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CASE REPORT

Prolonged ECMO Management (124 Days) in a Severe COVID-19 Patient Complicated by Acute Myocardial Infarction and Thrombocytopenia: A Case Report

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Abstract: COVID-19, caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is a respiratory illness with high mortality, especially among critically ill patients. The Extracorporeal Life Support Organization (ELSO) COVID-19 Interim Guidelines recommend extracorporeal membrane oxygenation (ECMO) for severe COVID-19 cases when the partial pressure of oxygen (PaO2)/fraction of inspired oxygen (FiO2) ratio remains below 80 mmHg despite conventional treatments. We present the case of a 62-year-old male with severe COVID-19 pneumonia who required veno-venous ECMO (V–V ECMO). During his treatment, he experienced an acute myocardial infarction, necessitating percutaneous coronary intervention and stent placement. Although initially a candidate for lung transplantation, complications related to myocardial infarction and heart failure led to delays. Management of anticoagulation and antiplatelet therapy was further complicated by thrombocytopenia secondary to both infection and ECMO therapy. Nevertheless, the patient remained on ECMO for 124 days without oxygenator replacement or significant bleeding events. This case underscores the successful long-term use of V–V ECMO in the face of COVID-19, myocardial infarction, and thrombocytopenia, emphasizing the value of multidisciplinary teamwork and individualized treatment strategies.

Keywords: infection, severe pneumonia, coronavirus disease 2019, respiratory failure, acute respiratory distress syndrome, extracorporeal membrane oxygenation, critical care, nursing, case report

Introduction

Coronavirus disease 2019 (COVID-19) is a respiratory illness caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).[1] First identified in December 2019, this virus is classified in the same subgroup as SARS-CoV-1 and Middle East respiratory syndrome coronavirus (MERS-CoV).[1] Patients with severe COVID-19 who are admitted to intensive care units (ICUs) often experience high mortality rates.[2–4] Based on the severity of the condition, respiratory support interventions are escalated as needed. These measures may include high-flow nasal oxygen therapy, invasive ventilation through an endotracheal tube, prone positioning, and, in critical cases, extracorporeal membrane oxygenation (ECMO).

During ECMO, blood is withdrawn from the patient, passed through a membrane oxygenator, and then returned to the body, providing vital respiratory and/or circulatory support. Proper maintenance of the ECMO circuit is essential for ensuring

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the system's effective operation. Veno-venous extracorporeal membrane oxygenation (V–V ECMO) is a potentially life-saving intervention.[5,6] Data from the Extracorporeal Life Support Organization (ELSO) registry, which included 213 hospitals worldwide, indicate a roughly 40% mortality rate among critically ill COVID-19 patients treated with ECMO, with a median support duration of 13.9 days.[7] In contrast, most studies report a median ECMO duration of 7–10 days for adult patients with severe acute respiratory distress syndrome (ARDS). These findings support current guidelines recommending the use of ECMO in centers with established expertise for managing refractory COVID-19-related respiratory failure.[7,8] However, data on the use of V–V ECMO beyond 14 days in COVID-19 patients remain scarce.

We present a case of severe COVID-19 pneumonia complicated by acute myocardial infarction and thrombocytopenia. The patient underwent 124 days of V–V ECMO support while awaiting lung transplantation. Unfortunately, the patient ultimately succumbed to complications from severe sepsis.

Case Presentation

A 62-year-old male with a history of hypertension was admitted to the hospital for COVID-19 pneumonia. He had contracted the virus over 20 days earlier, initially presenting with a dry cough. The day before admission, he developed a recurrent fever (reaching 38.5°C) and experienced progressively worsening dyspnea. Given the severity of his symptoms, he was admitted to the Infectious Diseases Department at our hospital. He denied a history of chronic cough, chronic interstitial lung disease, or other chronic pulmonary conditions. He also denied a history of tuberculosis and long-term use of warfarin or other anticoagulant drugs.

Initial Presentation, Diagnosis, and Treatment

Upon admission, the patient weighed 70 kg, was 169 cm tall, and presented with a temperature of 37.4°C, a heart rate of 88 beats per minute with a regular rhythm, and no significant pathological murmurs. Neurological examination was unremarkable. Respiratory rate was 20 breaths per minute, and auscultation revealed moist rales. To maintain adequate oxygenation, the patient required high-flow nasal oxygen therapy with a fraction of inspired oxygen (FiO_2) of 40%.

Laboratory tests showed a C-reactive protein (CRP) level of 126.27 mg/L and white blood cell (WBC) at 9.26×10^9/L (Figure 1A and B). A computed tomography (CT) scan performed on January 26, 2023, revealed bilateral ground-glass opacities and consolidation. RT-PCR testing of a pharyngeal swab confirmed SARS-CoV-2 infection.

Following admission, the patient was treated with Nirmatrelvir/ritonavir tablets, methylprednisolone sodium succinate 40 mg every 12 hours, and ambroxol hydrochloride injection, among other treatments.

Laboratory and Imaging Findings

During hospitalization, the patient underwent continuous laboratory tests and imaging examinations to monitor disease progression and treatment effectiveness. Laboratory results indicated persistently elevated inflammatory markers (Figure 1D and E) and a decrease in platelet count (Figure 1F), likely associated with the infection and ECMO therapy.

Imaging studies, including chest X-rays and CT scans, revealed progressive pulmonary infiltrates. Later stages showed complications such as pneumothorax and pleural effusion (Figure 2A and B). Head CT scans did not reveal any significant abnormalities (Figure 2E).

Mechanical Ventilation and ECMO Initiation

On the third day after admission, due to progressively worsening respiratory distress, the patient was intubated and transferred to the ICU for advanced treatment. Despite mechanical ventilation using pressure control mode (driving pressure 15 cmH_2O, PEEP 12 cmH_2O, FiO_2 80%) and prone positioning (17 hours per day), hypoxemia persisted, with a PaO_2/FiO_2 ratio of only 60.9 mmHg. Therefore, V–V ECMO was initiated on the fourth day in the ICU (Figure 2C).

For ECMO establishment, a 24Fr venous drainage cannula (Beijing Medos Medical Technology Co., Ltd, China) was inserted via the femoral vein to a depth of 42.5 cm, and an 18Fr arterial infusion cannula (Beijing Medos Medical Technology Co., Ltd, China) was inserted via the right internal jugular vein to a depth of 15 cm. A Maquet oxygenator (Germany) was used. The initial ECMO settings were: rotation speed of 3305 rpm, blood flow of 4.69 L/min, gas flow of 4 L/min, and oxygen

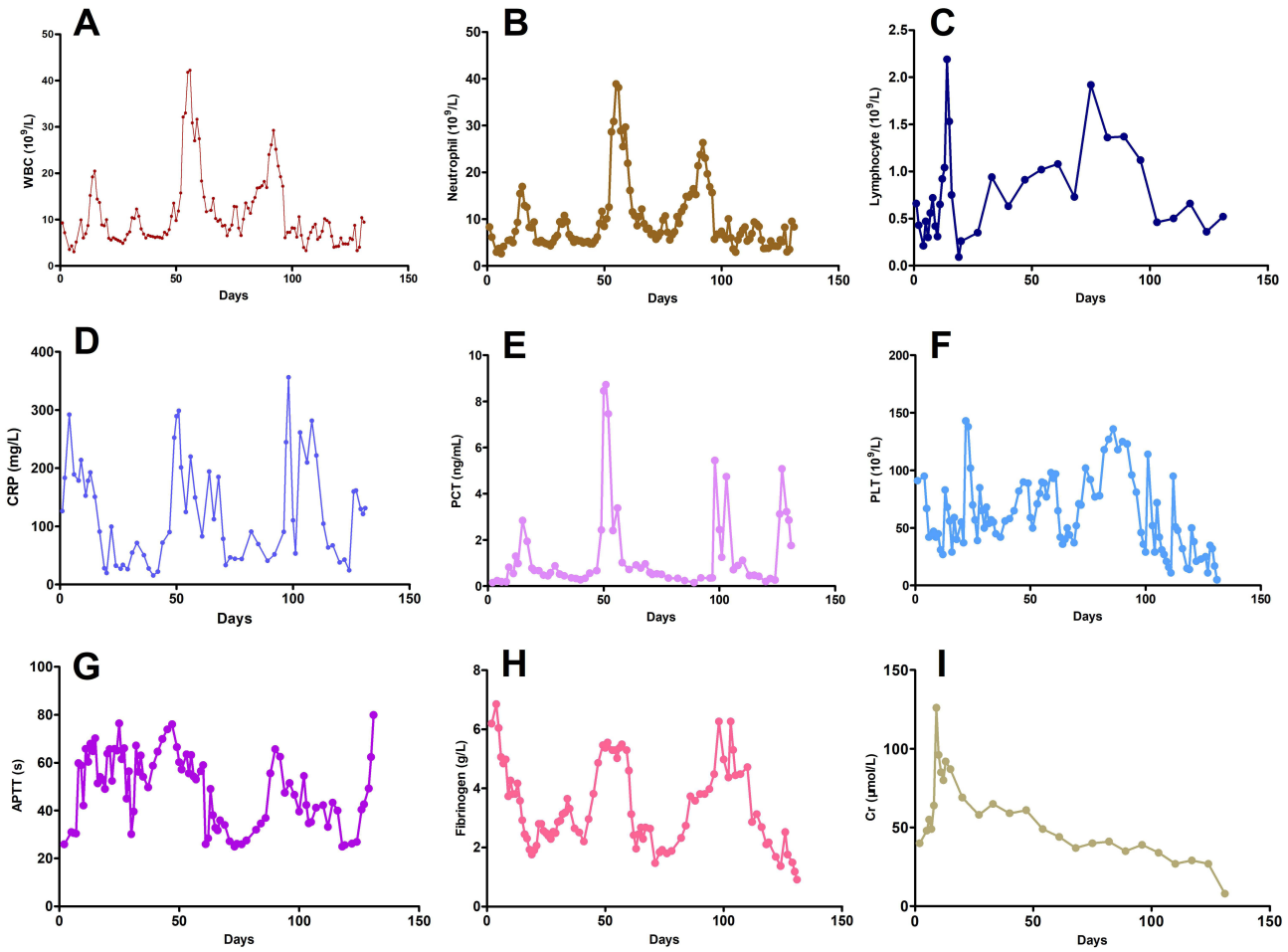

Figure 1 Biochemical parameters during hospitalization. (**A**) Changes in white blood cell (WBC) count (normal range, 4–10 × 10^9/L) during hospitalization; (**B**) Changes in neutrophil count (normal range, 2–7 × 10^9/L) throughout the treatment period; (**C**) Changes in lymphocyte count (normal range, 0.8–4.0 × 10^9/L) during hospitalization; (**D**) Changes in serum C-reactive protein (CRP) levels (normal range, 0–8 mg/L) over the course of treatment; (**E**) Changes in serum procalcitonin (PCT) levels (normal range, 0–0.5 ng/mL) during hospitalization; (**F**) Changes in platelet (PLT) count (normal range, 150–400 × 10^9/L) throughout the treatment period; (**G**) Changes in activated partial thromboplastin time (APTT) (normal range, 23.9–33.5 seconds) during hospitalization; (**H**) Changes in fibrinogen levels (normal range, 2.0–4.0 g/L) over the course of treatment; (**I**) Changes in serum creatinine (Cr) levels (normal range, 41–81 μmol/L) during hospitalization.

concentration of 100%. Ultrasound evaluation confirmed proper positioning of the drainage cannula, with no significant complications such as bleeding.

Cardiac Event

On the second day of ECMO support, ST-segment elevation was detected on the electrocardiogram (ECG), accompanied by markedly elevated levels of creatine kinase-MB (CK-MB) (716 U/L, normal range: 2–25 U/L) and high-sensitivity troponin I (304.797 ng/mL, normal range: 0.000–0.034 ng/mL). Emergency coronary angiography, arranged in consultation with cardiology, revealed complete occlusion of the left anterior descending artery. A drug-eluting stent was successfully implanted to restore coronary blood flow. Additionally, the patient received loading doses of aspirin and clopidogrel (300 mg each). Cardiac ultrasound evaluation indicated reduced left ventricular systolic function, with an estimated ejection fraction of approximately 45%, and weakened apical myocardial motion. Subsequently, the patient's renal function deteriorated rapidly (Figure 1I), prompting the initiation of continuous renal replacement therapy (CRRT).

ECMO Management

(1) Anticoagulation Therapy: To prevent thrombus formation in the ECMO circuit, systemic anticoagulation with heparin sodium was employed. The initial target for anticoagulation was an activated partial thromboplastin time (APTT) of

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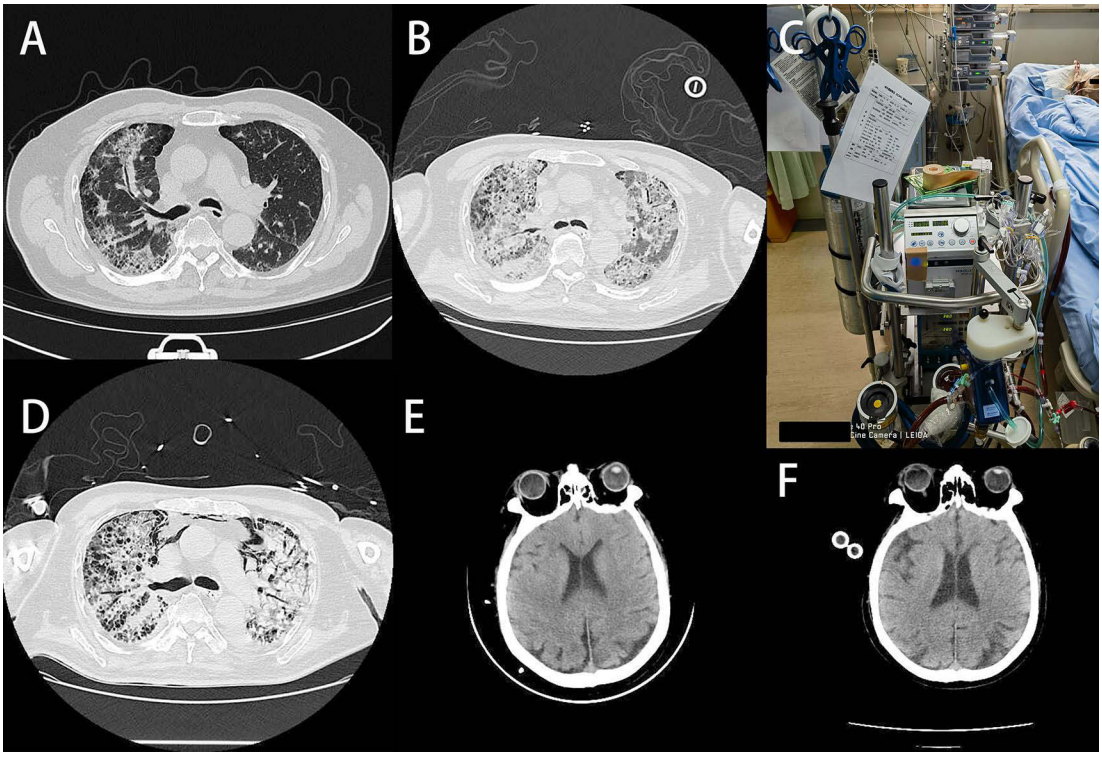

Figure 2 Radiological images and ECMO support during hospitalization. (**A**) Chest CT at admission showing multiple patchy ground-glass opacities and consolidations with blurred edges in both lungs; (**B**) Chest CT on day 3 in the ICU demonstrating diffuse progression of patchy ground-glass opacities and consolidations; (**C**) Photograph of the patient after successful initiation of veno-venous extracorporeal membrane oxygenation (V–V ECMO) on ICU day 4; (**D**) Chest CT on ICU day 31 revealing diffuse honeycombing, reticular shadows, consolidations, small pleural effusions, a small right pneumothorax, and mediastinal emphysema; (**E**) Head CT on ICU day 3 showing no significant abnormalities; (**F**) Head CT on ICU day 31 showing no evidence of intracranial hemorrhage or hematomas.

60–80 seconds. Heparin dosage was adjusted based on close monitoring of coagulation parameters, including APTT, plasma D-dimer levels, and fibrinogen levels (Figure 1G and H). If fibrinogen levels fell below 150 mg/dL, fresh frozen plasma or cryoprecipitate was administered.

(2) Antiplatelet Therapy: Following PCI, dual antiplatelet therapy with aspirin and clopidogrel was administered. We carefully managed this therapy to balance the thrombotic risk associated with the ECMO circuit and the risk of bleeding. Platelet counts and function tests were monitored to assess the adequacy of antiplatelet therapy and guide clinical decision-making.

(3) Thrombocytopenia: During the ICU stay, the patient developed progressive thrombocytopenia. Testing for anti-platelet factor 4 (PF4) antibodies was negative, ruling out heparin-induced thrombocytopenia (HIT). The thrombocytopenia was attributed primarily to severe pulmonary infection-induced bone marrow suppression and the effects of ECMO-related treatment. Platelet counts were closely monitored, and supportive care measures were implemented. When platelet counts fell below 30×10^9/L, aspirin and clopidogrel were discontinued in consultation with cardiology. Ticagrelor (90 mg BID) was initiated instead. Recombinant human thrombopoietin was administered subcutaneously to stimulate platelet production, and intermittent platelet transfusions were given to maintain counts above 50×10^9/L. The trend of platelet counts during the entire hospitalization is shown in Figure 1F.

(4) ECMO Monitoring and Oxygenator Function Assessment: Each nursing shift involved checking the integrity of the ECMO circuit to ensure there were no air or fluid leaks and documenting the number of thrombi in the oxygenator. The heat exchanger's operation was monitored hourly, and patient temperature was recorded to prevent hypothermia. Parameters such as ECMO rotation speed, circuit blood flow, and gas flow rates were monitored. Daily arterial blood gas analyses (oxygen and carbon dioxide partial pressures) were performed, and the proportion of fragmented red blood cells was assessed every other day. The oxygenator's function was evaluated daily by measuring the transmembrane pressure gradient (TMP), with a TMP above 30 mmHg indicating potential issues. The oxygen partial pressure difference between

the pre- and post-membrane points was also measured, with a significant difference generally indicating good oxygenation performance. The initial oxygen partial pressure at the ECMO outlet was 506 mmHg, and daily measurements at 7 AM consistently exceeded 400 mmHg, indicating satisfactory oxygenator function. The ECMO management team was prepared with contingency plans for emergencies, including the rapid replacement of the ECMO circuit if the outlet oxygen partial pressure fell below 300 mmHg or TMP increased significantly, with an estimated replacement time of less than 4 minutes.

(5) Percutaneous Dilatational Tracheostomy: Due to the need for prolonged mechanical ventilation, a percutaneous tracheostomy was performed at the bedside with fiberoptic bronchoscopy guidance on day 27 of ICU admission. To minimize bleeding risk, ticagrelor was discontinued 24 hours prior, and heparin was stopped 12 hours before the procedure. ECMO rotation speed was increased to ensure a blood flow rate above 4 L/min. These preparatory measures limited intraoperative blood loss to less than 10 mL. Heparin was resumed 6 hours post-operatively. The following day, the patient experienced minor bleeding at the tracheostomy site, which improved after application of a gelatin sponge.

Infection Prevention and Control

Nursing Team

Strict aseptic techniques were adhered to during all nursing procedures. For skin care, 2% chlorhexidine gluconate medical disinfectant wipes (CHG Bathing Wipe) were used daily to cleanse the entire body, maintaining skin hygiene and reducing infection risk. For ECMO cannula care, wide tape was applied in three layers to secure the ECMO cannula and prevent accidental dislodgement. Foam dressings (Biatain Foam Dressings) were used to prevent pressure ulcers caused by the cannula, and liquid dressings (3M Cavilon No Sting Barrier Film) were applied to prevent adhesive-related skin injuries. Any bloodstains or other contaminants on the ECMO cannula dressing were promptly replaced with sterile dressings. Contact isolation was implemented following the detection of multidrug-resistant organisms (MDROs) in the patient.

Respiratory Therapy Team

Airway management was enhanced, ensuring the patency of the suction above the tracheal tube cuff. Intermittent fiberoptic bronchoscopy was performed to thoroughly clear respiratory secretions, and samples were collected for monitoring and culture.

Clinical Pharmacy Team

On ICU day 25, the patient's sputum culture revealed Klebsiella pneumoniae, identified as a multidrug-resistant organism (MDRO). In collaboration with clinical pharmacists, the antimicrobial regimen was adjusted to ceftazidime/avibactam at 2.5g every 8 hours, with dosage adjustment based on renal function.

Lung Transplantation Consideration

In this reported case, after approximately one month on ECMO, the patient's lung function had not recovered. A follow-up test for COVID-19 returned negative, and a subsequent chest CT scan showed the presence of pulmonary fibrosis (Figure 2D). A head CT scan revealed no intracranial hemorrhage or significant cerebral infarction (Figure 2F). Our institution's lung transplant team evaluated the patient and determined that lung transplantation was indicated. However, due to the recent acute myocardial infarction, the patient would need to wait at least three months before undergoing lung transplantation.

Clinical Outcome

After 124 days of ECMO support, the patient's clinical course was marked by significant challenges, including severe infections and progressive multi-organ dysfunction. Despite meticulous management by the critical care and cardiology teams, he ultimately succumbed to a multi-drug resistant pulmonary infection and severe sepsis. His final days were centered on compassionate end-of-life care, emphasizing comfort and dignity.

Discussion

The ELSO recommends initiating ECMO for critically ill COVID-19 patients after maximizing traditional therapies, such as prone positioning, and excluding contraindications.[9,10]

We present a severe case of ARDS associated with SARS-CoV-2 infection. The patient had a history of hypertension but no other chronic conditions, such as diabetes or immunosuppression. Due to critical respiratory failure, V–V ECMO was initiated, during which the patient suffered an acute myocardial infarction.

With advancements in ECMO management, prolonged support durations are becoming more common. According to the ELSO registry, among 4361 adult patients who received prolonged ECMO for respiratory failure, the average duration was 22 days.[11] Additionally, prior cases have demonstrated that ECMO support can be maintained for up to 265 days without complications; however, one patient remained on ECMO for 403 days while awaiting lung transplantation but unfortunately died shortly after decannulation.[12,13] Several factors may contribute to the successful implementation of prolonged VV-ECMO in critically ill COVID-19 patients.[14]

Lung transplantation can be a lifesaving option for patients with severe COVID-19 who have not regained lung function after more than 8 weeks.[15] However, the emergence of acute cardiac events, such as myocardial infarction and subsequent acute heart failure, delayed the patient's listing for transplantation and eliminated the possibility of an immediate transplant.[16,17] Given the family's strong desire for a lung transplant and their willingness to wait, we pursued comprehensive management strategies, including mechanical ventilation, enhanced airway management, infection control, CRRT, and ECMO management, to provide the patient with the best chance of obtaining a lung transplant.

Coagulation function was closely monitored due to the high risk of thrombotic complications and coagulopathy in patients with COVID-19.[18] Bleeding and thrombosis are serious risks associated with ECMO use.[19] The interaction between blood and non-endothelial surfaces during ECMO activates coagulation and fibrinolytic pathways, as well as a complement-mediated inflammatory response. Heparin is the standard anticoagulant used globally for ECMO, and some corresponding anticoagulation guidelines have been established.[20,21] However, there is no consensus on how to monitor heparin levels or define therapeutic targets, leading to significant variability among institutions and posing challenges to achieving optimal clinical practice.[22] This underscores the challenges of managing ECMO in COVID-19 patients, especially when prolonged support is required.

Throughout the ECMO procedure, heparin was administered continuously to maintain anticoagulation. The patient had no history of long-term use of warfarin or other anticoagulant medications, and during hospitalization, neither warfarin nor any novel oral anticoagulants were prescribed. Coagulation parameters, including APTT, D-dimer, fibrinogen, and hemoglobin levels, were closely monitored to promptly detect thrombotic events, bleeding, or hemolysis. Coagulation dysfunction was the leading cause necessitating oxygenator replacement during ECMO support.[14]

Due to the acute myocardial infarction and stent placement, the patient required antiplatelet therapy.[23] We administered antiplatelet therapy throughout most of the ECMO operation, which increased the risk of bleeding.[24] Balancing the risk of bleeding with thrombus formation was crucial in the care of this patient, who needed both antiplatelet and anticoagulant treatment, and underwent a bedside percutaneous tracheostomy during the treatment.

We maintained close communication and collaboration with the cardiology, vascular surgery, and otolaryngology (ENT) teams. Due to appropriate management and multidisciplinary cooperation, we balanced the intensity of antiplatelet and anticoagulant therapies. When the patient experienced severe infection leading to thrombocytopenia, we adjusted the intensity of these therapies and closely monitored the performance of the ECMO oxygenator and the number of thrombi in the ECMO circuit. Ultimately, during the ECMO operation, our patient did not require circuit replacement, and a single set of tubing functioned for 124 days.

Infections are a frequent complication during ECMO and have a substantial impact on mortality. Reports estimate the prevalence of hospital-acquired infections during ECMO to be around 10–12%.[25] Additionally, bacterial superinfections are commonly seen in patients with severe COVID-19, regardless of ECMO use.[25] Moreover, the risk of infection increases with longer ECMO durations.[26] Other factors associated with ECMO that predispose patients to infections include the severity of the illness, a heightened risk of bacterial translocation from the gut, and ECMO-induced immune system dysfunction.[26]

Infection control measures were implemented in accordance with ELSO guidelines for COVID-19 patients.[9] The ECMO team underwent training on the correct use of personal protective equipment (PPE), and antibiotics were

administered as necessary, guided by bacterial culture results. Despite these efforts, the patient developed infectious complications, with sepsis further worsening his condition. Although our clinical pharmacists and respiratory therapy team worked collaboratively, the patient did not survive long enough to receive a lung transplant. Ultimately, the patient succumbed to a severe, multidrug-resistant pulmonary infection and bloodstream infection.

Although the patient did not survive to lung transplantation, this case offers valuable insights into managing severe respiratory failure with prolonged V–V ECMO. It demonstrates ECMO's potential as a bridge to lung transplantation and provides practical experience relevant to severe ARDS and other respiratory failures. The case was complicated by acute myocardial infarction, requiring both anticoagulation and antiplatelet therapies, adding complexity to management. Contributing factors to prolonged support included early ECMO initiation, continuous monitoring of coagulation and platelets, multidisciplinary care, and meticulous circuit maintenance. Notably, ECMO was maintained for 124 days without circuit replacement, demonstrating the feasibility of long-term support with careful management. Challenges such as high resource utilization and complications, including infections and multi-organ dysfunction, may limit applicability in resource-constrained settings. Balancing aggressive life support with socio-economic factors and patient-centered goals is crucial. Future cases might benefit from earlier transplant evaluation and enhanced infection control measures. Sharing this experience aims to guide critical care teams and improve outcomes for patients on prolonged ECMO.

Conclusion

Managing critically ill patients requiring ECMO presents significant clinical and logistical challenges. Prolonged ECMO support requires early initiation, individualized anticoagulation management, multidisciplinary collaboration, and vigilant circuit maintenance. In this case, successful 124-day V–V ECMO support was achieved without circuit replacement despite complex complications. This report offers valuable clinical and educational insights intended to guide future management of similarly complex cases, ultimately aiming to improve patient outcomes and survival rates.

Ethical Approval

This study was approved by the Clinical Research Ethics Committee of the First Affiliated Hospital of Zhejiang University School of Medicine (Ethical Approval Number: 2024-0842). Institutional approval was also required and obtained for the publication of the case details. All procedures performed were in accordance with the ethical standards of the institutional research committee and with the principles outlined in the Declaration of Helsinki and its amendments.

Consent Statement

The patient's family provided written informed consent for the publication of the case details and images before the patient's condition worsened. They were fully informed that the information would be used for academic purposes.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare no conflict of interest.

References

1. Sitter M, Pecks U, Rudiger M, et al. Pregnant and postpartum women requiring intensive care treatment for COVID-19-first data from the CRONOS-Registry. *J Clin Med*. 2022;11(3):701. doi:10.3390/jcm11030701
2. Richardson S, Hirsch JS, Narasimhan M, et al. Presenting characteristics, comorbidities, and outcomes among 5700 patients hospitalized with COVID-19 in the New York City Area. *JAMA*. 2020;323(20):2052–2059. doi:10.1001/jama.2020.6775
3. Grasselli G, Zangrillo A, Zanella A, et al. Baseline characteristics and outcomes of 1591 patients infected with SARS-CoV-2 admitted to ICUs of the Lombardy Region, Italy. *JAMA*. 2020;323(16):1574–1581. doi:10.1001/jama.2020.5394
4. Yang X, Yu Y, Xu J, et al. Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centered, retrospective, observational study. *Lancet Respir Med*. 2020;8(5):475–481. doi:10.1016/S2213-2600(20)30079-5
5. Ramanathan K, Antognini D, Combes A, et al. Planning and provision of ECMO services for severe ARDS during the COVID-19 pandemic and other outbreaks of emerging infectious diseases. *Lancet Respir Med*. 2020;8(5):518–526. doi:10.1016/S2213-2600(20)30121-1
6. Cho HJ, Heinsar S, Jeong IS, et al. ECMO use in COVID-19: lessons from past respiratory virus outbreaks-a narrative review. *Crit Care*. 2020;24(1):301. doi:10.1186/s13054-020-02979-3
7. Barbaro RP, MacLaren G, Boonstra PS, et al. Extracorporeal membrane oxygenation support in COVID-19: an international cohort study of the extracorporeal life support organization registry. *Lancet*. 2020;396(10257):1071–1078. doi:10.1016/S0140-6736(20)32008-0
8. Schmidt M, Hajage D, Lebreton G, et al. Extracorporeal membrane oxygenation for severe acute respiratory distress syndrome associated with COVID-19: a retrospective cohort study. *Lancet Respir Med*. 2020;8(11):1121–1131. doi:10.1016/S2213-2600(20)30328-3
9. Shekar K, Badulak J, Peek G, et al. Extracorporeal life support organization coronavirus disease 2019 interim guidelines: a consensus document from an international group of interdisciplinary extracorporeal membrane oxygenation providers. *ASAIO J*. 2020;66(7):707–721. doi:10.1097/MAT.0000000000001193
10. Brodie D, Slutsky AS, Combes A. Extracorporeal life support for adults with respiratory failure and related indications: a review. *JAMA*. 2019;322(6):557–568. doi:10.1001/jama.2019.9302
11. Posluszny J, Engoren M, Napolitano LM, Rycus PT, Bartlett RH. Predicting survival of adult respiratory failure patients receiving prolonged (>/=14 Days) extracorporeal membrane oxygenation. *ASAIO J*. 2020;66(7):825–833. doi:10.1097/MAT.0000000000001067
12. Wiktor AJ, Haft JW, Bartlett RH, Park PK, Raghavendran K, Napolitano LM. Prolonged VV ECMO (265 Days) for ARDS without technical complications. *ASAIO J*. 2015;61(2):205–206. doi:10.1097/MAT.0000000000000181
13. Umei N, Ichiba S, Sakamoto A. Idiopathic pulmonary fibrosis patient supported with extracorporeal membrane oxygenation for 403 days while waiting for a lung transplant: a case report. *Respir Med Case Rep*. 2018;24:86–88. doi:10.1016/j.rmcr.2018.04.015
14. Xu Z, Xu Y, Liu D, et al. Case report: prolonged VV-ECMO (111 Days) support in a patient with severe COVID-19. *Front Med*. 2021;8:681548. doi:10.3389/fmed.2021.681548
15. Schaheen L, Bremner RM, Walia R, Smith MA. Lung transplantation for coronavirus disease 2019 (COVID-19): the who, what, where, when, and why. *J Thorac Cardiovasc Surg*. 2022;163(3):865–868. doi:10.1016/j.jtcvs.2021.06.061
16. Le Pavec J, Pison C, Hirschi S, et al. Transplantation pulmonaire en France: actualisation des indications et contre-indications en 2022 [Updated indications and contraindications in 2022 for lung transplantation in France]. *Rev Mal Respir*. 2022;39(10):855–872. doi:10.1016/j.rmr.2022.10.005
17. Hirschi S, Le Pavec J, Schuller A, Bunel V, Pison C, Mordant P. Contre-indications a la transplantation pulmonaire [Contraindications to lung transplantation]. *Rev Mal Respir*. 2023;40 Suppl 1:e13–e21. doi:10.1016/j.rmr.2022.12.006
18. Iba T, Levy JH, Connors JM, Warkentin TE, Thachil J, Levi M. The unique characteristics of COVID-19 coagulopathy. *Crit Care*. 2020;24(1):360. doi:10.1186/s13054-020-03077-0
19. Thomas J, Kostousov V, Teruya J. Bleeding and thrombotic complications in the use of extracorporeal membrane oxygenation. *Semin Thromb Hemost*. 2018;44(1):20–29. doi:10.1055/s-0037-1606179
20. Murphy DA, Hockings LE, Andrews RK, et al. Extracorporeal membrane oxygenation-hemostatic complications. *Transfus Med Rev*. 2015;29(2):90–101. doi:10.1016/j.tmrv.2014.12.001
21. McMichael ABV, Ryerson LM, Ratano D, Fan E, Faraoni D, Annich GM. 2021 ELSO adult and pediatric anticoagulation guidelines. *ASAIO J*. 2022;68(3):303–310. doi:10.1097/mat.0000000000001652
22. Colman E, Yin EB, Laine G, et al. Evaluation of a heparin monitoring protocol for extracorporeal membrane oxygenation and review of the literature. *J Thorac Dis*. 2019;11(8):3325–3335. doi:10.21037/jtd.2019.08.44
23. O'Gara PT, Kushner FG, Ascheim DD, et al. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *Circulation*. 2013;127(4):e362–425. doi:10.1161/CIR.0b013e3182742cf6
24. Thiele H, Zeymer U, Akin I, et al. Extracorporeal life support in infarct-related cardiogenic shock. *N Engl J Med*. 2023;389(14):1286–1297. doi:10.1056/NEJMoa2307227
25. Fattorini L, Creti R, Palma C, et al. Bacterial coinfections in COVID-19: an underestimated adversary. *Ann Ist Super Sanita*. 2020;56(3):359–364. doi:10.4415/ANN_20_03_14
26. Biffi S, Di Bella S, Scaravilli V, et al. Infections during extracorporeal membrane oxygenation: epidemiology, risk factors, pathogenesis and prevention. *Int J Antimicrob Agents*. 2017;50(1):9–16. doi:10.1016/j.ijantimicag.2017.02.025