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CLINICAL STUDY

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Extracorporeal multi-organ support: ECMO, CRRT, and hemoperfusion for acute alcohol intoxication with renal and respiratory failure

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ABSTRACT

Introduction: Acute alcohol intoxication can lead to severe complications, including acute kidney injury (AKI), acute respiratory distress syndrome (ARDS), and systemic inflammatory response syndrome (SIRS). Conventional treatments often fail to stabilize critically ill patients, necessitating advanced extracorporeal life support. This study evaluates the effectiveness of extracorporeal membrane oxygenation (ECMO) combined with continuous renal replacement therapy (CRRT) and hemoperfusion (HP) in managing multi-organ failure after acute alcohol intoxication.

Methodology: A critically ill patient with alcohol-induced esophageal perforation, ARDS, and AKI was treated with ECMO, CRRT, and HP after conventional therapies proved insufficient. CRRT was used for fluid management and renal support, while HP facilitated cytokine removal to mitigate inflammation. The clinical course was monitored using respiratory parameters, renal function markers, inflammatory cytokine levels, and hemodynamic stability.

Results: The combination therapy improved oxygenation, stabilized renal function, and reduced systemic inflammation. The patient successfully underwent surgical repair for esophageal perforation and showed full recovery at two-year follow-up.

Conclusion: Integrating CRRT and HP into ECMO circuits offers a novel and effective approach for managing renal dysfunction in acute alcohol intoxication. This strategy may improve outcomes in critically ill patients requiring extracorporeal support. Further studies are needed to optimize its clinical application.

WHAT WAS KNOWN

- Acute alcohol intoxication can lead to acute kidney injury (AKI), acute respiratory distress syndrome (ARDS), and systemic inflammatory response syndrome (SIRS), requiring intensive care.
- Current treatment options, including mechanical ventilation and conventional renal replacement therapy, have limited success in severe multi-organ failure cases.
- The combined use of ECMO, CRRT, and hemoperfusion in alcohol-induced multi-organ failure has not been well explored, leaving a gap in optimized treatment strategies.

THIS STUDY ADDS

- A novel therapeutic approach integrating ECMO, CRRT, and hemoperfusion to improve outcomes in acute alcohol intoxication with AKI and ARDS.
- Clinical evidence that CRRT optimizes renal function and fluid balance, while hemoperfusion effectively reduces inflammatory cytokines, contributing to better organ recovery.
- Successful long-term patient recovery, demonstrating that this multimodal extracorporeal support enhances survival and may serve as a future guideline for alcohol-induced critical illness management.

POTENTIAL IMPACT

- The integration of ECMO, CRRT, and hemoperfusion as a multimodal extracorporeal support strategy could significantly improve the management of acute alcohol intoxication complicated by AKI and ARDS, leading to better clinical outcomes in critically ill patients.
- This study highlights the importance of combining extracorporeal therapies in managing alcohol-related multi-organ failure, potentially influencing clinical guidelines and expanding treatment protocols in nephrology and intensive care settings.

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Extracorporeal membrane oxygenation; continuous renal replacement therapy; hemoperfusion; acute alcohol intoxication; acute respiratory distress syndrome

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- By demonstrating the effectiveness of this comprehensive extracorporeal life support approach, the study could encourage further research and broader clinical adoption, ultimately improving survival rates and long-term prognosis for patients experiencing severe alcohol-related complications.

Introduction

Acute alcohol intoxication is a systemic pro-inflammatory condition that can cause multi-system damage [1]. According to the World Health Organization, alcohol is responsible for approximately 5% of deaths and 5% of the global disease burden. About 40% of patients with spontaneous esophageal perforation have a history of alcohol abuse or excessive drinking [2]. Esophageal perforation is a rare but high-risk condition [3]. Research has found that alcohol abuse is independently associated with sepsis, septic shock, and mortality [4]. Capillary leak syndrome (CLS) is a rare disorder that can lead to multi-organ failure and be life-threatening, with sepsis being the most common cause [5,6]. Alcohol can also induce lung injury and increase oxidative stress, resulting in acute respiratory distress syndrome (ARDS). Despite advancements in ventilation techniques and other therapies, the mortality rate for ARDS remains high. Veno-venous extracorporeal membrane oxygenation (V-V ECMO) treats patients with severe ARDS [7,8]. The European Society of Intensive Care Medicine's ARDS guidelines recommend extracorporeal membrane oxygenation (ECMO) treatment for severe non-COVID-19 patients at qualified ECMO centers, following the criteria established by the EOLIA trial [7,9].

In recent years, the HA380 Hemoperfusion (HP) cartridge has been found to reduce cytokine levels in the alveoli and circulation and balance the dysregulation of inflammatory factors [10,11]. Cytokine adsorption devices have been integrated into extracorporeal systems [12]. Acute kidney injury and fluid overload strongly justify the use of CRRT, which allows for more precise fluid management [13]. CRRT is most commonly added to the ECMO circuit in patients undergoing ECMO. The strategy proposed by Rubin et al. which involves connecting the CRRT drainage line to the post-ECMO pump circuit and the return line to the pre-ECMO pump, provides an important reference for our approach [14]. Incorporating the latest research findings, we integrated CRRT and the HA380 cartridge in series within the ECMO circuit, as illustrated in Figure 1(A).

Recent studies have further supported the combined use of CRRT and HP in treating critically ill patients. A 2022 study highlighted that combining CRRT with ECMO can improve outcomes for patients with acute kidney injury [15]. Additionally, research has shown that incorporating cytokine adsorption devices into ECMO can more effectively remove inflammatory cytokines, enhancing treatment efficacy [16]. A 2023 study further demonstrated that the combined application of CRRT and HP can improve clinical outcomes in critically ill patients [17].

Clinical value summary

This study explored an integrated treatment strategy incorporating CRRT and HP into the ECMO circuit, as illustrated in Figure 1. The research indicates that this combination improves treatment outcomes for patients with complications from acute alcohol intoxication through precise fluid management and the removal of inflammatory cytokines [15]. Specifically, the combination of ECMO, CRRT, and HP

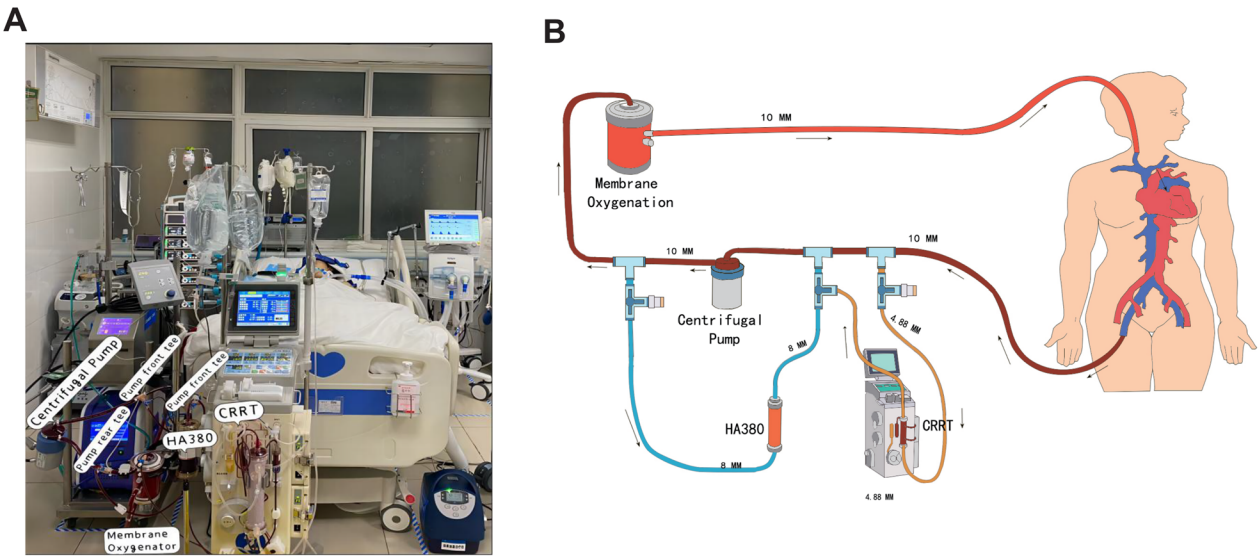

Figure 1. Schematic diagram of device connections. *Note:* (A) Diagram showing the device connected in a clinical setting; (B) Diagram illustrating the clinical mechanism of device connection. In the blood perfusion system, the drainage end is connected to the post-membrane of the pump, while the return end is connected to the anterior end of the pump. For CRRT, the drainage end is connected to the proximal anterior end of the pump, and the return end is connected to the distal anterior end of the pump.

therapy markedly reduces the incidence of complications such as esophageal perforation, ARDS, and CLS while decreasing hospital stay duration and medical costs [13]. This multi-modal therapy not only addresses complex conditions resulting from acute alcohol intoxication but also provides comprehensive life support for patients.

Additionally, precise volume management and effective removal of inflammatory cytokines improved the patient's respiratory function and overall prognosis. After treatment, the patient experienced marked improvement in respiratory function, alleviation of ARDS symptoms, reduction in inflammatory cytokine levels, and decreased pleural effusion. Long-term follow-up after discharge indicated a good recovery [9]. Currently, there is a lack of research on the simultaneous integration of CRRT and HP devices into the ECMO circuit. This study fills that gap by providing a novel treatment strategy and theoretical foundation, advancing the field [12]. By integrating the latest technologies and therapeutic approaches, this study demonstrates the potential applications of CRRT and HP within ECMO, offering valuable reference points for similar cases [10,16].

In conclusion, this study provides a novel approach to managing complications from acute alcohol intoxication by integrating advanced therapeutic techniques. This strategy not only enhances treatment efficacy but also improves patient prognosis.

Case

The patient was a 48-year-old male who experienced sudden respiratory distress, lip cyanosis, and incontinence of urine and feces three hours after consuming alcohol and subsequently vomiting severely. Upon arrival at the local hospital, he was in a comatose state. Arterial blood gas analysis showed an oxygen partial pressure of 50 mmHg. Immediate treatment included fluid resuscitation and mechanical ventilation with endotracheal intubation (ventilator settings: FiO_2 100%, PEEP 10 mmHg). After three hours of treatment, hypoxemia could not be corrected, necessitating urgent V-V ECMO, after which the patient was transferred to our hospital. He had no significant medical history.

Admission examination

Vital Signs: pulse: 132 beats per minute; blood bressure: 74/52 mmHg; consciousness: semi-comatose. Physical Examination: respiratory sounds were diminished in the right lung, with bilateral moist rales noted. No pathological reflexes were elicited. Laboratory Tests: white blood cell count (WBC): 22.57×10^9/L, interleukin-6 (IL-6): 1,918 pg/mL. Bronchoscopy: both main bronchi and branches were patent, but a large amount of white secretion was observed. Bronchoalveolar lavage fluid culture: the presence of *Klebsiella pneumoniae* was detected. Imaging studies: bedside chest X-ray: right pleural effusion with right lung atelectasis was noted. Thoracentesis: closed drainage revealed hemorrhagic fluid. On the second day, the drainage fluid appeared similar to gastric fluid. Methylene blue was injected into the gastric tube, and methylene blue was subsequently observed in the thoracic drainage tube. CT Scan: indicated pneumothorax and subcutaneous emphysema (Figure 2). Endoscopy: Bedside gastroscopy showed acute esophageal injury, suggesting perforation.

Treatment process

Day 1: Upon admission, the patient underwent fluid resuscitation and vasopressor therapy to stabilize hemodynamics, with continuous support from V-V ECMO. Day 2: Pleural effusion was drained *via* thoracentesis and confirmed gastric. The methylene blue test further confirmed esophageal perforation. Day 3: The patient developed severe generalized edema. CRRT was initiated in series (Figure 1B) for fluid management (Table 1), and HA380 was used to adsorb inflammatory cytokines (2-h sessions, twice daily) along with pharmacological treatment. Day 4: The patient's hemodynamics stabilized, allowing for the discontinuation of vasopressors. Day 5: Generalized edema gradually subsided, and the patient's condition showed significant improvement. Day 7: V-V ECMO was discontinued as the patient's spontaneous respiratory function recovered. Day 13: The patient's consciousness fully recovered, and the condition improved, leading to the removal of the ventilator and extubation. Day 14: The patient was transferred to surgery, where a 9 cm rupture on the right side of the esophagus was discovered. Pathological examination revealed local inflammatory exudation, granulation tissue proliferation, and a foreign body giant cell reaction. Day 59: The patient was discharged in a stable condition, with a follow-up period of over two years showing a full recovery.

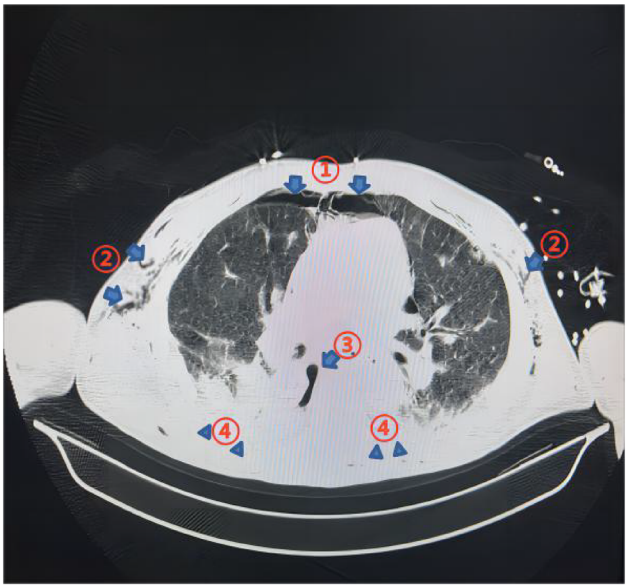

Figure 2. Patient's chest CT images. *Note:* The images show esophageal perforation with the following features: ① Pneumothorax; ② Subcutaneous emphysema; ③ Mediastinal emphysema; ④ Bilateral pleural effusion.

Table 1. Daily fluid input and output during critical care management.

	Input				Output				
Time	Crystalloids (mL)	Transfusion (mL)	Albumin (g)	Total (mL)	Urine (mL)	Gastric Tube (mL)	Pleural Fluid (mL)	CRRT (mL)	Total (mL)
1st day	9270	0	20	9370	1545	600	600	1500	2700
2nd day	4731	0	20	4831	3070	200	1800	4500	9570
3rd day	4300	800	40	5300	4625	200	800	3800	9425
4th day	2790	1200	40	4190	7930	200	900	7800	16830
5th day	2330	0	40	2530	5540	0	620	8300	14460
6th day	2640	0	40	2840	1600	0	600	11000	13200
7th day	2024	0	20	2124	4750	0	1100	0	5850

Detailed fluid input and output during the treatment period are presented in Table 1.

Surgical treatment process

The surgical procedure involved opening the esophageal rupture and performing suture repair. Cardiac protection measures, including continuous heart rate and blood pressure monitoring, were implemented intraoperatively. Postoperatively, the patient received thoracic drainage, prophylactic antibiotic therapy to prevent infection, and cardiac function monitoring alongside rehabilitative care.

Blood test indicators

Regular blood tests, including complete blood count and biochemical markers, were conducted preoperatively and postoperatively. Results showed that the patient's WBC and IL-6 levels gradually returned to normal. Other biochemical parameters, such as liver and kidney function and electrolytes, remained within normal ranges throughout the monitoring period.

Postoperative follow-up

The patient demonstrated a good recovery post-surgery, with follow-up over two years. Cardiac function assessments showed no abnormalities and pain management was effective. The patient experienced no long-term complications. Regular follow-up included imaging studies and laboratory tests to monitor long-term recovery.

Nursing interventions

The nursing interventions closely monitored the patient's heart rate, blood pressure, respiratory function, fluid management, and nutritional support. Nutritional intake was ensured through both enteral and parenteral nutrition. Antibiotic therapy was administered for Klebsiella pneumoniae infection and continuously monitored infection markers. The patient underwent respiratory exercises and physical therapy during rehabilitation to enhance pulmonary function and overall physical recovery. Flow and pressure monitoring was conducted throughout the ECMO treatment to ensure proper device operation, with parameter adjustments made according to the patient's condition.

Nutritional and antibiotic support

The patient received enteral and parenteral nutrition during treatment to ensure adequate nutritional intake. Based on the alveolar lavage fluid culture results, the patient underwent targeted antibiotic therapy for *Klebsiella pneumoniae*, continuously monitoring infection markers.

Rehabilitation therapy

During rehabilitation, the patient participated in respiratory function exercises and physical therapy to enhance pulmonary function and overall physical recovery.

In this case, the combined treatment strategy of ECMO, CRRT, and HP demonstrated significant clinical effectiveness in managing complications of acute alcohol intoxication. Precise fluid management and removing inflammatory factors led to marked improvements in the patient's respiratory function and overall prognosis. This study provides new insights and clinical evidence for the comprehensive treatment of acute alcohol intoxication and its complications.

Discussion

This study is the first to integrate CRRT and HP into the ECMO circuit, as illustrated in Figure 3, demonstrating an innovative, comprehensive treatment approach. By combining multiple support technologies with direct blood adsorption, we aim to evaluate the effectiveness and safety of this strategy in managing complications of acute alcohol intoxication. The study highlights the clinical value of reducing complications and improving prognosis and identifies current limitations and directions for future research. It provides new scientific evidence and practical guidance for treating acute intoxication.

Literature review

We conducted a comprehensive review of articles published between 2010 and 2024 using the PubMed database with the search terms 'Extracorporeal Membrane Oxygenation', 'Continuous Renal Replacement Therapy', 'Hemoperfusion', 'Acute Alcohol Intoxication', 'Esophageal Perforation', and 'Acute Respiratory Distress Syndrome'. As shown in Table 2, we summarized patients' clinical presentations, diagnostic methods, treatments, and prognoses in the 14 most relevant

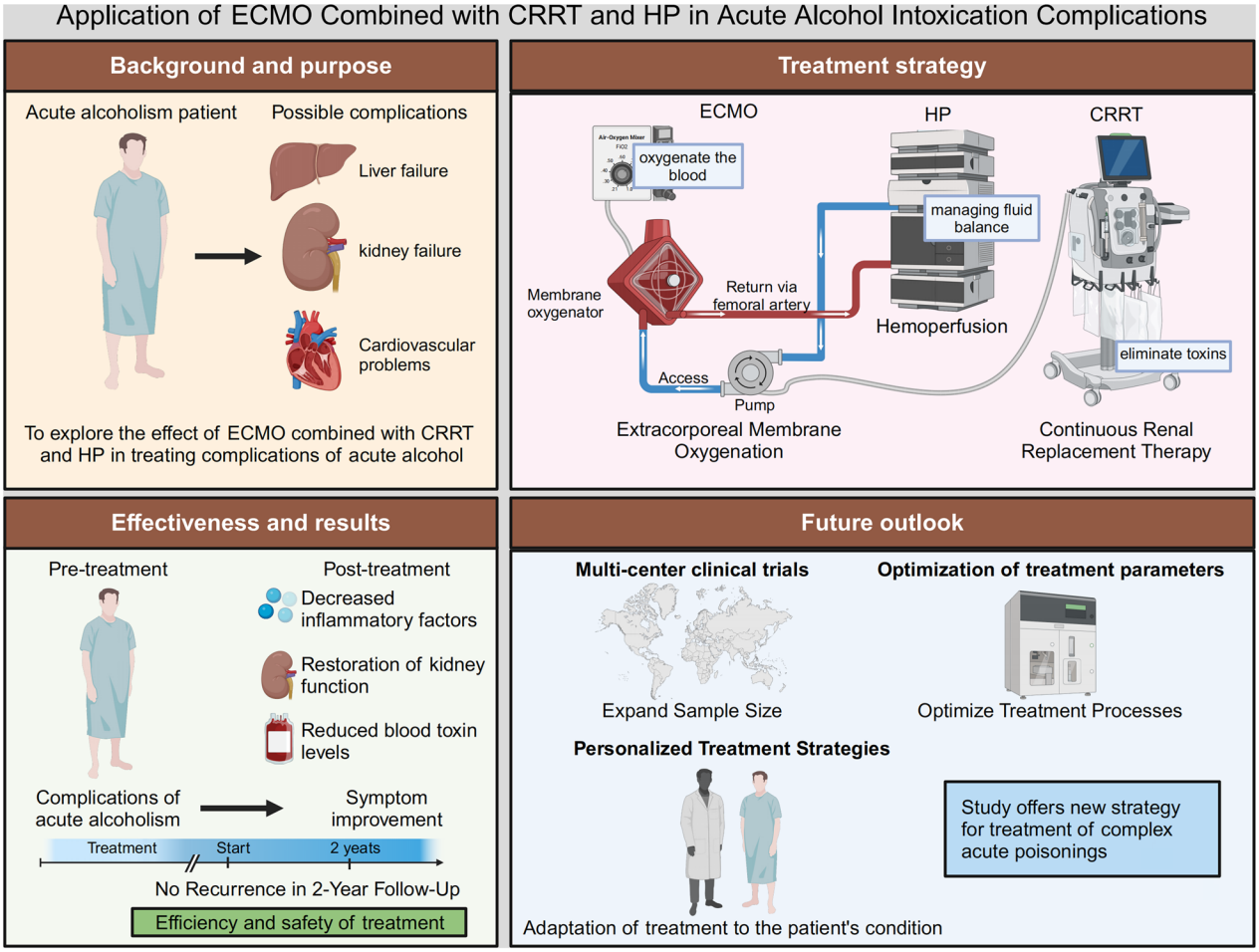

Figure 3. Application of ECMO combined with CRRT and HP in acute alcohol intoxication complications.

articles. The applications of these treatments are discussed in depth in the following sections.

Secondary mediastinal emphysema (SME) and VV-ECMO treatment caused by COVID-19

Previous studies have documented a case of a middle-aged male patient who developed extensive SME and retroperitoneal emphysema following mechanical ventilation. Initial treatment included VV-ECMO support, the insertion of two drainage tubes into the mediastinum and pleural cavity, prone positioning, and neuromuscular relaxation therapy. On the 15th day, the patient successfully weaned off VV-ECMO, recovered, and was discharged. This case suggests that SP may indicate extensive alveolar damage and serves as a potential predictor of poor prognosis in critically ill SARS-CoV-2 patients [18]. Furthermore, it underscores the importance of early identification and management of complications in COVID-19 treatment, particularly in patients undergoing mechanical ventilation. COVID-19 can cause extensive lung damage, leading to various complications, including SP, which are particularly common in severe cases. VV-ECMO provides essential respiratory support, alleviating the mechanical burden on the lungs. Drainage and prone positioning help reduce gas accumulation and improve ventilation/perfusion mismatch. The success of this treatment strategy demonstrates the potential of multimodal management in critically ill COVID-19 patients. However, this approach requires high monitoring and resources, emphasizing the importance of multidisciplinary collaboration in intensive care.

ARDS and ECMO treatment due to carbon monoxide poisoning and inhalation injury

In this study, a patient developed ARDS and a cytokine storm following carbon monoxide poisoning and inhalation injury from a fire. The patient recovered after implementing ECMO and direct HP using a polymyxin B-immobilized fiber column in the emergency department. This case indicates that early application of ECMO and HP may be effective in acute respiratory failure accompanied by a cytokine storm. This treatment approach rapidly improves oxygenation and effectively controls the inflammatory response, enhancing patient survival rates [19]. ARDS caused by carbon monoxide poisoning and inhalation injury is a complex and potentially fatal condition where traditional treatments often have limited effectiveness. ECMO provides extracorporeal oxygenation support,

Table 2. Summary of clinical presentations, diagnostic approaches, and treatment outcomes in ECMO, CRRT, and related therapies (2010–2024).

Journal	Authors	PMID	Year	Case presentation	Diagnosis	Treatment	Outcome
ID Cases [18]	Golino G, Forin E, Boni E, Martin M, Perbellini G, Rizzello V, Toniolo A, Danzi V	38681081	2024	44-year-old male with COVID-19 developed pneumomediastinum and pneumoperitoneum.	COVID-19, secondary pneumomediastinum, pneumoperitoneum	VV-ECMO, mechanical ventilation, chest drains	Good recovery and discharge
J Med Case Rep [19]	Jang JH, Jang HJ, Kim HK, Park JH, Kim HJ, Jo KM, Heo W, Kim SH, No TH, Lee JH	34521457	2021	34-year-old male with ARDS due to carbon monoxide poisoning after a fire.	ARDS, carbon monoxide poisoning	ECMO, direct hemoperfusion with polymyxin B-immobilized fiber column	Successful recovery
BMJ Case Rep [20]	Chavez JR, Danguilan RA, Arakama MI, Garcia JKG, So R, Chua E	31147412	2019	47-year-old male with leptospirosis presented with ARDS and AKI.	Leptospirosis, ARDS, AKI	ECMO, hemoperfusion	Successful recovery
Int J Artif Organs [21]	Piwowarczyk P, Kutnik P, Potręć-Studzińska B, Sysiak-Sławecka J, Rypulak E, Borys M, Czczuwar M	30919732	2019	Patient developed jaundice and hyperbilirubinemia after ECMO for septic shock.	Septic shock, hyperbilirubinemia	ECMO, hemoadsorption	Improved condition and transfer to regional hospital
Crit Care Explor [22]	Amerson SJ, Hoffman M, Abouzahr F, Ahmad M, Sterling RK, Gidwani H, Sousse LE, Dellavolpe JD	38415021	2024	28-year-old woman with STSS and multiple organ failure after cesarean section.	STSS, multiple organ failure	VA-ECMO, pathogen hemoperfusion, cell-directed immunomodulation	Stabilized condition, recovery
J Med Case Rep [23]	Taccone FS, Gardette M, Creteur J, Brasseur A, Lorent S, Grimaldi D	33557948	2021	27-year-old woman with methemoglobinemia due to iatrogenic Patent Blue V administration.	Methemoglobinemia, Patent Blue V intoxication	VV-ECMO, CytoSorb hemoadsorption	Improved hemodynamics and plasma lactate levels
J Artif Organs [24]	Lees NJ, Rosenberg A, Hurtado-Doce AI, Jones J, Marczin N, Zeriouh M, Weymann A, Sabashnikov A, Simon AR, Popov AF	27436098	2016	33-year-old patient with severe sepsis and ARDS due to Staphylococcus aureus pneumonia and H1N1.	Sepsis, ARDS, Staphylococcus aureus pneumonia, H1N1	ECMO, cytokine adsorption therapy	Successful recovery
Cureus [25]	Gaddameedi SR, Cherukuri PB, Khan MA, Atreya S, Bandari V, Ashok M, Shah S	38694661	2024	Patient with alcoholism and immobility-induced rhabdomyolysis.	Rhabdomyolysis, AKI	Hemodialysis	Recovery with hemodialysis
Ann Clin Lab Sci [26]	Hansard PC, Manning RA, Haseeb MA, Salwen MJ	16501243	2006	39-year-old male with hepatorenal syndrome and refractory ascites.	Hepatorenal syndrome, refractory ascites	CRRT	Clinical improvement
Interact Cardiovasc Thorac Surg [27]	Valance D, Bouchet B, Brulliard C, Delmas B, Puech B, Braunberger E, Allou N, Allyn J	29281011	2018	Patients with cardiogenic shock due to alcoholic cardiomyopathy.	Cardiogenic shock, alcoholic cardiomyopathy	VA-ECMO	Recovery in 3 patients, heart transplant in 1 patient
Transplantation [28]	Taghavi S, Jayarajan SN, Komaroff E, Shiose A, Schwartz D, Hamad E, Alvarez R, Wheatley G, Guy TS, Toyoda Y	25606795	2015	Heart transplantation outcomes using heavy drinking donors.	Heart transplantation outcomes, heavy drinking donors	Heart transplantation	Good outcomes
J Extra Corpor Technol [29]	Sansone F, Flocco R, Zingarelli E, Dato GM, Punta G, Parisi F, Forsennati PG, Bardi GL, Imbastaro I, Chiolero C, Balossino A, Borin P, Peretto V, del Ponte S, Casabona R	22416606	2011	Homeless patients with hypothermic cardiac arrest treated successfully with ECMO.	Hypothermic cardiac arrest	ECMO	Survived without neurological or cardiac complications
Int Heart J [30]	Imamura T, Kinugawa K	26346515	2015	Patient with Shoshin beriberi improved with thiamin administration.	Shoshin beriberi, thiamin deficiency	Thiamin administration	Dramatic improvement
Chest [31]	Shiloh AL, Kazzi MG, Mathew R, Eisen LA, Carlese AJ	24493554	2014	Man in his 40s with septic shock and ARDS related to alcohol dependency.	Septic shock, ARDS, alcohol dependency	ECMO, antibiotics, vasopressors	Survived with treatment

while polymyxin B HP efficiently removes inflammatory mediators, mitigating the systemic inflammatory response associated with a cytokine storm. The success of this combined treatment strategy suggests that early multimodal intervention can improve survival rates and reduce long-term complications in extremely acute situations.

Acute respiratory failure and acute kidney injury from leptospirosis treated with ECMO

A previous case involved a patient who developed severe acute respiratory failure and acute kidney injury after contracting leptospirosis from water exposure. Treatment with VV-ECMO and HP improved the patient's oxygenation and lung compliance, allowing for successful weaning from ECMO and eventual discharge [20]. This case illustrates that the combined use of ECMO and HP can effectively manage acute respiratory and multi-organ failure resulting from severe infections. The timely initiation of these interventions is crucial, particularly in cases of multi-organ failure. Therefore, the comprehensive use of advanced life support technologies can improve survival rates and recovery speeds in complex infectious cases.

Streptococcal toxic shock syndrome (STSS) and multimodal ECMO treatment

In a previous study, a patient developed STSS five days after a Cesarean section. Despite the ineffectiveness of conventional treatments, the patient gradually stabilized and recovered through a combined treatment approach involving Veno-Arterial Extracorporeal Membrane Oxygenation (VA-ECMO), Seraph 100 HP, and a selective cytogenetic device (SCD) [22]. This case is the first to report the use of VA-ECMO, Seraph 100 HP, and SCD in combination, highlighting the potential of this multimodal ECMO support strategy. The case underscores the promising application of multimodal therapy in managing extremely critical conditions. STSS is a severe infection caused by invasive group A Streptococcus, often associated with high mortality. Traditional treatment methods include antibiotics, surgical debridement, and supportive care, often insufficient in severe cases. VA-ECMO provides cardiopulmonary support, while Seraph 100 and SCD further reduce pathogens and inflammatory mediators. This multimodal treatment strategy improved the patient's prognosis, demonstrating that integrating multiple advanced technologies is key to enhancing outcomes in complex and critical infectious cases.

Drug overdose and ECMO treatment

Research has shown that a patient suffering from multi-organ failure due to drug overdose experienced a rapid reduction in blood methylene blue levels and significant hemodynamic improvement following treatment with VV-ECMO and CytoSorb hemoadsorption, ultimately returning to normal health [23]. This case illustrates the potential application of CytoSorb hemoadsorption in drug overdoses, particularly in complex poisoning cases, where it can enhance treatment efficacy and patient survival rates. Treating multi-organ failure resulting from drug overdose is complex and associated with high mortality. VV-ECMO plays a crucial role in maintaining stable vital signs, while CytoSorb hemoadsorption effectively removes circulating toxins and metabolic byproducts. This combined treatment strategy demonstrates the potential and necessity of multimodal intervention in acute poisoning scenarios. Future research should optimize this approach's timing and specific implementation to improve outcomes.

Cardiogenic shock and ARDS due to severe infection and ECMO treatment

In one study, a patient suffering from a severe infection caused by Panton-Valentine leukocidin-positive Staphylococcus aureus and H1N1 virus successfully recovered following treatment with ECMO and cytokine adsorption therapy [24]. This case demonstrates the effectiveness of combining ECMO with cytokine adsorption therapy in managing multiple organ failures resulting from infection. ECMO provides essential circulatory and respiratory support, while cytokine adsorption therapy effectively reduces inflammatory mediators, improving patient outcomes. Multi-organ failure due to infection, especially in cases of cardiogenic shock and ARDS, presents significant treatment challenges and poor prognosis. ECMO delivers crucial circulatory and respiratory support, whereas cytokine adsorption is vital in controlling the systemic inflammatory response. The clinical success of this combined treatment approach suggests that integrating multiple advanced therapeutic modalities is an effective strategy to enhance survival rates and improve prognoses in complex infectious cases.

The cases mentioned above demonstrate effective treatment strategies for various severe conditions, particularly in COVID-19, acute poisoning, and severe infections. Applying ECMO with other adjunctive therapies has proven effective in these contexts. These cases collectively illustrate that ECMO is crucial for circulatory and respiratory support. When combined with HP and cytokine adsorption techniques, ECMO can effectively control inflammatory responses and remove toxins, improving patient outcomes. These successful treatment cases highlight the potential and necessity of multimodal comprehensive management, emphasizing the importance of multidisciplinary collaboration in intensive care settings. Such approaches have been shown to enhance patient survival rates and accelerate recovery.

Scientific and clinical value of the study

Scientific Value: Novel Combined Treatment Strategy: This study is the first to incorporate CRRT and HP into the ECMO circuit, demonstrating an innovative, comprehensive treatment approach. Through precise fluid management and effective clearance of inflammatory factors, this strategy improved the

prognosis of patients with complications from acute alcohol intoxication, providing new therapeutic insights and scientific evidence. Research has shown that integrating CRRT and HP technologies can more effectively remove toxins and inflammatory factors, thereby improving clinical outcomes [15].

Integration of Multiple Support Technologies: By incorporating CRRT and HP into the ECMO circuit, this study demonstrated that integrating multiple support technologies can enhance treatment outcomes without increasing complications. This finding provides valuable guidance for treating similar cases in the future. Studies have indicated that integrating multiple support technologies into ECMO can enhance overall treatment effectiveness and reduce the occurrence of complications [32].

Application of Direct Hemoadsorption: there is growing evidence supporting the application of direct hemoadsorption technology, particularly in the combined use of ECMO and CRRT. This technology can reduce inflammatory factors in the blood and improve clinical outcomes. Research has demonstrated that direct hemoadsorption effectively removes inflammatory factors and improves patient prognosis [33,34].

Clinical Value: Reduction in Complication Rates: this study demonstrates that combining ECMO with CRRT and HP can reduce the incidence of complications such as ARDS and CLS, thereby decreasing hospital stay duration and medical costs. Research indicates that this combined treatment strategy can notably lower complication rates and reduce the consumption of medical resources [13].

Improvement in Patient Outcomes: through precise fluid management and effective clearance of inflammatory factors, patients experience significant improvements in respiratory function and overall prognosis. Long-term follow-up after discharge shows good recovery. Studies have shown that this comprehensive treatment strategy markedly enhances patients' long-term outcomes [9].

Reduction in Medical Resource Consumption: directly connecting CRRT to the ECMO circuit avoids the need for new dialysis catheters, reduces the number of vascular punctures, lowers anticoagulation risks, extends circuit lifespan, and decreases medical resource consumption. Research suggests that this method can reduce the consumption of medical resources and increase treatment efficiency [35].

Limitations

This study is based on a single case, with a limited sample size, making it difficult to fully assess the generalizability of this treatment strategy. More clinical trials and multicenter studies are needed to validate its efficacy and safety. For example, future multicenter randomized controlled trials could further verify the universality and effectiveness of this combined treatment strategy. Incorporating CRRT and HP into the ECMO circuit increases management complexity, requiring highly specialized technical support and monitoring. This complexity may limit the strategy's application in standard clinical settings, necessitating a specialized medical team and equipment to manage such an intricate treatment approach. Research indicates that increasing clearance media might reduce the concentration of therapeutic drugs, necessitating further investigation into the impact of different extracorporeal support technologies and flow adjustments on drug efficacy [36,37].

Future perspectives

Future research should further explore the combined application of CRRT and HP within ECMO, particularly regarding their effectiveness in treating different types of acute poisoning and multi-organ failure [38]. There is a need for in-depth studies on the hemodynamic effects of incorporating CRRT and HP into the ECMO circuit to optimize treatment parameters and protocols, ensuring patient safety [39]. Developing personalized treatment strategies based on individual patient conditions is crucial. This includes selecting appropriate extracorporeal support technologies and adjusting flow rates to enhance treatment efficacy and patient outcomes. For example, treatment plans can be tailored to the patient's medical condition, choosing the most suitable extracorporeal support technology and adjusting flow rates accordingly.

Through detailed discussions of the scientific and clinical value and analyses of limitations and future directions, this study not only provides a new comprehensive treatment strategy for complications related to acute alcohol intoxication but also highlights future research directions and issues that need to be addressed.

Conclusion

This study demonstrates the effectiveness and safety of combining ECMO with CRRT and HP in a case of acute alcohol intoxication complications. This innovative combined treatment strategy successfully reduced complication rates and hospitalization costs, with the patient showing good recovery over a two-year follow-up period. However, since this study is based on a single case, its generalizability and reproducibility must be validated through additional cases and clinical trials.

Scientifically, this study is the first to report the simultaneous incorporation of CRRT and HP devices into the ECMO circuit, providing a new perspective on the treatment of acute alcohol intoxication and its severe complications. The patient's prognosis improved through precise fluid management and effective clearance of inflammatory factors. However, the lack of a control group and the limited number of cases constrain the ability to establish clear causal relationships.

Looking ahead, larger sample sizes and multicenter studies are needed to validate the efficacy and safety of this strategy. Additionally, exploring the potential of combining ECMO with other therapeutic approaches could extend its application to different clinical scenarios. Long-term outcome evaluations are also crucial, and future research should comprehensively assess the strategy's impact on improving patient quality of life and reducing recurrence rates.

Authors' contributions

Xiting Dang: Conceptualization, patient management, data collection, study design, analysis, and manuscript drafting.. Shuzhi Lv: Data analysis, technical support for extracorporeal treatment procedures, and manuscript revision.. Miao Huang: Literature review, data interpretation, and manuscript preparation.. Huini Fu*: Study supervision, manuscript review and revision, and critical insights into case analysis and discussion.. All authors have read and approved the final version of the manuscript.

Ethical statement

This study was conducted in accordance with the ICMJE guidelines, the principles outlined in The Belmont Report, and the Declaration of Helsinki regarding research involving human participants. Ethical approval was obtained from the Clinical Ethics Committee of Nanyang Second General Hospital (Approval No. LY20240086). All human subjects provided written informed consent before participation, and details regarding the consent process are included in the manuscript. The study adhered to institutional and international ethical standards for the protection of research participants.

Disclosure statement

The authors declare that there are no conflicts of interest regarding the publication of this article. The authors confirm that none of the authors has been involved in the editorial handling or peer review. The authors confirm that no competing interests to declare.

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Data availability statement

All data can be provided as needed.

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