outcomes of out-of-centre extracorporeal membrane oxygenation implants in patients with coronavirus disease 2019 (March–April 2020)

| Variables | Patient 1 | Patient 2 | Patient 3 |
|-----------|-----------|-----------|-----------|
| Age (years) | 46       | 58       | 59       |
| Sex (male) | x        | X        | x        |
| Weight/height (kg/cm) | 100/181  | 70/178   | 140/180  |
| Comorbidities |          |          |          |
| Diabetes | x        |          |          |
| Hypertension |          | x        |          |
| Adipositas |          |          | x        |
| Days before ECMO Implant |          |          |          |
| Onset of symptoms | 18       | 16       | 17       |
| Hospital stay | 8        | 11       | 6        |
| Mechanical ventilation | 5        | 6        | 6        |
| Horowitz index before ECMO | 87       | 93       | 84       |
| Type of ECMO |          |          |          |
| V-V | x        | X        | x        |
| Cannulation site |          |          |          |
| Right vena jugularis interna | x        | x        | x        |
| Right vena femoralis communis | x        |          |          |
| Left vena femoralis communis |          |          |          |
| Perfusion cannula (Fr.) | 17       | 17       | 19       |
| Drainage cannula (Fr.) | 23       | 23       | 25       |
| Transport |          |          |          |
| Ground (ambulance) |          |          | x        |
| Air (helicopter) | x        |          |          |
| Duration of ECMO (days) | 6        | 9        | 28       |
| ECMO prognosis | Recovery | Recovery | Recovery |

ECMO: extracorporeal membrane oxygenation; Fr.: French; V-V: venovenous.
request and living will must be considered, and the relatives must be actively involved in the decision-making process. Before finally accepting a patient for an out-of-centre ECMO implant and transfer to our intensive care unit (ICU), the local resources were evaluated in detail to make sure optimal care was possible and guaranteed. The best transport routes were identified with the local emergency services before each operation, and the decision was made to use ground or airborne transport (ambulance or helicopter) (Fig. 1A).

Out-of-centre extracorporeal membrane oxygenation team

ECMO therapy is a well-established procedure at our centre in Zurich, with the first implant being performed around 40 years ago. With about 150 ECMO implants per year, our hospital runs one of the leading national ECMO programmes. Within the last 6 years, we performed 165 ECMO transports [5]. During the ongoing COVID-19 pandemic, 9 patients have been supported by ECMO in our hospital so far. All team members are trained on a special ECMO simulator and undergo regular retraining. Thus, we have extensive experience and an existing infrastructure that make it possible to establish such a demanding programme in times of a national crisis.

The mobile ECMO team in our centre comprises a cardiac surgeon, a perfusionist, a rescue doctor and a paramedic. The ECMO equipment is stowed in 5 robust, water-repellent transport bags and can be loaded compactly (Fig. 1B). For the transports, we routinely use the Cardiohelp System (Maquet Getinge AB, Rastatt, Germany) equipped with an HLS 7.0 oxygenator. In case a percutaneous implant is not feasible or complications arise, a complete surgical implant set is available. Upon arrival at the peripheral centre, the ECMO team should take the lead because the colleagues from the peripheral hospitals may not be familiar with the individual details of and supplies needed for an ECMO implant. A case presentation of the patient as well as joint planning of the implant process, with explanation of the individual steps by the surgeon, is essential. Each team member needs to be assigned a role. Before entering the isolated patient room, the cardiac surgeon and the perfusionist select the necessary surgical supplies, based on the size and weight of the patient and the planned ECMO setting [ivenoarterial or venovenous (V-V) ECMO, cannulation site]. Only supplies that are absolutely necessary for the implant procedure are taken into the isolation area (Table 3). Additional tools that may be required during the operation (additional hydrophilic or stiff wires, catheters, dilators, locks, canulaus, surgical equipment) are provided in front of the isolation area. It is advisable to instruct a local scrub nurse who can prepare further supplies if necessary. All isolation measures must be strictly observed. For the standard V-V ECMO setting, we recommend ultrasound-guided punctures of the right internal jugular and femoral vein. Alternatively, the femorofemoral configuration can be used.

Table 2: Contraindications for extracorporeal membrane oxygenation in patients infected with coronavirus disease 2019 at the University Hospital of Zurich

| Absolute contraindications                                                                 | Relative contraindications                                      |
|-------------------------------------------------------------------------------------------|-----------------------------------------------------------------|
| • Age >70 years                                                                            | • Obesity BMI >35                                               |
| • Clinical Frailty Scale category ≥3                                                     | • No legal medical decision maker available                      |
| • Malignant oncological disease in palliative care                                        | • Immunocompromised status                                      |
| • Uncontrolled shock (pH < 6.8, lactic acidosis)                                           | • High-dose vasopressor requirement (consider candidate for VA-ECMO) |
| • Multiple organ failure                                                                   |                                                                 |
| • Moderate to severe neurological impairment                                               |                                                                 |
| • Moderate to severe cognitive impairment                                                   |                                                                 |
| • Advanced lung disease                                                                   |                                                                 |
| • Chronic heart failure (EF <35%)                                                          |                                                                 |
| • Chronic kidney disease (GFR <30)                                                         |                                                                 |
| • Chronic liver failure (child > B)                                                        |                                                                 |
| • Protein-energy malnutrition                                                             |                                                                 |
| • Emergency implant setting                                                                |                                                                 |

BMI: body mass index; ECMO: extracorporeal membrane oxygenation; EF: ejection fraction; GFR: glomerular filtration rate; VA: venoarterial.

DISCUSSION

So far there is little information on the use of ECMO in critically ill patients with COVID-19. At the time of this writing, referring to the Extracorporeal Life Support Organization and the Euro Extracorporeal Life Support Organization registry, so far 858 patients with COVID-19 have been supported with ECMO (mean age 52 years; 95% V-V ECMO). In Switzerland, 20 ECMO implants (9 USZ, Zurich; 6 CHUV Lausanne; 3 Inselspital Bern; 2 Basel)
have been done in this challenging patient group [8]. Most studies are restricted to case reports and small series, reporting a mortality of up to 94% [9]. In patients treated with ECMO for other viral infections causing ARDS, like influenza A (H1N1) in 2009 or the Middle East Respiratory Syndrome Coronavirus in 2012, a decrease in mortality and length of stay in the ICU could be shown, supporting the use of ECMO as a rescue therapy in this population [10, 11]. There is clear evidence of increased mortality with advanced age and comorbidities that should not be overlooked [12]. As the disease burden increases and health systems could reach their limits during a global pandemic, selection criteria should be stringent in order to utilize this valuable resource for those most likely to benefit from this treatment and return to a good quality of life [13].

ECMO is a resource-intensive, highly specialized therapy requiring specially trained doctors and nursing staff. There is some evidence that outcomes from ECMO therapy are better in high volume centres [14]. The role of ECMO in the management of COVID-19 is unclear at this point. Results from prospective studies are currently not available. Should the initial experience with ECMO support in patients with COVID-19 be encouraging, it is likely that non-ECMO centres will refer their patients early to ECMO centres in anticipation of impending clinical deterioration.

This procedure will disproportionately affect centres with ECMO programmes, even when ECMO is not required [15]. The transport programme presented can help to avoid this situation, because the experts from the ECMO centre are preoperatively in close contact with the referring clinics and are actively involved in the indication for the ECMO implant. In China, approximately 5% of critically ill patients with COVID-19 have presented rapidly progressive respiratory failure and have developed ARDS [16]. These patients can deteriorate quickly and become unfit for transport to a centre. The ECMO programme presented brings precisely this patient group into a transportable state and enables further care in a higher-level centre. Because any supplies that have entered the isolation area must subsequently be discarded, good preparation and supply selection are key for a safe, successful and resource-saving implant procedure. For ECMO implants in peripheral hospitals, ECMO teams should develop a checklist for cannulation, and team members should ensure they take all necessary supplies with them prior to entering the isolation room. We recommend preparing a cannulation COVID-19 side table that contains all cannulas, extension hoses, connectors, guide wires, fluids, heparin, puncture sets and sterile sleeves needed for the implant procedure. In case additional supplies are needed, a backup bag should be prepared in the clean area.
Table 3: Equipment needed for extracorporeal membrane oxygenation implant procedure

| Vascular access kit       | Surgical instruments | ECMO circuit |
|---------------------------|----------------------|--------------|
| Disinfection kit          | Scalpel              | Cardiohelp (Maquet, Getinge AB, Rastatt, Germany) |
| Sterile covers and drapes | Scissors             | HLS 7.0 oxygenator |
| Vascular ultrasound cover and sterile gel | Needle holder       | Tubing system |
| Local anaesthesia         | Forceps              | 4 Sterile tubing clamps |
| Puncture needle           | Tubing scissors      | Tubing scissors |
| 20-ml syringe with NaCl   | Saline flusher       | Saline flusher |
| Sheath (2 × 5 Fr.)        | ECMO7 cannula        | ECMO7 circuit |
| Standard J-tip working guide wires (80 and 175 cm) |.ECMO cannulas |
|                          | Drainage cannula (23–25 Fr.) |
|                          | Perfusion cannula (17–21 Fr.) |
| Vascular access kit       | Surgical instruments | ECMO circuit |
| Personal protection equipment | ECMO cannulas       | Surgical instruments |
| Goggles                   | Personal protection equipment | Surgical instruments |
|                           | Sterile gowns and gloves |
|                           | Forceps              | Surgical instruments |
|                           | Needle holder       | Surgical instruments |
|                           | Vascular access kit | Surgical instruments |
|                           | Sterile covers and drapes |
|                           | Vascular ultrasound cover and sterile gel |
|                           | Local anaesthesia   | Surgical instruments |
|                           | Puncture needle     | Surgical instruments |
| ECMO cannulas             | Surgical instruments | Surgical instruments |
|                          | ECMO cannula        | Surgical instruments |
|                          | ECMO cannula        | Surgical instruments |
|                            | ECMO cannula        | Surgical instruments |

outside the isolation zone. We recommend instructing a dedicated person on the local staff who can provide additional needed equipment for those working in the isolated area.

CONCLUSION

Out-of-centre ECMO implant procedures in well selected patients with COVID-19 are feasible if a well-established organization is available and are safe for both the patient and the personnel. Building up such a programme is time- and resource-consuming and requires specialists from various disciplines. The implant should be performed by a well-trained, seasoned ECMO team, because resources are limited in most peripheral hospitals. Good preparation and selection of the required material are essential. Commissioning new inter-hospital implant and transport programmes for the purposes of treating patients with COVID-19 is therefore not recommended. Centres with already existing transport programmes should plan their operations well, particularly with regard to patient selection, logistics, personnel protection and patient isolation during transport.

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