Extracorporeal membrane oxygenation combined with minimally invasive surgery for acute respiratory failure and sudden cardiac arrest: A case report

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Abstract. Acute respiratory failure and sudden cardiac arrest caused by acute intrathoracic infection is a fatal clinical condition with a low resuscitation success rate. The present study describes the case of a patient with acute empyema secondary to an acute lung abscess rupture, complicated by acute respiratory failure and sudden cardiac arrest caused by severe hypoxemia. The patient recovered well through the administration of multiple therapeutic measures, including medication and closed chest drainage, cardiopulmonary resuscitation, extracorporeal membrane oxygenation combined with continuous renal replacement therapy, and minimally invasive surgical resection of the lung lesion with persistent alveolar fistula as the clinical manifestation. To the best of our knowledge, the treatment of such a severe condition combined with thoracoscopic surgery has rarely been reported before, and the present study may provide insight regarding therapeutic schedules for acute respiratory failure by intrathoracic infection, and excision of ruptured lung abscess.

Introduction

Suppurative pleural effusion caused by intrathoracic infection is the main manifestation of acute empyema (1). Severe empyema can be complicated by acute respiratory distress syndrome (ARDS) or, in severe cases, by respiratory and circulatory failure which can lead to death. Conventional treatments for acute empyema and ARDS include thoracic drainage and mechanical ventilation, extracorporeal membrane oxygenation (ECMO), and continuous renal replacement therapy (CRRT) may be necessary to provide effective respiratory and circulatory support and correct water and electrolyte imbalances (2). Additionally, a surgical procedure should be considered and may be critical to remove the focus of the infection completely, especially when conservative treatment has not been effective despite the extreme risk. Herein, we describe the case presentation of a 51-year-old man with acute empyema secondary to an acute lung abscess rupture complicated by a sudden cardiac arrest caused by rapidly progressing severe hypoxemia who was successfully treated with ECMO combined with CRRT and thoracoscopic minimally invasive surgery for persistent alveolar fistula.

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Case report

A 51-year-old man was admitted to emergency intensive care unit (EICU) of the Second Affiliated Hospital of Jiaxing University (Jiaxing, China) in July, 2020, due to a cough accompanied by left chest pain and high fever. On the afternoon of admission, he experienced sudden shortness of breath and a cough with yellow purulent foul-smelling sputum accompanied by systemic profuse sweating. Chest computed tomography (CT) was performed immediately (Fig. 1) and showed a left upper lung abscess and left empyema, considered indicative of infection. A cardiac color ultrasound showed blunt and paradoxical apex movement and mild aortic valve, mitral valve, and tricuspid regurgitation. His blood tests showed metabolic acidosis and hypoxemia and white blood cell (WBC) count of 65.5×10^9/l. The patient had a history of ankylosing spondylitis, a kind of autoimmune disease, and had been taking immunosuppressive drugs, including salazosulfadimidine and adrenocortical hormone. However, his family medical history was unremarkable.

After admission, bedside left thoracic closed drainage was performed immediately. After placement of a 24F thoracic drainage tube, a large amount of yellow pus and foul-smelling pleural effusion were drained. Simultaneously, meropenem

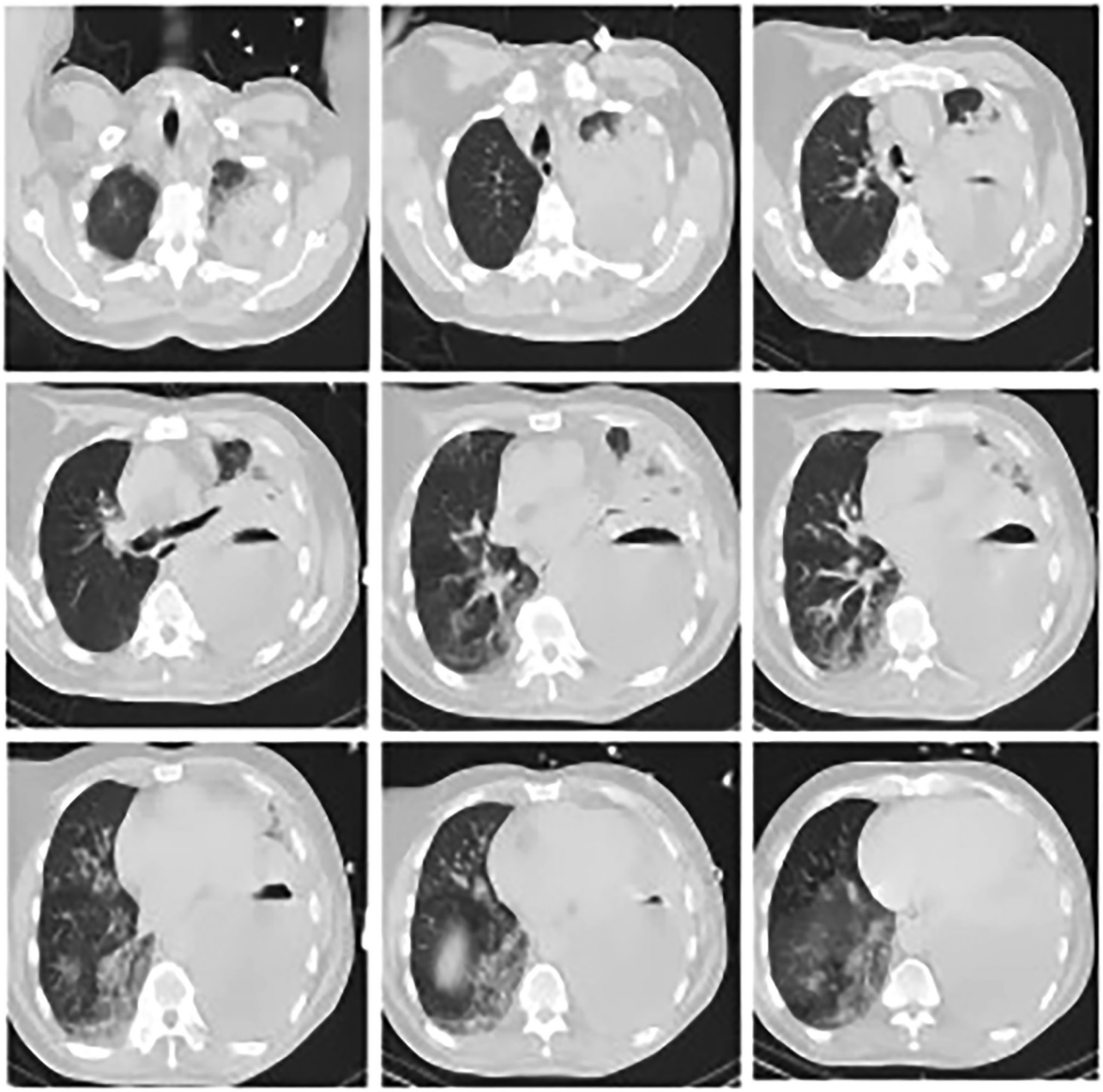

Figure 1. Chest computed tomography images of the patient on admission showing a large left pleural effusion, left lung consolidation, and right lower lung infection.

(1.0 g Q6h) and Vancomycin (0.5 g Q12H) was administered empirically as anti-infection measures. According to the bacteriological results of the pleural effusion after thoracic closed drainage, both gram-positive cocci and gram-negative bacilli were found in the pleural fluid smear, and the bacterial culture results indicated Streptococcus constellations. The blood culture was negative at that time. His chest distress improved, but his oxygenation levels remained unstable. A dynamic blood gas reanalysis revealed continuous deterioration of hypoxia and acidosis. He was ventilated with an endotracheal intubation ventilator 32 h after admission, and a second chest CT (Fig. 2) was performed immediately; it showed multiple infections in both lungs and a large consolidation in the left lung. A mega dose of methylprednisolone (500 mg) was administered to reduce inflammation. Compared with previous examinations, these conditions progressed significantly and rapidly, and he continued to present with low oxygenation under pure oxygen ventilation with endotracheal intubation. Thirty-four hours after admission, he experienced ventricular fibrillation and sudden cardiac arrest three times in the following two hours. Aggressive treatment, including cardiac compression, electrical defibrillation, and drug treatment, was immediately initiated. ECMO using veno-arterial catheterization (VA-ECMO) (flow rate, 2.8 l/min) was performed immediately after cardioversion. One hour after ECMO placement, arterial blood gas analysis showed a partial pressure of oxygen of 131 mmHg, suggesting a substantial improvement in his hypoxia and acidosis.

Four hours after ECMO implantation, the patient had continuous anuria and a urea nitrogen level of 8.9 mmol/l, and

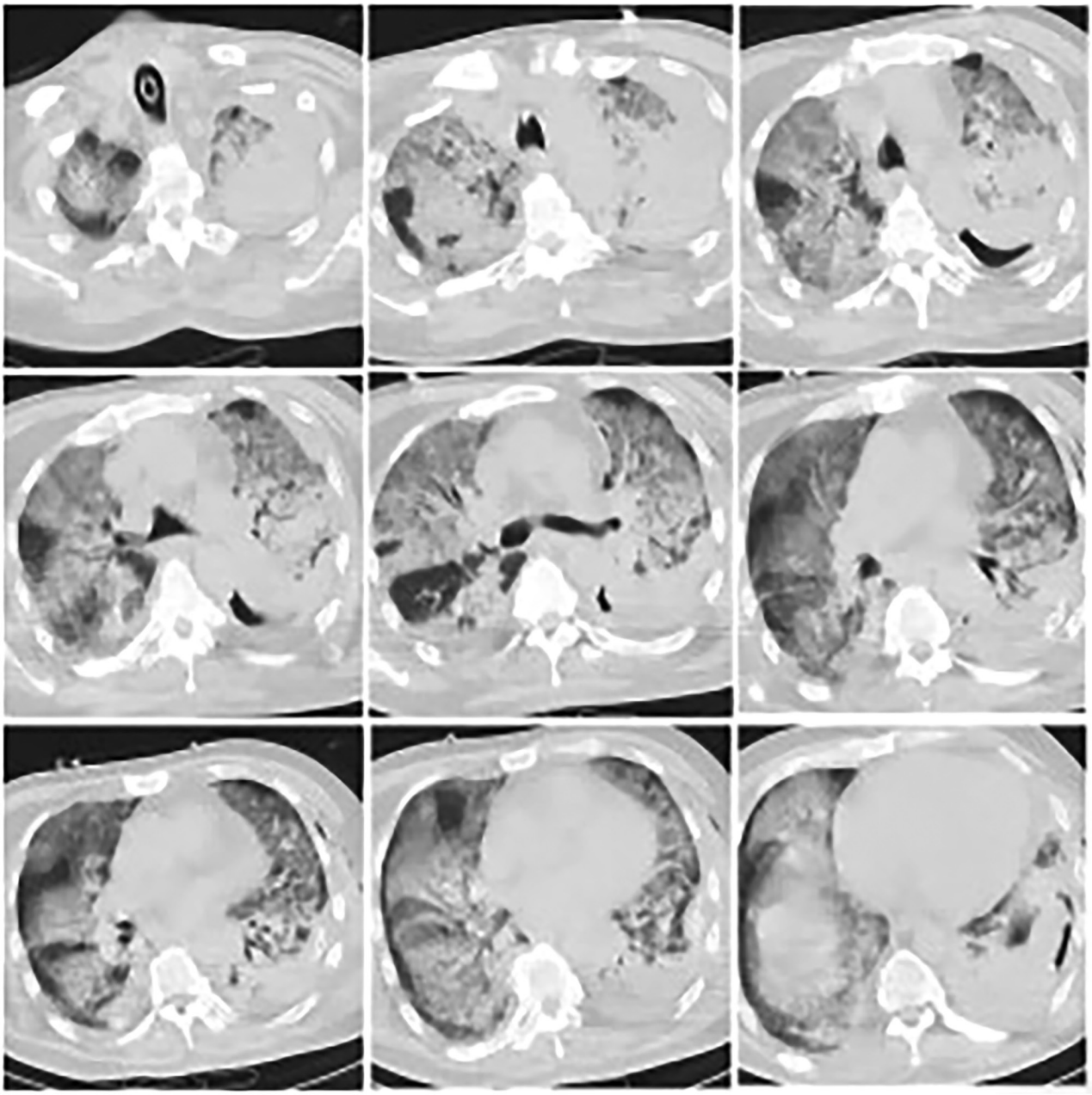

Figure 2. Chest computed tomography 32 h after admission showing multiple infections in both lungs and a large consolidation in the left lung.

his creatinine levels rose to 150.7 μmol/l. Bedside CRRT was performed immediately. The treatment mode was set to continuous venovenous hemofiltration (flow rate, 2,000 ml/h). The patient's condition gradually improved after this. On the 8th day after admission, both ECMO and CRRT were withdrawn after six days of treatment. On the 11th day, chest CT showed that the pulmonary infection had improved significantly. Tracheal extubation was then performed. After the patient was transferred to the thoracic surgery ward for subsequent treatment, he continued to have air bubble overflow in the left chest tube (1-2 degrees of air leakage) while coughing. On the 20th day after admission, he developed a low-grade fever and leukopenia. Routine blood tests showed a WBC count of $1.8x10^9$/l, neutrophil count of $0.2x10^9$/l (11.3%), and hemoglobin level of 67 g/l. Drug-induced myelosuppression was considered after discussion with a multidisciplinary team (MDT). All drugs, including antibiotics, were discontinued, and a subcutaneous injection of granulocytes was subsequently administered. Three days later, his body temperature was back to normal.

A chest CT on the 35th day after admission (Fig. 3) demonstrated that the exudation in both lungs was absorbed, but a left upper lung abscess with bronchopleural fistula was considered as a possible diagnosis. After MDT discussions, minimally invasive surgery-having only a single-hole (Fig. 4A)-was performed the next day, including wedge resection of the left upper lung lesion and empyema removal. Intraoperative exploration revealed a peripheral abscess with an alveolar fistula in the left upper lung lesion. The total operation time was ~70 min. During intraoperative exploration, lesions were observed in the visceral pleura. The surrounding lung tissues showed inflammatory changes and demonstrated a brittle texture. After the lesion was removed using Endo-GIA staplers

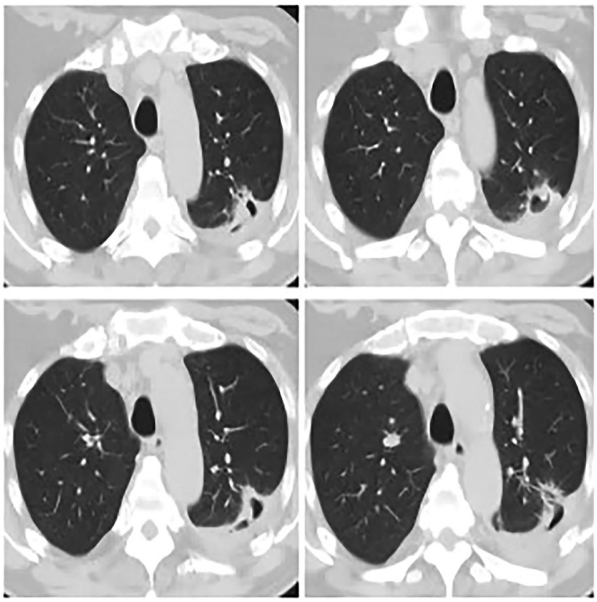

Figure 3. Chest computed tomography on the 35th day after admission showing a bronchial abscess with bronchopleural fistula in the left upper lung, a very difficult condition to treat without surgery.

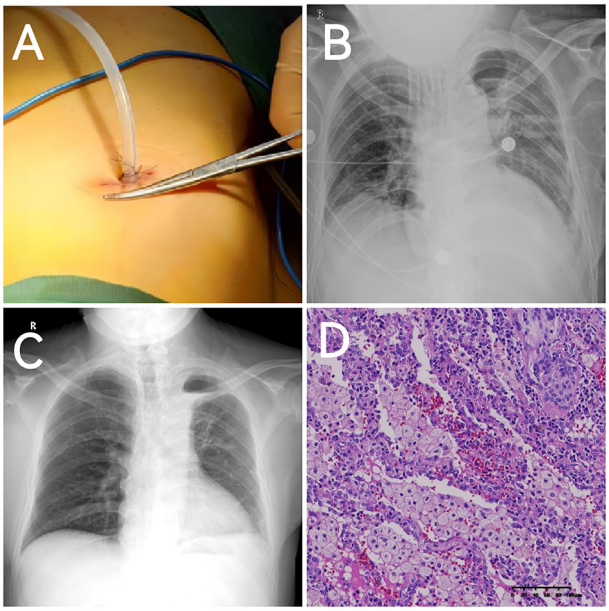

Figure 4. Surgical approach, chest radiography and postoperative pathology images. (A) Image showing the location of the single-port surgical incision, approximately 3 cm in length, and placement of the #19 drainage tube. (B) Chest X-ray at 2 h after surgery revealing no significant hydropneumothorax in the left thoracic cavity. (C) Good re-expansion of the left lung and only a small residual cavity at the top of the left thoracic cavity is observed at 3 weeks after surgery. (D) Image corresponding to the pathological examination of the lung lesion revealing pulmonary fibrous hyperplasia, with massive neutrophil and plasma cell infiltration, and massive foam cell accumulation in the alveolar space (magnification, x200).

(Ethicon, Somerville, NJ, USA), 4-0 prolene thread (Ethicon) was used for continuous suture reinforcement of the wound surfaces to reduce postoperative air leakage.

Chest radiography performed the day after surgery revealed no significant hydropneumothorax in the left thoracic cavity (Fig. 4B). There was no air leakage in the left thoracic duct one week postoperatively. The chest tube was removed two weeks postoperatively and chest radiography at three weeks (Fig. 4C) showed that the left lung had recovered well. Postoperative pathology (Fig. 4D) revealed fibrous hyperplasia with massive neutrophil and plasma cell infiltration, and massive foam cell accumulation in the alveolar space in the left upper lung. His vital signs were stable, and he was discharged uneventfully. The timeline of the treatment process is shown in Fig. 5. The critical information that reflects the severity of the disease included partial pressure of oxygen (PaO_2)/fraction of inspired oxygen (FiO_2) ratio (P/F ratio) and endogenous creatinine clearance rate (Ccr) are shown in Fig. 6. After one year of post-operative follow-up, his cardiopulmonary function continued to be stable, with no recurrence of infection.

Discussion

ARDS caused by acute intrathoracic infection usually progress rapidly because of systemic inflammatory storm, especially in patients with a history of autoimmune disease. With accumulating evidence (3,4), ECMO has demonstrated strong potential for a good prognosis and good application prospects in the treatment of adult ARDS. For example, venovenous ECMO (VV-ECMO) plays a definitive role in improving hypoxia, correcting carbon dioxide retention, and protecting lung tissue (2). However, controversies still remain regarding the selection of VV-ECMO or VA-ECMO (5). After an MDT discussion, the patient finally underwent VA-ECMO. The reasons were: first, echocardiography on admission revealed paradoxical movement of the ventricular wall, significantly elevated creatine kinase myocardial band (142 ng/ml, ref 0-5), myoglobin (>3,000 ng/ml, ref 20-80), and high-sensitivity troponin levels (1,592 ng/l, ref 0-0.04), suggesting pre-existing infectious myocarditis and myocardial damage. Second, he had experienced three episodes of ventricular fibrillation and sudden cardiac arrest due to hypoxia, so the myocardial damage was substantially aggravated. Third, he experienced hemodynamic instability after cardiopulmonary resuscitation. Although VA-ECMO can increase the risk of stroke, bleeding, renal failure, and cobra syndrome (i.e., selective upper body hypoxia) compared to that with VV-ECMO (6-8), this patient experienced no associated adverse events.

Protection of renal function and hemofiltration are especially important in the presence of multiple organ failure. The main purpose of CRRT is to remove excessive water and metabolic waste, correct water and electrolyte imbalances. CRRT is mostly used for treating acute and chronic kidney diseases. Since CRRT can also remove various cytokines and inflammatory mediators, it has likewise been successfully applied to the treatment of severe liver, lung, heart, pancreas, and other organ damage as well as sepsis (9). For this patient, we conducted bedside CRRT to protect the patient's renal function in the early stages of renal impairment, and thus avoided additional deterioration of renal function, adjusted the stability of his internal environment, and provided the proper preconditions for drug efficacy. It should be also noted that CRRT can remove small molecules, promoting the recovery of cardiac function (his left ventricular ejection fraction increased from 39 to 58%). Moreover, CRRT can also help patients with

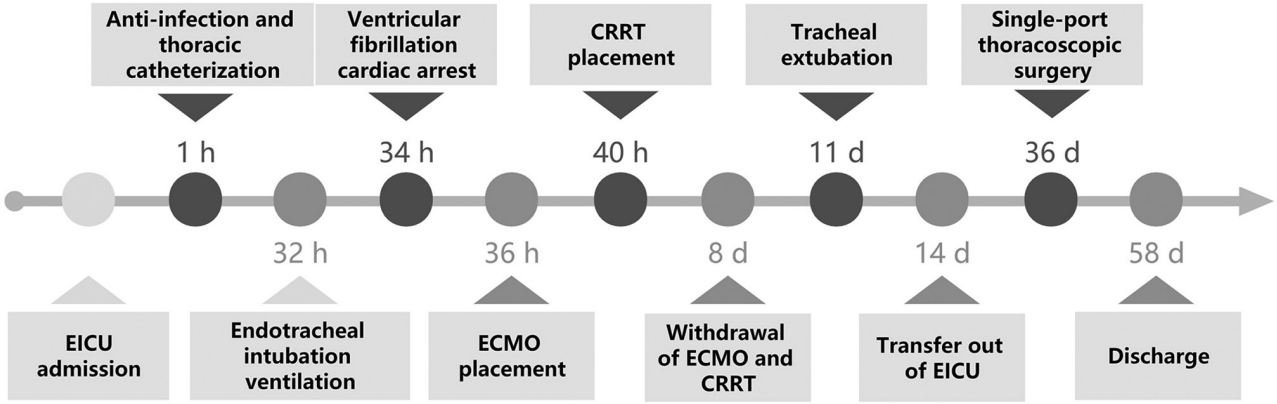

Figure 5. Treatment timeline. EICU, emergency intensive care unit; ECMO, extracorporeal membrane oxygenation; CRRT, continuous renal replacement therapy.

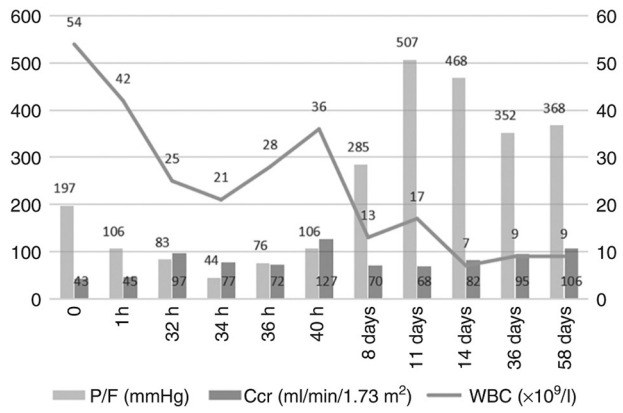

Figure 6. Trend chart of oxygenation index (P/F ratio), endogenous Ccr and WBC count during the whole treatment cycle. P/F ratio, partial pressure of oxygen (PaO_2)/fraction of inspired oxygen (FiO_2) ratio; Ccr, creatinine clearance; WBC, white blood cell; h, hours; d, days.

severe ARDS with hemodynamic instability by accurately implementing fluid management strategies (10,11). A previous retrospective study showed better fluid management with than without CRRT among surviving patients treated with ECMO, and that fluid overload during ECMO was an important factor associated with a poor prognosis (12).

After the patient was transferred to the general ward at our hospital, chest CT showed a left upper lung abscess (~1.5 cm in diameter) with an alveolar fistula accompanied by two clinical problems: persistent air leakage in the left chest tube and intermittent low-grade fever. A prior study confirmed that surgical treatment should be selected for patients with small lung abscesses, localized empyema, symptoms lasting >12 weeks, and little hope for the efficacy of conservative treatment (13). Additional surgical indications include massive hemoptysis, persistent septic fever, bronchopleural fistula, and empyema caused by abscess rupture (14). Recommended surgical methods include lobectomy, segmentectomy, and pulmonary wedge resection, which are selected according to the lesion size and location (14). The prognosis for surgery depends on the patient's systemic status and immune function. Although postoperative mortality as high as 11-28% was reported, as of 2005 the mortality rate has decreased with the recent popularization of effective and minimally invasive techniques (15).

In summary, acute empyema may rapidly develop into ARDS and lead to fatal consequences especially in immunocompromised patients, thus this critical situation warrants vigilance from clinicians. Also, timely and effective use of ECMO can increase the success rate of rescue, and the choice of ECMO mode depends on comprehensively evaluating the patient's condition. Moreover, minimally invasive surgery, even for high-risk patients, should still be considered when conservative treatment fails.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

JZ and HW conceived and designed the work. DG collected and collated the data and wrote the manuscript. CW, JW and QR implemented the placement and withdrawal of ECMO. HW guided the use of CRRT. JG, ZL, XW, LX and XH participated in the operation and the collation of patient information. YB guided the anti-infection drug treatment and collected data. JZ critically revised the manuscript. All authors read and approved the final manuscript. DG and JZ confirm the authenticity of all the raw data.

Ethics approval and consent to participate

This report was approved and presented according to the guidelines of the Ethics Committee of the Second Hospital of Jiaxing (approval no. JXEY-LWSC080).

Patient consent for publication

Written informed consent was obtained for the publication of the patient's data and images in this case report.

Competing interests

The authors declare that they have no competing interests.

References

1. Man MY, Shum HP, Wu A, Lee RA and Yan WW: A case of severe empyema with acute respiratory distress syndrome caused by slackia exigua requiring veno-venous extracorporeal membrane oxygenation. Anaerobe 48: 7-11, 2017.
2. Tandukar S and Palevsky PM: Continuous renal replacement therapy: Who, when, why, and how. Chest 155: 626-638, 2019.
3. Australia and New Zealand Extracorporeal Membrane Oxygenation (ANZ ECMO) Influenza Investigators; Davies A, Jones D, Bailey M, Beca J, Bellomo R, Blackwell N, Forrest P, Gattas D, Granger E, *et al*: Extracorporeal membrane oxygenation for 2009 influenza A(H1N1) acute respiratory distress syndrome. JAMA 302: 1888-1895, 2009.
4. Peek GJ, Mugford M, Tiruvoipati R, Wilson A, Allen E, Thalanany MM, Hibbert CL, Truesdale A, Clemens F, Cooper N, *et al*: Efficacy and economic assessment of conventional ventilatory support versus extracorporeal membrane oxygenation for severe adult respiratory failure (CESAR): A multicentre randomised controlled trial. Lancet 374: 1351-1363, 2009.
5. Kon ZN, Bittle GJ, Pasrija C, Pham SM, Mazzeffi MA, Herr DL, Sanchez PG and Griffith BP: Venovenous versus venoarterial extracorporeal membrane oxygenation for adult patients with acute respiratory distress syndrome requiring precannulation hemodynamic support: A review of the ELSO registry. Ann Thorac Surg 104: 645-649, 2017.
6. Delius R, Anderson H III, Schumacher R, Shapiro M, Otsu T, Toft K, Hirsch J and Bartlett R: Venovenous compares favorably with venoarterial access for extracorporeal membrane oxygenation in neonatal respiratory failure. J Thorac Cardiovasc Surg 106: 329-338, 1993.
7. Oshima K, Kunimoto F, Hinohara H, Ohkawa M, Mita N, Tajima Y and Saito S: Extracorporeal membrane oxygenation for respiratory failure: A comparison of venovenous versus venoarterial bypass. Surg Today 40: 216-222, 2010.
8. Papademetriou MD, Tachtsidis I, Banaji M, Elliott MJ, Hoskote A and Elwell CE: Optical topography to measure variations in regional cerebral oxygenation in an infant supported on veno-arterial extra-corporeal membrane oxygenation. Adv Exp Med Biol 737: 71-76, 2012.
9. Zhu CY, Pan AJ, Mei Q and Chen T: Successful cure of a patient with urosepsis using a combination of extracorporeal membrane oxygenation and continuous renal replacement therapy: A case report and literature review. Chin J Traumatol 23: 372-375, 2020.
10. Han F, Sun R, Ni Y, Hu X, Chen X, Jiang L, Wu A, Ma L, Chen M, Xv Y and Tu Y: Early initiation of continuous renal replacement therapy improves clinical outcomes in patients with acute respiratory distress syndrome. Am J Med Sci 349: 199-205, 2015.
11. Laggner AN, Druml W, Lenz K, Schneeweiss B and Grimm G: Influence of ultrafiltration/hemofiltration on extravascular lung water. Contrib Nephrol 93: 65-70, 1991.
12. Cavagnaro F, Kattan J, Godoy L, Gonzáles A, Vogel A, Rodríguez JI, Faunes M, Fajardo C and Becker P: Continuous renal replacement therapy in neonates and young infants during extracorporeal membrane oxygenation. Int J Artif Organs 30: 220-226, 2007.
13. Kuhajda I, Zarogoulidis K, Tsirgogianni K, Tsavlis D, Kioumis I, Kosmidis C, Tsakiridis K, Mpakas A, Zarogoulidis P, Zissimopoulos A, *et al*: Lung abscess-etiology, diagnostic and treatment options. Ann Transl Med 3: 183, 2015.
14. Pagès PB and Bernard A: Lung abscess and necrotizing pneumonia: Chest tube insertion or surgery? Rev Pneumol Clin 68: 84-90, 2012 (In French).
15. Herth F, Ernst A and Becker HD: Endoscopic drainage of lung abscesses: Technique and outcome. Chest 127: 1378-1381, 2005.