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CASE REPORT / ПРИКАЗ БОЛЕСНИКА

Care of a patient with heat stroke combined with multi-organ failure treated with extracorporeal membrane oxygenation combined with continuous renal replacement therapy

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SUMMARY
Introduction Heat stroke (HS) can cause many complications, including acute kidney injury and acute respiratory distress syndrome. To date, the use of extracorporeal membrane oxygenation (ECMO) combined with continuous renal replacement therapy (CRRT) in the treatment of patients with HS and multiple organ failure has not been studied. We describe a patient with HS who was treated for the first time with ECMO combined with CRRT. This case report aims to contribute insights into the clinical management of heat -related illness by disseminating information pertaining to the treatment processes.
Case outline A 34-year-old male patient with HS and multiple organ dysfunction was admitted to the intensive care unit (ICU) for emergency symptomatic treatment. The comprehensive diagnosis encompassed HS, multiple organ dysfunction syndrome, electrolyte imbalance and hypoalbuminemia. The patient's vital signs, including heart rate, blood pressure, respiratory rate and oxygen saturation, were monitored, and ECMO and CRRT life-support therapies were rapidly applied. The patient was successfully weaned off ECMO, CRRT, and mechanical ventilation, and showed stable vital signs; thereafter, he was transferred out of the ICU.
Conclusion This case demonstrates that prompt symptomatic treatment and early ECMO combined with CRRT can effectively treat patients with severe HS. Additionally, it is crucial for healthcare professionals to be vigilant in detecting changes in the patient's vital signs and to collaborate effectively in administering the necessary treatments.
Keywords: heat stroke; acute respiratory distress syndrome; extracorporeal membrane oxygenation; continuous renal replacement therapy; nursing care

INTRODUCTION

Heat stroke (HS) is a clinical syndrome caused by central thermoregulatory dysfunction, characterized by elevated core temperature (> 40°C) due to an imbalance between heat production and heat dissipation following exposure to a hot environment and/or strenuous exercise; the mortality rate is up to 60% in patients with severe HS [1]. Studies have shown that severe complications of HS include rhabdomyolysis, acute kidney injury, disseminated intravascular coagulation (DIC) and acute respiratory distress syndrome (ARDS) [1]; ARDS is a direct threat to the patient's life.

Patients managed with extracorporeal membrane oxygenation (ECMO) benefit from its ability to provide oxygenation and circulation independently of mechanical ventilation, supporting the patient's respiratory needs while allowing for better management of lung function. When conventional mechanical ventilation cannot meet the oxygenation needs of patients with ARDS, ECMO can be used to replace lung function, meet the body's oxygenation needs, maintain the stability of vital signs and gain time for other treatments [2]. Moreover, continuous renal replacement therapy (CRRT) can reduce the inflammatory response, remove excess fluid, clear toxic metabolites and correct electrolyte and acid–base imbalances, thereby maintaining homeostasis [3, 4]. Although CRRT has been extensively studied for its effectiveness in treating sepsis [5, 6], its potential benefits in HS therapy warrant further exploration.

This report describes the first instance in which ECMO combined with CRRT has been used to treat a patient with HS. Given the acute onset, rapid progression, complexity and difficulty of care associated with HS, ECMO support and CRRT were administered, totaling 161 hours from the second to the ninth day of admission. We present detailed information about the diagnostic and therapeutic processes for HS to provide a theoretical basis and reference for clinical nurses collaborating with physicians in the treatment and care of patients with HS.

CASE REPORT

Case information

On July 3, 2021, a patient with severe HS was admitted to the Department of Critical Care

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Medicine of our hospital with the primary complaint of 'fever and fatigue for two days and unconsciousness for two hours after working in high temperature.' The patient had a body temperature of 40°C with multiple organ dysfunction and was diagnosed with HS, multiple organ dysfunction syndrome, electrolyte disorder, and hypoproteinemia. The patient's respiratory rate was 18/minute, blood pressure was 77/39 mmHg, oxygen saturation (SpO_2) was 97%, and blood glucose was 1.2 mmol/L. On the day of admission, the patient's condition worsened further, with sudden loss of consciousness, generalized convulsions, airway spasms and continuous decrease in oxygen saturation. The patient's laboratory results showed a blood creatinine of 420.25 µmol/L, blood urea nitrogen of 29.63 mmol/L, alanine aminotransferase of 147.74 U/L, and total bilirubin of 82.47 µmol/L.

Therapeutic measure

Upon admission, emergency endotracheal intubation and mechanical ventilation were performed to assist with breathing and to ensure that the patient had an adequate oxygen supply (respiratory rate of 8–20 breaths/minute). Simultaneously, symptomatic treatments – such as organ-function protection, maintenance of internal-environment stability, early enteral nutrition using a short-peptide enteral-nutrition suspension via nasogastric tube at 50 mL/hour and parenteral nutrition including intravenous amino acids, multivitamins, and fat emulsions – were administered (enteral-nutrition-solution composition: 38 g of protein, 34 g of fat, 138 g of carbohydrates, 0.26 g of vitamins, and 4.24 g of trace elements per 1000 mL. Calorie density was 2.4 kcal/mL, 2000 mL required daily, total calories ≈ 4800 kcal. Daily amino-acid supplementation 3–5 g/kg, fat-emulsion supplementation 10–20%). Probiotics (*Bacillus subtilis*, 0.5 g TID) and itopride hydrochloride (50 mg TID) were administered to regulate intestinal flora [7]. Sedation was achieved with remifentanil 160 µg/hour and midazolam 5 mg/hour, with dosages adjusted as needed. Blood microbiological analyses were followed by anti-infective therapy including piperacillin–tazobactam (initially 3.75 g Q8h, then 4.5 g Q8h), cefoperazone–sulbactam 4.5 g Q8h, and minocycline 100 mg Q12h, guided by procalcitonin levels. Dopamine 1–5 µg/kg·min and norepinephrine 0.1–2 µg/kg·min were used as needed to stabilize hemodynamics. Measures such as a hypothermia-treatment device, warm-water bath (preventing hypothermia while managing the patient's elevated temperature) and ice-saline enema were employed to control body temperature.

Rapid cooling is a key factor in HS treatment. Upon admission, the patient's rectal temperature was 40.2°C. Immediately, an ice-blanket hypothermia-treatment device was used (water 4–10°C) while continuous surface-temperature monitoring was performed via thermocouple. Additionally, a 40% alcohol sponge bath was applied. However, after one hour, these cooling methods reduced the surface temperature only to 38.8°C, while rectal temperature remained at 40°C. Therefore, 4°C saline was infused for rehydration and 4°C enema fluid was used. One hour later, rectal temperature was 39.8°C, but cooling was still unsatisfactory. To achieve better core-temperature reduction, we initiated CRRT. After right femoral vein catheterization, continuous venovenous hemodialysis started. Replacement fluid (10°C) ran at 150 mL/hour blood-flow and 2000 mL/hour of replacement-fluid with zero fluid removal. After three hours, rectal temperature fell to 38.3°C and surface temperature to 37.5°C. To prevent excessive cooling and arrhythmias, replacement fluid at room temperature was then used.

Subsequently, the patient developed severe electrolyte imbalances (potassium 3.07 mmol/L, sodium 127.7 mmol/L, calcium 1.67 mmol/L). Continuous blood purification was therefore continued to reinforce temperature control and maintain internal environment stability. Routine monitoring (vital signs, respiratory function, hemodynamics, etc.) was maintained, and nurses observed cerebral oxygen supply. On the second day, the patient's condition deteriorated further: blood pressure remained unstable and cardiopulmonary function was severely impaired, causing hypoxemia. Therefore, ECMO was used to support heart and lung function via extracorporeal circulation, improving oxygenation and maintaining organ perfusion. A venovenous ECMO (VV ECMO) mode was selected, and intravenous heparin was continued for anticoagulation. To avoid local bleeding or hematoma from frequent puncture, an arterial catheter was placed in the right radial artery before systemic heparinization, providing real-time hemodynamic monitoring and easy blood sampling; a peripheral venous needle was left in the left upper limb for transfusion. During ECMO, D-dimer was checked every six hours; the results are shown in Figure 1.

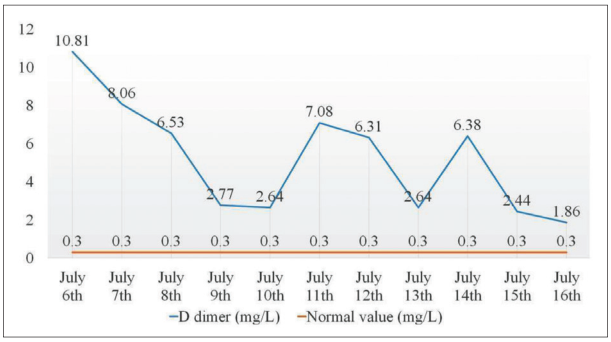

Figure 1. Changes of D dimer in the patient

Between day 2 and day 9, 161 hours of ECMO life support were performed, during which the ECMO flow rate was 3.4 L/min, and the centrifugal pump speed was 3500 rpm. Continuous renal replacement therapy was initiated using a high-flux filter to remove excess fluid, metabolic waste, toxins and inflammatory mediators, correct electrolyte imbalances and support renal recovery. The CRRT was performed continuously during the ECMO support using a Prismaflex system (Baxter International Inc., Deerfield, IL, USA) with an AN69ST filter. Anticoagulation was maintained with unfractionated heparin to ensure extracorporeal circuit patency. Specific CRRT parameters included a blood flow rate of 150–200 mL/min, dialysate flow of

Table 1. Changes in the patient's temperature and management measures

Time	4:20	7:00	11:00	15:00	19:00	23:00	3:00	7:00	11:00	19:00	19:00	23:00
Body surface temperature (°C)	40	38.8	37.4	37.5	37.2	36.3	37.5	35.9	35.2	35.5	36.2	36
Anal temperature (°C)	40.2	40	38.7	38.3	37.9	38.1	38	36.3	35.5	36.1	36.3	36.2
Cooling measures	MHT-IB	MHT-IB	MHT-IB	MHT-IB	MHT-IB	MHT-IB	MHT-IB	MHT-IB	MHT-IB	MHT-IB	MHT-IB	MHT-IB
	-	-	-	CRRT	CRRT	CRRT	CRRT	CRRT	CRRT	CRRT	CRRT	CRRT
	WWSB	ASB	ASB	-	-	-	-	-	ECMO	ECMO	ECMO	ECMO

MHT-IB – use mild hypothermia therapeutic instrument (ice blanket); WWSB – warm-water sponge bath; ASB – alcohol sponge bath

Table 2. Changes of brain natriuretic peptide in the patient

Day	Brain natriuretic peptide (pg/ml)	D dimer (mg/L)	White blood cell ($\times 10^9$/L)	Myoglobin (μg/L)	Creatinine (mg/dL)	C-reactive protein (mg/L)
1	604	10.81	9.39	19.34	10.3	17.6
2	1075.9	8.06	-		-	-
3	498	6.53	-		-	-
4	352.4	2.77	8.61	8.46	8.7	15.3
5	232.2	2.64	-		-	-
6	293.1	7.08	-		-	-
7	246	6.31	7.45	5.07	6.4	12.6
8	193.4	2.64	-		-	-
9	160.6	6.38	-		-	-
10	170.1	2.44	-		-	-
11	112	1.86	7.13	3.9	5	8.7

1000 mL/hour and replacement fluid at 500 mL/hour. Coagulation profiles and electrolyte levels were closely monitored throughout the treatment period to optimize therapeutic efficacy and patient safety. After a series of treatments, when hemodynamic parameters demonstrated stability and there was effective oxygenation and efficient carbon dioxide removal, the ECMO and CRRT were successfully removed on day 9, and the patient was successfully transferred out of the intensive care unit (ICU) on day 15. The detailed laboratory parameters, metabolic indicators, inflammation markers, and myoglobin levels, along with their trends over time during the patient's treatment, are summarized and presented in Tables 1, 2, and 3.

Ethics: Written informed consent was obtained from the patient for publication of this case report and any accompanying images.

DISCUSSION

This report describes a case of severe HS treated in our ICU. Because conventional treatments, such as assisted ventilation, CRRT and hypothermia therapy, were unable to control the condition, the ECMO rescue plan was immediately initiated. Due to the patient's underlying conditions, which included hepatitis B and coagulopathy, the treatment and care of the patient posed significant challenges. Through meticulous treatment and nursing care, the patient's condition was successfully stabilized from a critical state. Rapid cooling and organ support have been effective strategies for treating HS, but mortality is high. In one study, the HS mortality within 28 days after a heat wave was as high as 58% [8]. Ni et al. [9] reviewed 138 HS patients admitted over the previous seven years who presented with systemic multiple-organ dysfunction. Significant improvement was seen with hyperbaric oxygen therapy, with mortality rates of 0% and 8.49% in the hyperbaric and control groups, respectively. Elbashir et al. [10] also found in the treatment of patients ranging from heat stroke to multi-organ failure that the patients were gradually stabilized through 18 days in the ICU. In this case, the patient's condition progressed rapidly, and ventilator-assisted breathing and high-dose vasoactive drugs could not maintain the stability of his vital signs. In this emergency, ECMO was used to rapidly capture key changes in the patient's vital signs at each stage of the condition's development; important condition information was fed back to the doctor to provide the basis for the next treatment [11]. Brain tissue hypoxia is one of the main characteristics of heat-related illness [12]. Therefore, based on routine monitoring (vital signs, respiratory function, hemodynamics, etc.), nurses monitored the cerebral oxygen supply at the same time, allowing them to apply the corresponding treatment. Moreover, in the context of

Table 3. The change of procalcitonin and the dosage of antibiotics in this patient

Day	1	2	3	4	5	6	7	8	9	10	11
Procalcitonin	21.59	16.51	19.92	19.99	15.6	12.3	7.68	5.04	4.87	3.32	2.02
Antibiotic	PST[1] 3.75 g Q8h	PST 3.75 g Q8h	PST 3.75 g Q8h	PST 3.75 g Q8h	PST 3.75 g Q8h	PST 3.75 g Q8h	-	-	-	-	-
	-	-	-	-	-	-	PST 4.5g Q8h	PST 4.5g Q8h	PST 4.5g Q8h	-	-
	-	-	-	-	-	-	-	-	-	CPSB 4.5g Q8h	CPSB 4.5g Q8h

PST – piperacillin sodium and tazobactam sodium; CPSB – cefoperazone and sulbactam

CRRT, precise ultrafiltration proves beneficial in mitigating organ oedema and alleviating cardiac overload. A study treating 16 patients with HS reported improved hemodynamics, reduced serum-enzyme concentrations and zero mortality [13]. The study by Ni et al. [9] demonstrated that HS-related parameters exhibited a significant reduction in the CRRT group compared with the control group. These findings suggest that CRRT effectively eliminates serum enzymes and metabolic by-products, interrupts the cascade of inflammatory mediators and mitigates metabolite-induced damage to renal tubules. Importantly, there was a significantly lower mortality rate in the CRRT group than in the control group. Consequently, early initiation of CRRT therapy should be considered for patients with HS, particularly as HS carries a high mortality risk in its advanced stages, especially when associated with DIC. In conclusion, reviewing the whole rescue process, rapid hypothermia, strict condition observation, timely initiation of ECMO life support, appropriate anticoagulation strategy, refined volume management and strict infection prevention and control ensured the smooth progress of all treatments and brought the patient to safety. This patient presented with a sudden onset, rapid progression and complex condition, making the nursing care extremely challenging. Nurses played a crucial role in the implementation of cooling measures, close monitoring of vital signs, ECMO management and CRRT administration, all of which were key aspects of the life-saving treatment.

Conflict of interest: None declared.

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Нега болесника са топлотним ударом удруженим са мултиорганском инсуфицијенцијом леченим екстракорпоралном мембранском оксигенацијом уз континуирану реналну заменску терапију

Хајинг Ли, Лу Јан, Фанг Ченг, Ђинтинг Ланг, Јинг Ли
Народна болница у Ђинченгу, Одељење за интензивну медицину, Ђинченг, Шанси, Кина

САЖЕТАК

Увод Топлотни удар (ТУ) може изазвати бројне компликације, укључујући акутно оштећење бубрега и синдром акутног респираторног дистреса. До сада није проучавана примена екстракорпоралне мембранске оксигенације (ЕКМО) у комбинацији са континуираном реналном заменском терапијом (*CRRT*) у лечењу болесника са ТУ и вишеструком дисфункцијом органа. У овом раду је описан први случај болесника са ТУ који је лечен применом ЕКМО удруженог са *CRRT*-ом, са циљем да се пружи увид у клиничко збрињавање топлотних обољења путем детаљног приказа терапијских поступака.

Приказ болесника Мушкарац стар 34 године, са ТУ и мултиорганском дисфункцијом, примљен је на одељење интензивне неге ради симптоматске реанимације. Дијагноза је обухватила ТУ, синдром мултиорганске дисфункције, дисбаланс електролита и хипоалбуминемију. Пажљиво су праћене виталне функције болесника – срчана фреквенција, крвни притисак, респираторна фреквенција и засићење крви кисеоником, а животно потпорне терапије ЕКМО и *CRRT* примењене су без одлагања. Болесник је успешно одвојен од ЕКМО, *CRRT*-а и механичке вентилације, уз стабилне виталне знакове, а потом пребачен из Јединице интензивне неге.

Закључак Овај случај показује да правовремена симптоматска терапија и рано увођење ЕКМО у комбинацији са *CRRT*-ом могу ефикасно да лече тешке форме ТУ. Такође је од кључне важности да здравствени радници будно прате промене виталних параметара болесника и сарађују у спровођењу неопходних терапијских мера.

Кључне речи: топлотни удар; синдром акутног респираторног дистреса; екстракорпорална мембранска оксигенација; континуирана ренална заменска терапија; нега болесника