Nursing Management of a Patient With COVID-19 **Receiving ECMO:** A Case Report

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Introduction Venovenous extracorporeal membrane oxygenation has been recommended as an effective rescue therapy for select critically ill patients with COVID-19. This case report describes a first experience caring for a patient with COVID-19 who received venovenous extracorporeal membrane oxygenation and expands the literature by discussing relevant nursing management and operational considerations.
Clinical Findings A 46-year-old man presented to a hospital emergency department with pleuritic chest pain, dyspnea, anorexia, and chills. The patient was intubated for pneumonia-associated acute respiratory distress syndrome.
Diagnosis A nasopharyngeal swab specimen was positive for SARS-CoV-2, and chest radiography confirmed a diagnosis of COVID-19 with acute respiratory distress syndrome.
Interventions After no improvement with mechanical ventilation and prone positioning, the patient began receiving venovenous extracorporeal membrane oxygenation and was transferred to an extracorporeal membrane oxygenation center. Frontline critical care nurses played a vital role in coordinating patient care activities, monitoring changes in the patient's condition, and detecting complications early.
Outcomes The patient was decannulated on day 15 and extubated on day 17. The patient was successfully discharged home on hospital day 24.
Conclusion Caring for a patient with COVID-19 receiving venovenous extracorporeal membrane oxygenation posed unprecedented challenges that required deviations from standards of care to optimize infection control measures and staff safety while providing quality care. This case report may inform, prepare, and guide other critical care nurses who will be caring for similar patients during this pandemic.
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On March 11, 2020, the World Health Organization declared COVID-19 a pandemic.[1] As of August 2020, more than 5.5 million cases had been confirmed in the United States, and more than 175 000 COVID-19–related deaths had occurred.[2] COVID-19 is caused by SARS-CoV-2, and an individual with COVID-19 may become critically ill with acute respiratory distress syndrome (ARDS), an acute lung injury characterized by severe hypoxemia and diffuse alveolar damage.[3] Typically, patients with COVID-19 and ARDS are treated with lung-protective mechanical ventilation and prone positioning in an intensive care unit (ICU).[3] For select patients with COVID-19 who have refractory hypoxemia and who fail maximal conventional therapies, various guidelines recommend venovenous extracorporeal membrane oxygenation (ECMO) as an effective rescue therapy.[4-6]

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Our public academic medical center serves as a major referral center with established ECMO teams, structures, and management protocols, where patients requiring ECMO are treated by experts. During the COVID-19 pandemic, our 24-bed cardiothoracic ICU became a COVID-19 ECMO unit, which challenged us to expand our imagination and to be innovative in the ways we cared for critically ill patients. In this retrospective case report, we describe, according to the 2013 Case Report guidelines,[7] our first experience caring for a patient with COVID-19 who required venovenous ECMO. We provide insight for critical care nurses by discussing nursing considerations and the novel operational approaches we used in caring for this patient.

Case Report

Patient Information

A 46-year-old man presented to an emergency department with pleuritic chest pain and progressive dyspnea. One week later, the patient presented to a different emergency department with prodromal anorexia and chills, which he had been experiencing for 9 days. He tested positive for COVID-19 and was intubated for pneumonia-associated ARDS. The patient was paralyzed, placed in the prone position, and started receiving inhaled nitric oxide, but he did not improve. The patient was subsequently given venovenous ECMO and transferred to our unit for a higher level of care. Table 1 provides the timeline of this case report.

Clinical Findings

The patient had a medical history of obesity, prediabetes mellitus, atrial fibrillation after cardioversion, cardiomyopathy, nonsustained ventricular tachycardia, hyperlipidemia, and stage 2 chronic kidney disease. He arrived in our cardiothoracic ICU sedated, paralyzed, and intubated, receiving mechanical ventilation, and supported with venovenous ECMO.

At admission his vital signs were pulse rate 90 beats/min, blood pressure 102/66 mm Hg, and oxygen as measured by pulse oximetry (Spo_2) 98%. Arterial blood gas results showed a pH of 7.45, Pco_2 57 mm Hg, Po_2 107 mm Hg, HCO_3 38.7 mEq/L (to convert to mmol/L, multiply by 1.0), arterial oxygen saturation (Sao_2) 98%. Significant laboratory results revealed creatinine 1.4 mg/dL (to convert to µmol/L, multiply by 88.4), troponin I 0.54 ng/mL (to convert to µg/L, multiply by 1.0), procalcitonin 18.03 µg/L, and lactate 24 mg/dL.

Table 1 Timeline of case report

Day 1: Patient with pneumonia-related ARDS and refractory hypoxemia was placed on VV-ECMO via the femoral-femoral approach and transferred from an external hospital to our CTICU. ECMO day 1: flow 4.4 L/min, sweep 3 L/min, F_{IO_2} 1.00 Ventilator day 6: PC, PEEP 12 cm H_2O, F_{IO_2} 0.60	Vital signs: HR 90/min, BP 102/66 (77) mm Hg, Spo_2 98% Laboratory results: pH 7.45, P_{CO_2} 57 mm Hg, P_{O_2} 107 mm Hg, HCO_3 38.7 mEq/L, procalcitonin 18.03 μg/L, lactate 24 mg/dL, creatinine 1.4 mg/dL IV infusions: fentanyl 250 μg/h, midazolam 20 mg/h, cisatracurium 9 mg/h, esmolol 100 μg/kg/min, heparin 400 U/h, insulin 2 U/h Chest radiograph: small bilateral pleural effusions (larger on right than left); patchy and coalescent consolidation in the peripheral airspace, suggesting multifocal pneumonia
Day 2: ECMO sweep increased to 7 L/min; ventilator F_{IO_2} decreased to 50%; started norepinephrine and furosemide infusions; SARS-CoV-2 detected in upper respiratory tract ECMO day 2: flow 3.9 L/min, sweep 7 L/min, F_{IO_2} 1.00 Ventilator day 7: PC, PEEP 12 cm H_2O, F_{IO_2} 0.50	Vital signs: HR 109/min, BP 96/62 (73) mm Hg, Spo_2 96% Laboratory results: pH 7.50, P_{CO_2} 51 mm Hg, P_{O_2} 98 mm Hg, HCO_3 38.7 mEq/L, lactate 16 mg/dL IV infusions: fentanyl 200 μg/h, midazolam 10 mg/h, cisatracurium 5 mg/h, esmolol 100 μg/kg/min, norepinephrine 0.02 μg/kg/min, heparin 1400 U/h, insulin 2.5 U/h, furosemide 10 mg/h Other medications: cefepime, vancomycin, hydroxychloroquine, azithromycin
Day 5: ECMO sweep increased to 9 L/min, ventilator F_{IO_2} decreased to 0.40; fentanyl discontinued; propofol, hydromorphone, and vasopressin started ECMO day 5: flow 3.2 L/min, sweep 9 L/min, F_{IO_2} 1.00 Ventilator day 10: PC, PEEP 12 cm H_2O, F_{IO_2} 0.40	Vital signs: HR 105/min, BP 84/57 (66) mm Hg, Spo_2 91% Laboratory results: pH 7.43, P_{CO_2} 54 mm Hg, P_{O_2} 66 mm Hg, HCO_3 34.5 mEq/L IV infusions: midazolam 4 mg/h, propofol 50 μg/kg/min, hydromorphone 4 mg/h, cisatracurium 5 mg/h, norepinephrine 0.08 μg/kg/min, vasopressin 4 U/h, heparin 2300 U/h, insulin 16 U/h, furosemide 40 mg/h Other medications: amiodarone, metoprolol, ascorbic acid, vitamin A
Day 6: ECMO sweep increased to 11 L/min, ventilator F_{IO_2} increased to 0.50; discontinued midazolam; started epinephrine ECMO day 6: flow 3.2 L/min, sweep 11 L/min, F_{IO_2} 1.00 Ventilator day 11: PC, PEEP 12 cm H_2O, F_{IO_2} 0.50	Vital signs: HR 117/min, BP 123/68 (83) mm Hg, Spo_2 91% Laboratory results: pH 7.42, P_{CO_2} 55 mm Hg, P_{O_2} 63 mm Hg, HCO_3 34.5 mEq/L IV infusions: propofol 40 μg/kg/min, hydromorphone 4 mg/h, cisatracurium 4 mg/h, esmolol 100 μg/kg/min, norepinephrine 0.1 μg/kg/min, epinephrine 0.04 μg/kg/min, vasopressin 4 U/h, heparin 2000 U/h, insulin 14 U/h, furosemide 80 mg/h Other medications: amiodarone, ascorbic acid, vitamin A Chest radiograph: moderate right pleural effusion, increased right lower lobe density, and multifocal peripheral and central patchy airspace opacities, consistent with pneumonia
Day 10: ECMO sweep decreased to 7 L/min and F_{IO_2} decreased to 0.90; ventilator PEEP increased to 14 cm H_2O; cisatracurium, esmolol, vasopressin, and furosemide discontinued; midazolam restarted; chest radiograph showed resolving pneumonia and fewer pleural effusions ECMO day 10: flow 4 L/min, sweep 7 L/min, F_{IO_2} 0.90 Ventilator day 15: PC, PEEP 14 cm H_2O, F_{IO_2} 0.40	Vital signs: HR 106/min, BP 107/52 (68) mm Hg, Spo_2 92% Laboratory results: pH 7.46, P_{CO_2} 53 mm Hg, P_{O_2} 68 mm Hg, HCO_3 36.4 mEq/L IV infusions: midazolam 10 mg/h, hydromorphone 5 mg/h, norepinephrine 0.04 μg/kg/min, epinephrine 0.02 μg/kg/min, heparin 1500 U/h, insulin 14 U/h Other medications: amiodarone, ascorbic acid, vitamin A, cholecalciferol Chest radiograph: improvement of patchy and coalescent airspace opacities across intervals throughout both lungs, consistent with resolving pneumonia; small bilateral pleural effusions (larger at right than left)
Day 13: ECMO weaning trial: flow decreased to 3.6 L/min, sweep turned off, F_{IO_2} decreased to 0.21; norepinephrine and epinephrine discontinued ECMO day 13: flow 3.6 L/min, sweep 0 L/min, F_{IO_2} 0.21 Ventilator day 18: PC, PEEP 10 cm H_2O, F_{IO_2} 0.40	Vital signs: HR 99/min, BP 119/65 (80) mm Hg, Spo_2 100% Laboratory results: pH 7.49, P_{CO_2} 45 mm Hg, P_{O_2} 91 mm Hg, HCO_3 33.5 mEq/L IV infusions: midazolam 3 mg/h, hydromorphone 4 mg/h, heparin 1000 U/h, insulin 7.5 U/h Other medications: ascorbic acid, vitamin A, cholecalciferol
Day 14: Patient self-extubated during weaning trial but was quickly reintubated at the bedside; ECMO sweep increased to 6 L/min and F_{IO_2} increased to 0.80; norepinephrine restarted; dexmedetomidine started; bronchoalveolar lavage performed; SARS-CoV-2 detected in lower respiratory tract ECMO day 14: flow 3.6 L/min, sweep 6 L/min, F_{IO_2} 0.80 Ventilator day 19: PC, PEEP 10 cm H_2O, F_{IO_2} 0.40	Vital signs: HR 92/min, BP 106/46 (64) mm Hg, Spo_2 94% Laboratory results: pH 7.49, P_{CO_2} 36 mm Hg, P_{O_2} 73 mm Hg, HCO_3 27 mEq/L IV infusions: midazolam 6 mg/h, hydromorphone 5 mg/h, propofol 30 μg/kg/min, dexmedetomidine 0.5 μg/kg/h, norepinephrine 0.03 μg/kg/min, heparin 1000 U/h, insulin 5 U/h Other medications: ascorbic acid, vitamin A, cholecalciferol, quetiapine, amiodarone, furosemide Chest radiograph: after reintubation, bilateral airspace opacities worsened, consistent with infection and acute lung injury

Continued

Table 1 *Continued*

Day 15: ECMO decannulated; no ventilator changes; heparin infusion discontinued; chest radiograph showed improved lung volume; no significant change of patchy peripheral consolidation ECMO day 15: decannulated, off ECMO Ventilator day 20: PC, PEEP 10 cm H_2O, F_{IO_2} 0.40	Vital signs: HR 101/min, BP 96/55 (67) mm Hg, Spo_2 100% Laboratory results: pH 7.42, P_{CO_2} 45 mm Hg, P_{O_2} 125 mm Hg, HCO_3 28.5 mEq/L IV infusions: midazolam 5 mg/h, hydromorphone 2.5 mg/h, dexmedetomidine 1 µg/kg/h, norepinephrine 0.065 µg/kg/min, insulin 2 U/h Other medication: ascorbic acid, vitamin A, cholecalciferol, ergocalciferol quetiapine, amiodarone, furosemide Chest radiograph: improving lung volume; no significant change of patchy peripheral consolidation
Day 17: Patient extubated and off mechanical ventilation; transitioned to nasal cannula (flow 6 L/min); midazolam and insulin infusion discontinued; chest radiograph showed mild improvement of pneumonia with no pleural effusion; patient sat with legs dangling over the edge of the bed. Ventilator day 22: extubated	Vital signs: HR 120/min, BP 121/86 (88) mm Hg, Spo_2 100% via NC 6 L/min Laboratory results: pH 7.5, P_{CO_2} 38 mm Hg, P_{O_2} 134 mm Hg, HCO_3 29.2 mEq/L IV infusions: hydromorphone 2.5 mg/h, dexmedetomidine 1 µg/kg/h, norepinephrine 0.065 µg/kg/min Other medications: ascorbic acid, cholecalciferol, amiodarone, olanzapine Chest radiograph: patchy multifocal consolidations consistent with pneumonia showing some mild interval improvement, no pleural effusion
Day 18: Patient remained off ECMO and mechanical ventilation; weaned from nasal cannula (flow 6 L/min) to room air; hydromorphone and norepinephrine infusions discontinued; arterial catheter removed; moved from bed to cardiac chair.	Vital signs: HR 93/min, BP 141/75 (90) mm Hg, Spo_2 95% on room air IV infusion: dexmedetomidine 1 µg/kg/h Other medications: metoprolol, furosemide, cholecalciferol, ascorbic acid Echocardiogram: ejection fraction 65%-70%, normal left ventricular size and normal systolic function, mild left diastolic dysfunction
Day 21: Patient remained on room air; dexmedetomidine and all IV infusions discontinued; moved from bed to chair; transferred to a medical-surgical unit; SARS-CoV-2 not detected.	Vital signs: HR 89/min, BP 111/86 (95) mm Hg, Spo_2 93% on room air IV infusion: none Other medications: metoprolol, carvedilol, furosemide, cholecalciferol
Day 24: repeat SARS-CoV-2 not detected; discharged home	Vital signs: HR 89/min, BP 111/86 (95) mm Hg, Spo_2 93% on room air

Abbreviations: ARDS, acute respiratory distress syndrome; BP, blood pressure; CTICU, cardiothoracic intensive care unit; ECMO, extracorporeal membrane oxygenation; F_{IO_2}, fraction of inspired oxygen; HR, heart rate; IV, intravenous; NC, nasal cannula; PC, pressure control; PEEP, positive end-expiratory pressure; Spo_2, oxygen saturation as measured by pulse oximetry; VV-ECMO, venovenous extracorporeal membrane oxygenation.

Diagnosis

A nasopharyngeal swab specimen had been collected during one of the patient's previous emergency department visits and indicated a positive result for SARS-CoV-2. Upon admission to our cardiothoracic ICU, another nasopharyngeal swab specimen was collected; reverse transcription polymerase chain reaction confirmed SARS-CoV-2 infection. Chest radiography revealed an enlarged cardiomediastinal silhouette with small, bilateral pleural effusions and patchy, coalescent consolidation in the peripheral airspace, which suggested multifocal pneumonia. These diagnostic results are consistent with COVID-19 with ARDS. The clinical manifestations and findings of COVID-19 are described in Table 2.[4,5]

Interventions

The patient received venovenous ECMO for 15 days and was intubated and received mechanical ventilation for 22 days. Various combinations of drugs were infused intravenously—cisatracurium, fentanyl, hydromorphone, midazolam, dexmedetomidine, and propofol—to paralyze the patient and achieve target sedation levels. Deep sedation and analgesia were initially required and were achieved through the use of multiple medications; lighter sedation was indicated later in preparation for extubation. Hemodynamic stability was achieved with intravenous infusions of vasopressin, norepinephrine, and epinephrine, to control blood pressure.

During days 1 through 9 of hospitalization, we attempted to wean the patient from the paralytic but he did not tolerate it, even with deeper sedation. After the patient was successfully weaned from the paralytic on day 10, his level of sedation was decreased from day 11 through day 14. On day 14, the patient self-extubated during a ventilator weaning trial and was immediately reintubated. He was decannulated from venovenous ECMO on day 15. On day 17, the patient was successfully extubated. Within 2 days the patient progressed to sitting in a chair and ambulating. On day 21, he was transferred to a medical-surgical unit, where he remained for 4 days before being discharged.

Table 2 Clinical manifestations of and findings in COVID-19[4,5]

Asymptomatic

Mild disease
- Fever
- Cough
- Sore throat
- Fatigue
- Rhinorrhea/nasal congestion
- Chills/rigors
- Myalgia
- Headache
- Nausea, vomiting, diarrhea
- Conjunctivitis
- Loss of smell or taste

Severe disease
- Dyspnea within 1 week after onset of initial symptoms
- Hypoxia
- Pneumonia
- Respiratory failure
- Acute respiratory distress syndrome
- Multiorgan dysfunction

Radiographic findings
- Chest radiogram: bilateral opacities
- Computed tomography scan: bilateral peripheral ground glass opacities; areas of consolidation (later in clinical course)

Laboratory findings
- Lymphopenia
- Leukopenia
- Elevated aminotransferase
- Elevated lactate
- Elevated inflammatory markers: ferritin, C-reactive protein, erythrocyte sedimentation rate
- Elevated D-dimer
- Elevated serum procalcitonin

Table 3 Treatment of patients with COVID-19 and ARDS[4,5]

Supportive care and management of signs and symptoms
- Supplemental oxygen: target Spo_2 92% to 96%
- Empiric antibiotics
- Diuretics and continuous renal replacement therapy for renal failure
- Hemodynamic support with vasoactive agents

Early endotracheal intubation for respiratory failure

COVID-19 with mild ARDS
- Ventilation with a low tidal volume
- Empiric antibiotics
- Conservative fluid strategy

COVID-19 with moderate to severe ARDS
- Higher PEEP
- Neuromuscular paralytic infusion
- Traditional recruitment strategies
- Ventilation in prone position for 12-16 h
- Short-course systemic corticosteroids

COVID-19 with severe ARDS
- Corticosteroids (including dexamethasone)
- Ventilation in prone position for 12-16 h
- Neuromuscular paralytic infusion
- Inhaled nitric oxide

Venovenous ECMO

Potential therapies/clinical trial drugs
- Convalescent plasma
- Antivirals: remdesivir, lopinavir/ritonavir
- Interleukin-6 inhibitors: toclizumab, sarilumab, siltuximab

Abbreviations: ARDS, acute respiratory distress syndrome; ECMO, extracorporeal membrane oxygenation; PEEP, positive end-expiratory pressure; Spo_2, oxygen saturation as measured by pulse oximetry.

Outcomes

The patient was discharged home on hospital day 24 with orders for home health care, physical therapy, and oxygen therapy, as needed. Follow-up consisted of telemedicine appointments with internal medicine physicians and cardiologists. During follow-up, the patient required oxygen therapy when transferring to a chair or ambulating to the bathroom. The patient reported no fever, cough, dyspnea, or loss of appetite, and his functional status improved gradually.

Discussion

Management of critically ill patients with COVID-19 who are receiving ECMO is challenging and requires collaboration among an interprofessional team. Nevertheless, critical care nurses at the frontline are vital: they coordinate patient care activities, monitor changes in the patient's condition, and detect complications early. Here we discuss deviations from standards of care and pertinent nursing considerations related to the management of patients with COVID-19 who are receiving venovenous ECMO. In our unit, our hospital's COVID-19 evidence-based protocols guide the management of patients with COVID-19; these protocols were discussed with the interprofessional team during daily bedside rounds. A full review of the management of patients with both COVID-19 and ARDS is beyond the scope of this article, but Table 3 provides a summary of current treatment.[4,5]

Nursing Considerations for Patients With COVID-19 Receiving ECMO

Neurological Considerations.

Critically ill patients with COVID-19 who are receiving mechanical ventilation and ECMO require analgesia, sedation, and paralytics to achieve (1) safety and comfort, (2) lower

oxygen consumption, and (3) patient-ventilator synchrony, which promotes lung rest and minimizes injury.[6,8,9] Evidence suggests that the ECMO circuit may affect both the pharmacokinetics and pharmacodynamics of sedatives and analgesics.[10] Therefore, higher levels of sedation and analgesia may be necessary to achieve targeted goals. Nurses assessed and titrated sedative and analgesic infusions using the Richmond Agitation-Sedation Scale (to achieve a score of 4), the Critical-Care Pain Observation Tool (to achieve a score of 0), and train-of-four monitoring (with a goal of 0-2 twitches). Continuous physiological measures (ie, pulse rate, blood pressure, oxygen saturation, and respiratory rate) were used as cues to initiate further assessment and minimize entry into a patient's room.[11] Because of the increased risk of delirium in patients with COVID-19 undergoing prolonged sedation and mechanical ventilation, and because of the potential inflammatory response of the central nervous system to viral infection, nurses screened patients for delirium using the Confusion Assessment Method for the Intensive Care Unit during each shift.[12] Nurses were also vigilant in assessing patients' neurological status every 4 hours (during clustered care) to address the risk of intracranial hemorrhage due to the anticoagulation needed to prevent blood from clotting as it passes through the ECMO circuit and the risk of stroke due to hypercoagulability associated with COVID-19.[13]

The ECMO circuit activates the clotting cascade and can cause platelets to aggregate within the circuit; therefore, intravenous anticoagulation is required while a patient is receiving ECMO to prevent thrombi.

Respiratory Considerations. For patients with COVID-19 receiving venovenous ECMO, guidelines recommend lung-protective ventilation strategies—targeting a plateau pressure less than 30 cm H_2O, a low tidal volume (6-8 mL/kg), a respiratory rate 4 to 10/min, and positive end-expiratory pressure 10 to 15 cm H_2O.[5,6] The ARDSnet protocol—initial fraction of inspired oxygen 0.60, positive end-expiratory pressure 12 cm H_2O, and tidal volume 6 mL/kg—was applied to avoid barotrauma and help facilitate lung recovery.[5] These settings were maintained for several days, with minimal changes. The nurses were responsible for obtaining arterial blood gas measurements at least every 6 hours to assess for adequate oxygenation and ventilation. Daily chest radiographs were not ordered to prevent staff exposure and to preserve personal protective equipment (PPE). If any staff had to enter a patient's room to reconnect a disconnected ventilator or perform an aerosol-generating procedure that might increase viral load, all additional staff had to wait 1 hour before entering that room. In this case, the patient was decannulated before being extubated. A patient is usually put in the prone position before ECMO is considered. If they are placed prone while receiving ECMO, however, planning is required to ensure all team members are available to coordinate the activity.

Cardiovascular Considerations. Acute cardiac injury, arrhythmia, myocarditis, and cardiac dysfunction have been reported in patients with COVID-19.[14] Because venovenous ECMO does not provide cardiac support, close monitoring of the cardiovascular system is important for early detection of any cardiac complications. Nurses should closely monitor these patients for any electrocardiographical changes, anticipate bedside echocardiography for evaluation of cardiac function, monitor serial troponin levels, and correct electrolyte abnormalities. If a patient is enrolled in a COVID-19 clinical trial and is receiving a medication that has cardiovascular side effects, such as hydroxychloroquine, then nurses should also monitor the QT interval.[15]

An optimal fluid strategy for hemodynamically supporting patients with COVID-19 is not known; however, guidelines recommend conservative use of crystalloids instead of colloids.[5] In our unit, fluids are often necessary to maintain blood pressure and ECMO flow rate, but they are used sparingly to prevent fluid overload. The choice of fluid was based on the patient's hematocrit level and their need for fresh frozen plasma or platelets. Nurses considered skin temperature, capillary refill, and serum lactate when assessing fluid responsiveness.[5] If a patient does not respond to fluid therapy, then vasoactive agents should be initiated. In our unit, norepinephrine was administered as the first-line vasoactive agent, followed by vasopressin or epinephrine. These infusions were titrated to achieve a target mean arterial pressure of 60 to 65 mm Hg.

Klok et al[16] reported that the prothrombotic state of patients with COVID-19 increases their risk of venous thromboembolic events. Although venovenous ECMO cannulation decreases the risk of cannula-related arterial ischemia, nurses should perform vascular checks during

clustered care by assessing the color of, edema in, and pulses in the lower extremities to identify early signs of thrombosis and ischemia.

Hematological Considerations. Hypercoagulability has occurred in patients with COVID-19.[16] In addition, the ECMO circuit activates the clotting cascade and can cause platelets to aggregate within the circuit. Therefore, intravenous anticoagulation is required while a patient is receiving ECMO to prevent thrombi, with consideration to achieve partial thromboplastin time level at the higher end of the therapeutic range for COVID-19.[6] Heparin infusion is the first-line anticoagulation therapy in our unit. Activated clotting time is routinely measured every 1 to 2 hours. For this patient, however, the heparin infusion was titrated on the basis of partial thromboplastin time, which was measured every 4 to 6 hours as part of clustered care to preserve PPE and limit how often staff entered the patient's room. Nurses closely monitored the complete blood count, coagulation, and signs of bleeding, as with every patient receiving ECMO.

Transfusion of blood products may be required to maintain hemostasis. The Extracorporeal Life Support Organization guideline recommends maintaining hemoglobin more than 7 g/dL (to calculate g/L, multiply by 10.0), platelet count higher than $50 \times 10^3/\mu L$ (to calculate $\times 10^9/L$, multiply by 1.0), and fibrinogen more than 100 mg/dL (to calculate g/L, multiply by 0.01).[6] Lower levels were accepted in our unit in the absence of hemodynamic compromise.

Gastrointestinal Considerations. Adequate nutrition is essential for critically ill patients with COVID-19. Studies have shown that early enteral nutrition reduces mortality and infections.[17] Concerns exist about the safety of enteral nutrition, particularly in patients receiving high-dose vasopressors and requiring ECMO support, because of the risk of bowel ischemia.[18] Recommendations center on initiating low-dose trophic, high-protein enteral nutrition within 48 hours of hospitalization and advancing to a target rate within 3 to 5 days.[6,19] Nasogastric feeding was used in our unit, and guidelines recommend it instead of postpyloric feeding because tube placement is easier and it reduces the time during which staff are exposed inside a patient's room.[17] In addition, a fecal containment device was inserted to assist with fecal incontinence for this patient. When caring for patients with COVID-19, staff must decrease their risk of exposure, given existing evidence that the virus can be found in esophageal, gastric, and rectal mucosa.[20,21]

Renal Considerations. Patients with COVID-19 who are receiving ECMO are at risk for acute kidney injury due to hypotension, which leads to decreased renal perfusion and activates systemic inflammatory cascade (due to the ECMO circuit), a virus-induced cytokine storm, and direct viral invasion of renal cells.[6,22] Nurses played a pivotal role in monitoring signs of worsening kidney function, such as elevated creatinine, elevated blood urea nitrogen, and reduced urine output. Monitoring urine output hourly posed a challenge for nurses because of the need to limit how often they entered a patient's room. Therefore, nurses estimated hourly urine output from the total amount collected in the urometer each time they entered the room to provide clustered care. Continuous renal replacement therapy may be indicated for renal failure or fluid management and its inlet and outlet tubing can be connected directly to the ECMO circuit.[23]

The ECMO Circuit and ECMO Monitoring Considerations. The key elements of ECMO monitoring are prevention and early detection of complications including bleeding, infection at the insertion sites, skin breakdown related to malpositioning of the cannulas, and circuit dysfunction.[24] It is imperative that nurses collaborate with the perfusionist to identify complications early. In our unit, the perfusionist is responsible for monitoring the overall integrity of the ECMO circuit. The Extracorporeal Life Support Organization guideline recommends daily monitoring of pre- and postmembrane blood gas values to assess oxygenator function.[6] In this case, however, the perfusionist measured blood gas values every 72 hours to limit staff exposure in the room and to preserve PPE. In preparation for ECMO decannulation for a patient with COVID-19, the Extracorporeal Life Support Organization also recommends applying your institution's preexisting protocol for weaning a patient from venovenous ECMO.[6] In this case, during the patient's ECMO weaning trials, nurses monitored arterial blood

Patients with COVID-19 who are receiving ECMO are at risk for acute kidney injury due to hypotension.

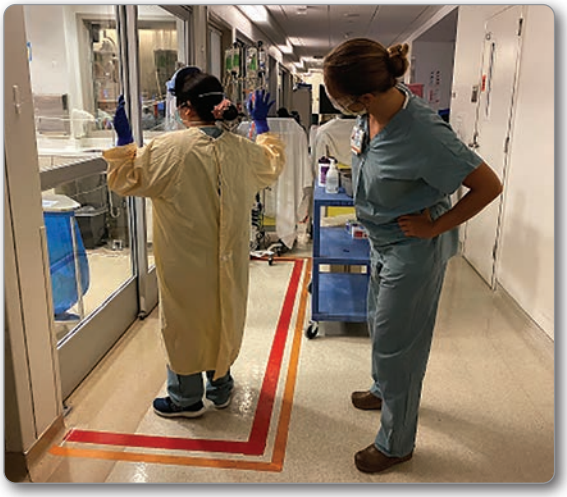

Figure 1 Safety champion monitoring the process of donning personal protective equipment.

gas values and hemodynamic stability. When the patient finally tolerated weaning, anticoagulation was discontinued and he was decannulated at the bedside.

Operational Considerations. A highly contagious novel virus causes COVID-19, making strict infection control measures of paramount importance to limit staff exposure and ensure their safety, and to minimize the risk of cross-contamination within the unit. In our cardiothoracic ICU, one strategy we used for infection control was to expand the role of clinical nurses from bedside nurse to "safety champion." Here we highlight the role of the safety champion and discuss challenges we encountered and how we addressed these complexities.

The role of "unit champion" has emerged as an effective model to engage bedside nurses in driving unit-based changes.

Role of the Safety Champion. The role of "unit champion" has emerged as an effective model to engage bedside nurses in driving unit-based changes.[25] Similarly, the role of "safety champion" was created for bedside nurses in our unit to guide best practices in the care of patients with COVID-19. Safety champions are charged with maintaining up-to-date knowledge of COVID-19–related best practice advisories and hospital policies, and they serve as a resource for the entire interprofessional team during each shift. Safety champions also educate other staff about proper PPE use and monitor the donning and doffing processes to ensure adherence to PPE procedures (Figure 1). This monitoring was particularly critical during procedures performed at the bedside and emergencies such as cardiac arrest. The safety champions also organized clinical management tasks from outside the patient room; such tasks included retrieving equipment, preparing medications, and sending specimens to the laboratory.

Staffing. The nurse-to-patient ratio is 2:1 for all newly admitted patients with COVID-19 who are receiving ECMO. The staffing ratio may change to 1:1 depending on the patient's stability, the frequency of interventions, and the need for other medical devices or procedures.

Personal Protective Equipment. In our unit, enhanced droplet precautions were applied for all patients, requiring staff to use a face shield or goggles, an N95 mask, an isolation gown, and gloves. Unit leadership and safety champions maintained an open line of communication with the hospital's command center to ensure supplies were available and to stay current with evolving PPE guidelines.

Equipment. In order to minimize nurse exposure to the virus and preserve PPE, intravenous pumps for patients with COVID-19 were kept outside of the rooms (Figure 2). Nurses were able to access pumps, administer medications, and titrate infusions without needing to don PPE and enter the room. The unit designated an ultrasound machine, a defibrillator, and a code medication kit for use with patients with COVID-19. Durable equipment was cleaned inside the room, and then again outside the room immediately after it was removed. After a patient vacated a room, it remained empty for 1 hour before being cleaned and then sterilized with ultraviolet light.

Environment. In order to avoid cross-contamination within the unit, patients with COVID-19 were grouped in the west side of the cardiothoracic ICU; hot, warm, and cold zones were designated throughout the area (Figure 3). Rooms housing COVID-19–positive patients or patients suspected of having the virus had designated hot zones. The area directly outside the room was demarcated with a border of red tape, which indicated where staff must doff PPE after exiting the room. The area adjacent to a hot zone was considered a warm zone and was demarcated with orange tape; only staff caring for these patients were permitted in the warm zones. The cold zone was a low-risk area within the unit that was

distinguished with yellow tape, where all other staff not caring for patients with COVID-19 remained.

Family Considerations. Family-centered care was a challenge because of the hospital's restricted visitation policy. Bedside nurses arranged frequent phone calls to keep family members updated about the patient's condition, discuss the plan of care, and provide emotional support. In addition, bedside nurses arranged daily communication between the patient and family members via video conferencing through the Zoom application on an iPad assigned to each room.

Strengths and Limitations

To our knowledge, this case report is the earliest to describe an initial experience with a patient with COVID-19 who was receiving venovenous ECMO and demonstrated positive short-term outcomes, and is the first to provide nursing considerations for the management of such patients. The considerations discussed in this case report are novel approaches because of the unprecedented nature of the pandemic, and they may not be applicable in other acute care settings. Treatment of COVID-19 and the management of patients with the disease are evolving; new research data and findings are becoming available daily, providing a clearer and more comprehensive understanding of clinical management. This report may serve as a starting point in preparing nurses to meet the challenges of caring for patients with COVID-19 who are receiving ECMO.

Conclusion

In a time of uncertainty about the spread and transmission of SAR-CoV-2, caring for a patient with COVID-19 who was receiving venovenous ECMO posed many challenges, specifically ones related to infection control and staff safety. Clustering patient care was a key strategy for limiting staff exposure and reducing the frequency at which nurses entered an isolation room. The role of safety champion was another key strategy that ensured staff adherence to evidence-based safety practices. We recommend other ICUs consider implementing these strategies for all patients with COVID-19 (not only those receiving ECMO). As we continuously improve our nursing management of patients with COVID-19 who are receiving ECMO, we hope that sharing our experience will inform, prepare, and guide other critical care nurses during this pandemic. CCN

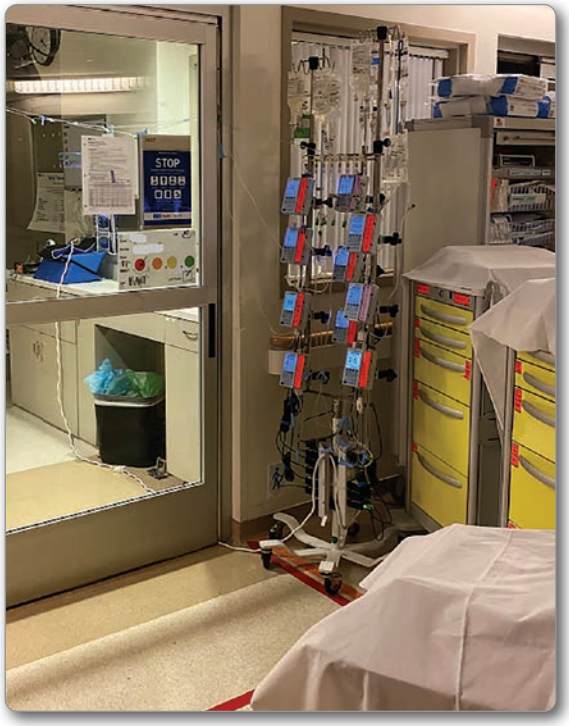

Figure 2 Intravenous pumps located outside of a patient room.

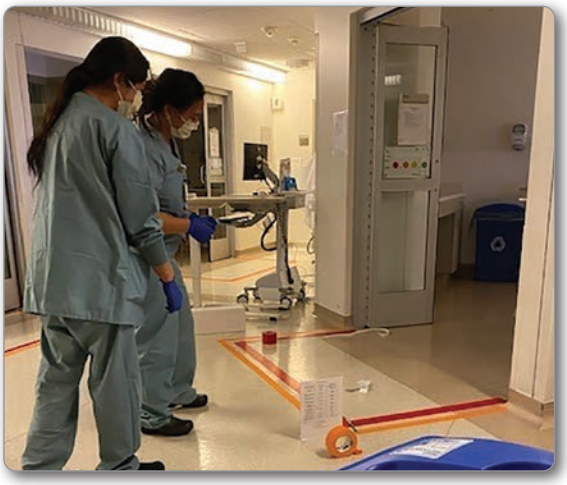

Figure 3 Hot, warm, and cold zones demarcated by tape.

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None reported.

See also

To learn more about extracorporeal membrane oxygenation, read "Pharmacokinetics and Extracorporeal Membrane Oxygenation in Adults: A Literature Review" by Tukacs in *AACN Advanced Critical Care,* 2018;29(3):246-258. Available at **www.aacnacconline.org**.

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