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Case Report / Приказ болесника

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

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

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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 with 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 radiation disease 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 symptomatic rescue treatment. The comprehensive diagnosis encompassed HS, multiple organ dysfunction syndrome, electrolyte imbalance and hypoalbuminemia. The patient's life indicators, including heart rate, blood pressure, respiratory rate and oxygen saturation, were monitored, and ECMO and CRRT life support treatments 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

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. Овде 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 пацијента – 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; потом је 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

INTRODUCTION

Heat stroke (HS) is a clinical syndrome caused by central thermoregulatory dysfunction characterised by elevated core temperature (>40°C) due to an imbalance between heat production and heat dissipation caused by exposure of the body to a hot environment and/or strenuous exercise; the mortality rate is up to 60% in patients with severe HS [1]. Studies show 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 is the first time that 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 life support and CRRT were administered, totalling 161 h from the second to the ninth day of admission. We report detailed information about the diagnosis and treatment process for HS to provide a theoretical basis and reference for clinical nurses to collaborate with doctors in the treatment and care of patients with HS.

CASE REPORT

Case information

On 3 July 2021, a patient with severe HS was admitted to the Department of Critical Care Medicine of our hospital with the primary cause of 'fever and fatigue for 2 days and unconsciousness for 2 h after working in high temperature'. The patient had a body temperature of 40°C with multiple organ dysfunction and was diagnosed with HS, multi-organ dysfunction syndrome, electrolyte disorder and hypoproteinaemia. The patient's respirations were 18/min, blood pressure 77/39 mmHg, oxygen saturation (SpO_2) 97%, and blood glucose 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, a urea

nitrogen of 29.63 mmol/L, an alanine aminotransferase of 147.74 U/L, and a total bilirubin of 82.47 μmol/L.

Therapeutic measure

Upon admission, emergency endotracheal intubation and mechanical ventilation were performed to assist with respiration 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 (Short peptide, SP) enteral nutrition suspension via nasogastric tube at 50 mL/h 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 carbohydrate, 0.26 g of vitamins and 4.24 g of trace elements per 1000 mL. Calorie density is 2,4 kcal/mL, 2000 mL required daily, total calories approximately 4800 kcal. Daily amino acid supplementation was 3-5 g/kg, and fat emulsion supplementation was 10-20 per cent). 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 at 160 μg/h and midazolam at 5 mg/h, with dosages adjusted based on the patient's response. Blood microbiological analyses were followed by treatment with anti-infective measures including piperacillin-tazobactam (initially 3.75 g Q8h, then adjusted to 4.5 g Q8h), cefoperazone-sulbactam (4.5 g Q8h) and minocycline (100 mg Q12h), guided by calcitonin levels. Dopamine (1-5 μg/kg·min), norepinephrine (0.1-2 μg/kg·min) as needed to stabilise haemodynamics. Measures such as a hypothermia treatment device, warm water bath (preventing the risk of hypothermia while effectively managing the patient's elevated temperature) and ice saline enema were employed to control body temperature.

Rapid cooling is a key factor in the treatment of HS. Upon admission, the patient's rectal temperature was 40.2°C. Immediately, an ice blanket hypothermia treatment device was used, with water temperature set at 4°C–10°C, while continuous surface temperature monitoring was performed via a thermocouple. Additionally, a 40% alcohol sponge bath was applied. However, after 1 h, these cooling methods were only able to reduce the surface temperature temporarily to 38.8°C, while the rectal temperature remained at 40°C. Therefore, in addition to the aforementioned cooling methods, we proceeded with the infusion of 4°C saline for rehydration and used 4°C enema fluid. One hour later, the rectal temperature was 39.8°C, but the cooling effect was still unsatisfactory. To achieve a better reduction in core blood temperature in the right

femoral area, we initiated Continuous Renal Replacement Therapy (CRRT) treatment. After performing the right femoral vein catheterisation with the help of specialist doctors, we began continuous venovenous haemodialysis therapy. The replacement fluid was stored in a refrigerator at 10°C, with a blood flow rate of 150 mL/h and a replacement fluid rate of 2,000 mL/h, maintaining zero fluid removal. After 3 h of treatment, the rectal temperature dropped to 38.3°C and the surface temperature to 37.5°C. To prevent excessive cooling and avoid arrhythmias due to rapid temperature decrease, we switched to using room-temperature replacement fluid for continued therapy.

Subsequent the patient presented with severe electrolyte imbalances (potassium: 3.07 mmol/L, sodium: 127.7 mmol/L, calcium: 1.67 mmol/L). Consequently, immediate, continuous blood purification treatment was initiated to reinforce temperature control and maintain internal environment stability. In addition, routine monitoring (vital signs, respiratory function, haemodynamics, etc.) was performed, and nurses observed the cerebral oxygen supply. On the second day after admission, the patient's condition continued to deteriorate. The patient's blood pressure remains unstable, and their cardiopulmonary function is severely impaired, resulting in hypoxemia. Therefore, ECMO is used to replace the functions of the heart and lungs through an extracorporeal circulation system, in order to improve the oxygenation level of patients and maintain blood perfusion to important organs. Select vvECMO mode and continue intravenous heparin for anticoagulant therapy. To avoid local bleeding or haematoma caused by frequent puncture and blood sampling, an arterial catheter was placed in the right radial artery before systemic heparinisation to provide real-time haemodynamic monitoring and facilitate the collection of blood specimens; meanwhile, a peripheral venous needle was left in the patient's left upper limb for blood transfusion. During the ECMO operation, the patient's D-dimer was checked every 6 h; the results are shown in Figure 1.

Between day 2 and day 9, 161 h of ECMO life support was performed, during which the ECMO flow rate was 3.4 L/min, and the centrifugal pump speed was 3,500 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 Healthcare) 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 1,000 mL/h and replacement fluid at 500 mL/h. Coagulation profiles and electrolyte levels were closely monitored

throughout the treatment period to optimise therapeutic efficacy and patient safety. After a series of treatments, when haemodynamic 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 1–3.

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

DISCUSSION

This case reported 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 coagulation dysfunction, 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 the therapy of 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 past 7 years who presented with systemic multi-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 heatstroke to multi-organ failure that the patients were gradually stabilized through 18 days in the intensive care unit. 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 capture the key links of the changes in the patient's vital signs at each stage of the development of the condition rapidly; important condition information was fed back to the doctor at any time to provide the basis for the next treatment [11]. Brain tissue hypoxia is one of the main characteristics of heat radiation disease [12]. Therefore, based on routine monitoring (vital signs, respiratory function, hemodynamics, etc.), nurses observed the cerebral oxygen supply at the same time, allowing them to apply the corresponding treatment.

Moreover, in the context of 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]. Ni's study demonstrated that HS-related parameters exhibited a significant reduction in the CRRT group compared with the control group [9]. 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 turned 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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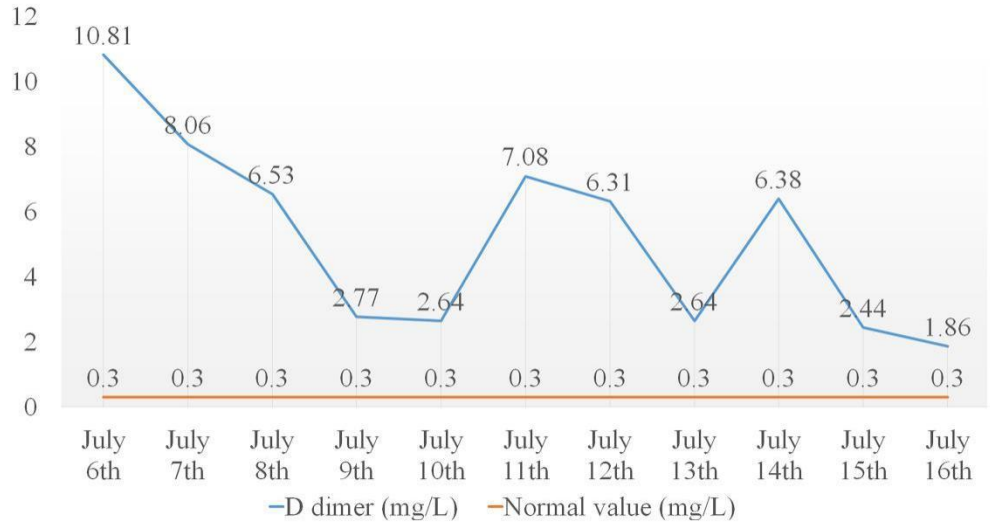

Figure 1. Changes of D dimer in the patient

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 (℃)	40	38.8	37.4	37.5	37.2	36.3	37.5	35.9	35.2	35.5	36.2	36
Anal temperature (℃)	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

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] 3.75g Q8h	PST 3.75g Q8h	PST 3.75g Q8h	PST 3.75g Q8h	PST 3.75g Q8h	PST 3.75g 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

