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# Regional extracorporeal membrane oxygenation retrieval service during the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic: an interdisciplinary team approach to maintain service provision despite increased demand

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## Abstract

**OBJECTIVES:** Coronavirus disease 2019 is a new contagious disease that has spread rapidly across the world. It is associated with high mortality in those who develop respiratory complications and require admission to intensive care. Extracorporeal membrane oxygenation (ECMO) is a supportive therapy option for selected severely ill patients who deteriorate despite the best supportive care. During the coronavirus disease 2019 pandemic, extra demand led to staff reorganization; hence, cardiac surgery consultants joined the ECMO retrieval team. This article describes how we increased service provisions to adapt to the changes in activity and staffing.

**METHODS:** The data were collected from 16 March 2020 to 8 May 2020. The patients were referred through a dedicated Web-based referral portal to cope with increasing demand. The retrieval team attended the referring hospital, reviewed the patients and made the final decision to proceed with ECMO.

**RESULTS:** We reported 41 ECMO retrieval runs during this study period. Apart from staffing changes, other retrieval protocols were maintained. The preferred cannulation method for veno-venous ECMO was drainage via the femoral vein and return to the right internal jugular vein. There were no complications reported during cannulation or transport.

**CONCLUSIONS:** Staff reorganization in a crisis is of paramount importance. For those with precise transferrable skills, experience can be gained quickly with appropriate supervision. Therefore, the team members were selected based on skill mix rather than on roles that are more traditional. We have demonstrated that an ECMO retrieval service can be reorganized swiftly and successfully to cope with the sudden increase in demand by spending cardiac surgeons services to supplement the anaesthetic-intensivist roles.

**Keywords:** Coronavirus disease 2019 • Pandemic • Extracorporeal membrane oxygenation • Retrieval • Veno-venous-extracorporeal membrane oxygenation • Severe acute respiratory syndrome coronavirus 2

## INTRODUCTION

Coronavirus disease 2019 (COVID-19) is a new contagious disease, a public health emergency and a pandemic. It is caused by severe acute respiratory syndrome coronavirus 2, a novel coronavirus that has spread rapidly across the world since the first reports in December 2019 [1] from Wuhan, China. Current

evidence suggests a zoonotic source, transmitted to humans that spreads via droplets. It has a spectrum of clinical presentations, from mild coryzal-like symptoms to respiratory failure. It is associated with high mortality in those who develop respiratory complications and require admission to the intensive care unit (ICU), with preliminary data from the Intensive Care National Audit and Research Centre of the UK indicating up to 50% mortality [2]. Extracorporeal membrane oxygenation (ECMO) is a treatment option to support selected severely ill patients who deteriorate

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despite mechanical ventilation and best supportive care. Its use has been more established in patients with severe respiratory failure since the H1N1 pandemic [3–6]. Table 1 shows the UK guidelines for ECMO indications for patients in severe respiratory failure.

During COVID-19, it was anticipated that an increasing number of the patients would be referred for ECMO and intensive care support. We predicted a surge in ECMO retrieval activity that would require a larger number of medical personnel to staff ICUs and the ECMO team. Our normal 3-person ECMO retrieval team would be insufficient to cope with the increasing demand during the COVID-19 pandemic. It was not practical in terms of both resources and time to recruit and train new staff. Therefore, we reconfigured our ECMO retrieval team to include cardiac surgeons. We paired the most experienced surgical consultant with a senior anaesthetic fellow (trainee) and the less experienced surgical consultants with an anaesthetic consultant. This plan fulfilled the obligation to provide a consultant grade team leader and an airway-trained doctor. Our goal was to report our initial experience with this expanded ECMO retrieval team in the eastern region of the UK during the 2020 COVID-19 pandemic.

## MATERIALS AND METHODS

The data were collected from 16 March 2020 to 8 May 2020 (54 days). Until 25 March, we received referrals by telephone on a standard pro forma. Thereafter, we used a dedicated electronic referral portal to cope with the increased demand—referrapatient<sup>®</sup> (Bloomsbury Health Limited, London, UK). The electronic-based referral system was user-friendly, secure and improved efficacy in communication. It did not require additional training or hardware resources.

A team of 3 experienced intensive care consultants reviewed the ECMO referrals. They provided direct advice and activated the retrieval team when necessary following multidisciplinary discussions with 2 other senior intensivists working alternate days. Before considering ECMO support, as a prerequisite, referring units were advised to place the patient in a prone position to improve the ventilation [9]. There was no specific time frame for patient to stay prone before considering for ECMO, decision was based on clinical progression of the patient.

To ascertain the candidacy of the patient for ECMO, the retrieval team initially assessed the patient in the ICU, and reviewed the chest radiographs and results of blood tests. We obtained verbal consent for ECMO from the patient's next of kin over the telephone explaining the risks and potential benefits.

When the decision is made to proceed with ECMO, our preference is that cannulation be performed in the referring hospital's operating room. We require a dedicated anaesthetist, theatre practitioner and a radiographer with an image intensifier from the referring team to insert a new central venous line on the left side of the neck and facilitate ECMO insertion, respectively. A World Health Organization surgical safety checklist was completed prior to cannulation. We observed the recommendations from the Extracorporeal Life Support Organization (that venovenous ECMO (VV-ECMO) be initiated by staff personal protective equipment with full contact precautions) [10]. Before the patient arrived in the operating room, the ECMO retrieval team had scrubbed and donned the appropriate apparel. The equipment was ready so the team could proceed immediately (Fig. 1) in case the patient became unstable. Changing the patient from the prone to the supine position for cannulation was performed onto

**Table 1:** UK ECMO referral guidelines during the coronavirus disease 2019 pandemic

| Inclusion criteria <sup>a</sup>   |
|---|
| <ul style="list-style-type: none"> <li>• Potentially reversible severe respiratory failure</li> <li>• Lung injury score [7] <math>\geq 3</math></li> <li>• Failed trial of ventilation in the prone position <math>\geq 6</math> h (unless contraindicated)</li> <li>• Failed airway pressure release ventilation or 'high positive end-expiratory pressure ventilation strategy' <math>\geq 6</math> h (unless contraindicated)</li> <li>• Clinical frailty scale [8] category <math>\leq 3</math></li> <li>• If the Respiratory Extracorporeal Membrane Oxygenation Survival Prediction score [9] is <math>\leq 3</math>, ECMO should be considered only after agreement across at least 2 centres</li> </ul> |
| Exclusion criteria  |
| <ul style="list-style-type: none"> <li>• Refractory multiorgan failure</li> </ul>   |

<sup>a</sup>Revised in response to the coronavirus disease 2019 pandemic.  
ECMO: extracorporeal membrane oxygenation.

the operating table. Under aseptic conditions, the femoral vessel was punctured percutaneously under directed ultrasound guidance and the old central line in the neck was rewired for insertion of the return cannula into the internal jugular vein (our preference is to insert return cannulas on the right side of the neck because of the straighter path to the right atrium). Once the positions of both guide wires were confirmed with the image intensifier, systemic heparin was administered, initially 2500 IU and another 2500 IU if required based on body surface area. We followed our institutional anticoagulation guidelines. A higher than usual degree of anticoagulation may be indicated, and a case-by-case assessment of bleeding versus thrombotic risks is recommended pending further evidence in patients with COVID-19 [10]. The puncture site was then dilated sequentially to the appropriate diameter of the cannula. For drainage, we used the femoral venous Maquet (BIOLINE coating) HLS cannula<sup>®</sup> (Getinge AB, Gothenburg, Sweden), type PVL-2555 with an outer diameter of 7.6–8.3 mm (23–25 Fr) and a maximum insertion length of 380–550 mm; it connects to standard 9.5 mm (3/8 inch) diameter tubing. The return internal jugular venous cannula used is the Maquet (BIOLINE coating) HLS arterial cannula<sup>®</sup> type PAS-1915 with an outer diameter of 6.3 mm (19 Fr) and a maximum insertion length of 150 mm. It has 2 side holes with a perforation length of 10 mm and connects to standard 9.5 mm (3/8 inch) tubing. The cannulae were fixed securely in position with 3 sutures and Hollister<sup>®</sup> dressings (Hollister Limited, Wokingham, UK). We used Thoratec Levitronix<sup>®</sup> (Levitronix GmbH, Zurich, Switzerland) consoles and ranges of oxygenators depending on availability (Paragon<sup>®</sup> Chalice Medical Limited, Worksop, Nottinghamshire, UK; Eurosets<sup>®</sup> Eurosets S.R.L, Medolla, Italy and Medos hilite<sup>®</sup>, Inspiration Healthcare, Crawley, UK).

All patients were transferred by a dedicated ECMO ambulance service (Amvale Medical Transport Limited, Scunthorpe, UK) [11]; 2 vehicles were used for transfer to ensure social distancing. A standardized ECMO report was recorded for every patient. Management of ECMO in patients with COVID-19 was similar to that in standard patients with ECMO.

## RESULTS

In total, 229 referrals (21.2% of UK referrals) were received during the period of the study at the peak of the COVID-19 pandemic in



**Figure 1:** Extracorporeal membrane oxygenator insertion trolley setup.

the UK (Fig. 2). This number was approximately an eight-fold increase compared with the same period in 2019. Of the 229 referred patients, 41 (17.9%) were considered suitable for ECMO support. The retrieval team assessed all patients clinically on arrival at the referring hospital; 4 of these patients were not suitable for ECMO support for various reasons. Two of these 4 were transferred to Royal Papworth Hospital (RPH) for non-ECMO support and monitoring (Table 2). One of these 2 patients who were retrieved without ECMO needed ECMO support while at RPH within 24 h due to further deterioration in clinical condition; the other died of multiple organ failure. None of the patients were turned down because of staffing or resource limitations. Retrieval runs involved 19 different hospitals in the region; the hospitals visited were on average 52.3 km (range 0–104 km) away. The mean retrieval time (time from when the team left RPH until they arrived back) was 6.6 h (range 2.6–10.5 h). There was no difference in mean retrieval time when the team was led by surgeons or by an anaesthetist-intensivist group (6.5 vs 6.6 h;  $P=0.7$ ). At the time of referral, all patients had either positive test results for severe acute respiratory syndrome coronavirus 2 or were considered highly suspicious due to clinical presentation and radiological signs [12]. When a decision to proceed with ECMO was made, all patients were successfully cannulated at the referring hospital. The preferred cannulation method for VV-ECMO was drainage via the femoral veins in all cases (right 84.2% and left 15.8%) and return to the internal jugular vein in all cases (right 97.3% and left 2.7%).

The mean age was 45 years (range 23–66 years); the male-to-female ratio was 3; and the mean body mass index was 32.2 (range 20.8–73.0). One patient had a subsequent groin haematoma that was managed conservatively; no other procedural complications were noted. All patients had a post-ECMO insertion whole-body computed tomography scan on arrival at RPH. Thirty-seven patients were cannulated in the operating room under image intensifier guidance in a controlled fashion; 1

patient was cannulated in the ICU without the use of an image intensifier.

There were no complications during transfer, and all transfers were accomplished by road. In total, 90.3% cases were transferred to the RPH, but due to capacity constraints at the time, 9.7% were transferred to other ECMO centres.

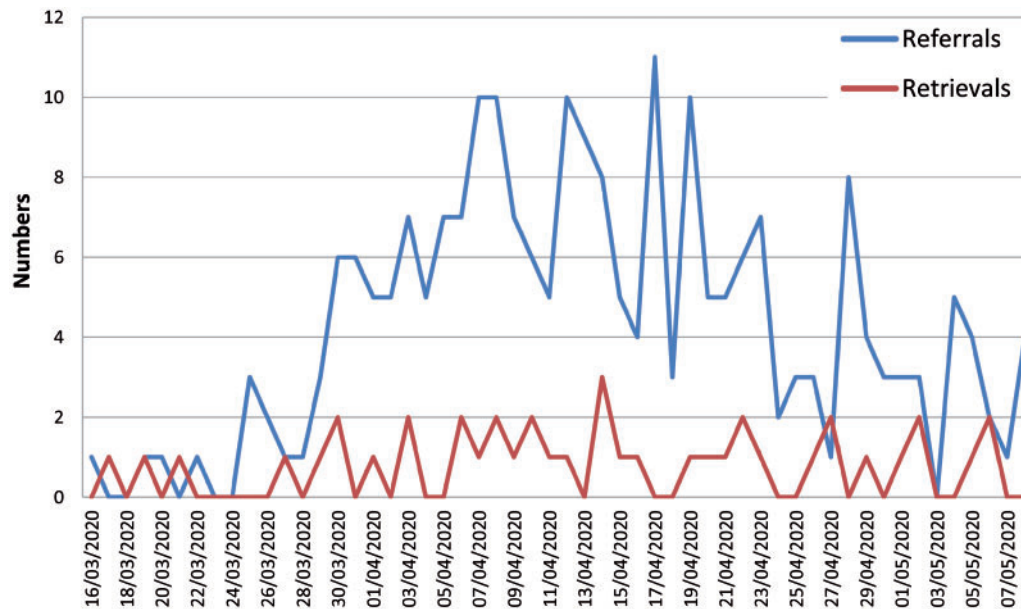
## DISCUSSION

The COVID-19 pandemic has tested the resilience of every health care service and society. This virus spreads easily and has a high mortality rate in the population [13]. In addition, deficiencies in the supplies of personal protective equipment have been a problem in several countries [14]. Many surgical groups and advisory committees have advised caution when operating on patients with COVID-19. Cardiothoracic surgery is considered high risk [15], and reports in the literature suggest a higher rate of mortality in patients with, or contracting, COVID-19 in the perioperative period.

In the UK, the National Health Service England has commissioned 5 surgical centres on a regional basis to cover the whole country to provide ECMO support for adult respiratory failure. The RPH covers the eastern region of the UK and is one of the designated centres for ECMO. Each centre provides an around-the-clock retrieval service and under usual operating conditions is responsible for providing 3 ECMO beds. The current system was developed in response to the increasing number of the patients requiring ECMO support for respiratory failure, first seen in the H1N1 influenza pandemic of 2010 [4]. This provision can be increased further during surge conditions in response to winter influenza epidemics. During the COVID-19 pandemic, the number of beds at each centre increased to 20.

In our tertiary cardiothoracic centre, the utilization of ICU beds was expanded to more than usual capacity (from 46 to 65 beds) and redirected to patients with COVID-19. Further surge





**Figure 2:** Extracorporeal membrane oxygenator referrals versus retrieval to Royal Papworth Hospital (referapatient<sup>®</sup> system; Bloomsbury Health Limited, London, UK; live from 25 March 2020).

plans were in place to increase the ICU bed capacity to 100 if required. In response to national and other centres' recommendations, all elective cardiac surgery activity was paused to provide this expansion in ICU beds [15].

Normally the team that provided ECMO assessment and retrieval at RPH included a consultant (attending) anaesthetist, an ECMO specialist nurse and a perfusionist. During the 2010 H1N1 influenza pandemic, our VV-ECMO retrieval team was expanded to include surgeons, but over time, an anaesthetist-intensivist team took over completely. During the COVID-19 pandemic, there was a need for extended intensive care requiring additional medical staff and more resident anaesthetic consultants. Hence, we anticipated that the ECMO retrieval team would be busier than usual and would be more difficult to staff using the original team model. To deal with this problem, we reconfigured the original ECMO team by adding cardiac surgery consultants to the ICU rota and the ECMO retrieval team to ensure that we could provide both safe service delivery and equitable patient care.

The rationale for redeploying cardiac surgical consultants to the ECMO retrieval team was that the surgical consultants were the ideal choice. Firstly, they are familiar with cardiopulmonary bypass circuits and ECMO due to their subspecialist surgical services, for example cardiothoracic transplant and pulmonary endarterectomy surgery. Secondly, they also have experience in percutaneous cannulation of major vessels due to their work with transcatheter aortic valve implantation, minimally invasive cardiac surgery and the intra-aortic balloon pump. Thirdly, they were available because of reduced surgical activity, and they required no additional training or supervision. The rest of the ECMO team included nurses, all of whom were experienced with the equipment, retrieval and transfer protocols. It was also anticipated that due to uncertainty of support from referring hospitals under adverse stress during the pandemic, the difficulties in

communicating in full personal protective equipment and the complexity of some patients, the current 3-person ECMO team would be insufficient to deal with the demand and the support required at the peripheral hospital. Hence, we added an additional surgical member to the ECMO retrieval team. The ECMO retrieval teams were organized to be self-sufficient, with less reliance on medical help from the hospital from which the patients were retrieved.

The Extracorporeal Life Support Organization recommends that VV-ECMO should only be considered for carefully selected patients with COVID-19. It should not be considered for patients who are unlikely to benefit and for those with significantly reduced life expectancy from pre-existing disease. At the start of the COVID-19 pandemic, the outcome of ECMO for patients with this new disease remained unknown, and the rationale for ECMO support was based on prior experience in other viral pneumonia pandemics [4, 16]. VV-ECMO is a highly technical supportive therapy and is resource intensive. Although the distribution of this therapy should be as equitable as possible, during a pandemic such as COVID-19, eligibility for ECMO support should focus on optimal candidates for recovery [10, 16]; the UK national ECMO guidelines were altered to reflect this approach (Table 1). This report describes the changes that we made to our ECMO retrieval service to cope with the eight-fold increase in activity.

Modification of the interdisciplinary ECMO retrieval service during this pandemic crisis to involve cardiac surgeons and intensivists, in addition to anaesthetists, perfusionists and ECMO-trained nursing staff (who had extensive experience working together as a retrieval team in the last several years because of the H1N1 pandemic) was advantageous. It allowed the service to cope successfully with an unprecedented increase in demand in a very limited time. It facilitated the release of intensive care and

**Table 2:** Details of patients treated with veno-venous extracorporeal membrane oxygenation

| Age (years) | Sex | BMI (kg/m <sup>2</sup> ) | Comorbidities   | Team leader | COVID status | Retrieval time (h) | Destination        | Complications  |
|-------------|-----|--------------------------|-----------------|-------------|--------------|--------------------|--------------------|----------------|
| 66          | M   | 32.1                     |                 | I           | +            | 6.3                | RPH                |                |
| 57          | M   | 27.8                     |                 | I           | +            | 5.8                | RPH                | PE             |
| 24          | F   | 73.0                     |                 | I           | +            | 8.0 <sup>a</sup>   | NA                 | NA             |
| 50          | M   | 25.9                     |                 | I           | +            | 5.5                | RPH                | PE             |
| 30          | F   | 27.0                     |                 | S           | +            | 6.7                | RPH                | PE             |
| 37          | F   | 20.8                     | HT, PCOS        | I           | +            | 3.0                | RPH                | ICH            |
| 41          | F   | 27.5                     |                 | S           | +            | 6.5                | RPH                | PE, Pnx        |
| 56          | M   | 25.6                     |                 | S           | +            | 7.8                | RPH                | PE, ACP        |
| 58          | M   | 31.1                     | DM, HTN         | I           | +            | 5.8                | RPH                | PE             |
| 49          | M   | 25.2                     |                 | S           | +            | 5.4                | RPH                | MOF            |
| 45          | M   | 37.2                     | DM              | S           | +            | 6.3                | RPH                | PE             |
| 45          | M   | 24.5                     |                 | S           | +            | 6.3                | RPH                | MOF            |
| 23          | F   | 29.4                     | SCT, SLE        | S           | +            | 7.2                | RPH                |                |
| 32          | F   | 27.7                     |                 | I           | +            | 7.1                | RPH                | PE             |
| 42          | M   | 32.1                     |                 | S           | +            | 6.2                | RPH                | ICH            |
| 60          | M   | 27.7                     | HBV, DM         | I           | +            | 10.5               | RPH                | PE             |
| 47          | M   | 23.6                     | DM, HTN         | S           | +            | 8.9                | RPH                | PE, ICH        |
| 48          | M   | 41.6                     |                 | S           | +            | 6.3                | RPH                | PE             |
| 42          | M   | 32.1                     |                 | S           | +            | 6.9                | RPH                | PE             |
| 28          | M   | 39.5                     | DM              | S           | +            | 8.1                | RPH                | STE            |
| 49          | F   | 33.2                     |                 | S           | +            | 5.2                | RPH                | MOF            |
| 51          | M   | 23.1                     |                 | S           | +            | 7.3                | RPH                |                |
| 25          | M   | 46.3                     |                 | S           | +            | 8.3                | RPH                |                |
| 50          | M   | 34.0                     |                 | S           | -            | 6.9                | RPH                | PE             |
| 37          | M   | 21.3                     |                 | S           | +            | 2.7                | RPH                | PE, PF         |
| 39          | M   | 32.9                     | DM              | S           | +            | 5.8                | RPH                |                |
| 51          | M   | 26.0                     | HTN             | S           | +            | 4.6                | RPH                | PF, Pnx        |
| 50          | M   | 32.1                     | HTN, asthma     | S           | +            | 7.3                | RPH                | PF             |
| 44          | M   | 33.9                     | HT, Sa          | S           | +            | 7.3                | RPH                |                |
| 37          | M   | 23.2                     | HTN, HC, asthma | S           | +            | 5.5                | RPH                | Fungal empyema |
| 49          | F   | 45.4                     | IGT             | I           | +            | 6.2                | RPH                |                |
| 43          | M   | 37.9                     |                 | S           | +            | 6.8                | Other <sup>b</sup> |                |
| 57          | M   | 30.7                     |                 | S           | +            | 7.0                | Other <sup>b</sup> |                |
| 57          | M   | 32.3                     |                 | I           | +            | 7.1                | RPH                | ICH            |
| 60          | M   | 30.8                     | HC              | S           | +            | 5.3 <sup>a</sup>   | NA                 |                |
| 46          | F   | 33.8                     | DM, HTN, asthma | S           | +            | 5.1                | RPH                |                |
| 53          | M   | 27.4                     |                 | S           | -            | 5.2                | RPH                | PE             |
| 35          | M   | 36.7                     |                 | S           | +            | 7.5                | RPH                | PF             |
| 46          | M   | 43.2                     | HTN             | S           | +            | 7.3                | RPH                | PE, ICH        |
| 45          | F   | 33.3                     | Gout            | S           | +            | 7.9                | Other <sup>b</sup> |                |
| 53          | M   | 38.1                     | DM              | S           | +            | 10.5               | Other <sup>b</sup> |                |

<sup>a</sup>Retrieval time for the team.

<sup>b</sup>Guy's and St Thomas Hospital, London and Glenfield Hospital, Leicester; further details for these patients are not available.

ACP: acute cor pulmonale; BMI: body mass index; COVID-19: coronavirus disease 2019; DM: diabetes mellitus; HBV: hepatitis B virus infection; HC: hypercholesterolaemia; HTN: hypertension; HT: hypothyroidism; I: intensivist/anaesthetist consultant; ICH: intracranial haemorrhage; IGT: impaired glucose tolerance; MOF: multiple organ failure; NA: not applicable (patient was not retrieved); PCOS: polycystic ovarian syndrome; PE: pulmonary embolism; PF: pulmonary fibrosis; Pnx: pneumothorax; RPH: Royal Papworth Hospital; S: surgical consultant; Sa: sarcoidosis; SCT: sickle cell trait; SLE: systemic lupus erythematosus; STE: systemic thromboembolism.

anaesthetic consultant staff for additional intensive care work and being resident on-call. It permitted the service to be sustained and allowed us to train and expose more doctors to this experience in a short time. Further benefits included close integration of the team, skill sharing and learning opportunities for all ECMO team including both anaesthetists and surgeons. Surgeons gained the opportunity to experience out-of-theatre organization and to deal with critically ill patients in unfamiliar and remote environments (where hands-on experience from a surgical colleague is not available and the team members have to help each other from the available resources and personnel). This experience helped the team to develop leadership qualities and clinical skills, which are valuable in their normal day-to-day activities. Surgeons who were both confident in cannulation and able

to recognize and deal with the consequences of complications mentored the less experienced members of the team.

## Limitations

This study has several limitations. The numbers of the patients included in this study are limited at the time of submission due to the novel nature of COVID-19 and the limited number of patients needing ECMO support. The population included is adults only. The selection and referral of patients for consideration for ECMO is dependent on the local ICU team, and the outcome of ECMO for this disease was unknown at the start of the epidemic. An alternative strategy of patient assessment and transfer in the prone position, with delayed ECMO

cannulation, has been advocated by others but has not been directly compared here because the numbers did not permit such a comparison. This study is not a clinical outcome study but rather a consideration of the reorganizing and restructuring of locally available resources to establish a team of medical personnel.

## CONCLUSION

We are satisfied that it was possible to initiate ECMO in every patient when necessary, there were no cannulation complications and none of the patients deteriorated during transfer. We therefore recommend this model of staffing; it was successful in our experience during an unprecedented increase in demand for ECMO retrieval. It allowed our service to rapidly increase capacity and cope successfully with the sustained pressure over an 8-week period. If there is a further surge in the COVID cases in future, we can reintroduce this staffing model quickly.

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**Conflict of interest:** None declared.

## Author contributions

**Muhammad U. Rafiq:** Data curation; Formal analysis; Methodology; Project administration; Resources; Validation; Writing—original draft; Writing—review & editing. **Kamen Valchanov:** Conceptualization; Supervision; Writing—review & editing. **Alain Vuylsteke:** Conceptualization; Writing—review & editing. **Fouad J. Taghavi:** Writing—review & editing. **Swetha B. Iyer:** Writing—review & editing. **Catherine D. Sudarshan:** Writing—review & editing. **Jo-Anne Fowles:** Data curation; Resources; Validation; Writing—review & editing. **Simon Anderson:** Writing—review & editing. **Pooveshni Govender:** Writing—review & editing. **Miranda Holmes:** Writing—review & editing. **Alexander White:** Writing—review & editing. **Abhi Mishra:** Data curation. **Lucy Mwaura:** Data curation; Writing—review & editing. **David P. Jenkins:** Conceptualization; Methodology; Supervision; Validation; Writing—original draft; Writing—review & editing.

## Reviewer information

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