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SUCCESSFUL MANAGEMENT OF SEVERE EXERTIONAL HEAT STROKE WITH ENDOVASCULAR COOLING AFTER FAILURE OF STANDARD COOLING MEASURES

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☐ **Abstract—Background: Exertional heat stroke (EHS) is a potentially life-threatening emergency requiring rapid reduction in core body temperature. Methods of cooling include cold water immersion, ice packs, cold water lavage, and chilled saline, among others. We report a case of EHS successfully cooled using an endovascular cooling device after traditional cooling methods failed to reduce core body temperature. Case Report: A 24-year old soldier collapsed during a 12-mile foot march while training in southern Georgia. His initial rectal temperature was 43.1°C (109.6°F). External cooling measures (ice sheet application) were initiated on site and Emergency Medical Services were called to transport to the hospital. Paramedics obtained a repeat rectal temperature of 42.4°C (108.4°F). Ice sheet application and chilled saline infusion were continued throughout transport to the Emergency Department (ED). Total prehospital treatment time was 50 min. Upon ED arrival, the patient's rectal temperature was 41.2°C (106.2°F). He was intubated due to a Glasgow Coma Scale score of 4, and endovascular cooling was initiated. Less than 45 minutes later his core body temperature was 37.55°C (99.6°F). He was admitted to the intensive care unit, where his mental status rapidly improved. He was found to have rising liver enzymes, and there was concern for his developing disseminated intravascular coagulation, prompting transfer to a tertiary care center. He was subsequently discharged from the hospital 14 days after his initial injury without any persistent sequelae. Why Should an Emergency Physician Be Aware of This?: The primary treatment for EHS is rapid reduction of core body temperature. When external cooling methods fail, endovascular cooling can be used to rapidly decrease core body temperature. Published by Elsevier Inc.**

☐ **Keywords—exertional heat stroke; endovascular cooling; intravascular cooling; cold water immersion; heat illness**

INTRODUCTION

Exertional heat stroke (EHS) is a life-threatening emergency that requires immediate intervention to rapidly reduce core body temperature to prevent permanent organ damage. Reduction in temperature can be achieved through a variety of methods, including evaporative cooling, ice packs, cold water immersion, cold water lavages, and chilled intravenous (i.v.) fluids. Of these, the most effective method is full-body cold water immersion (CWI) (1,2). However, CWI presents logistical challenges for an emergency department (ED), including lack of adequate space or drainage, the need for electronic patient monitoring, rapid facilitation of patient entry and exit from the immersion tank, and environmental safety concerns surrounding management of spilled ice and water in proximity to electrical equipment.

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Ice sheeting (covering the subject with bed linens that have been soaked in ice water) is routinely used at Fort Benning, Georgia, to approximate CWI with fewer logistical constraints. Ice sheets are often initiated at the point of injury, and the Fort Benning Emergency Medical Services (EMS) protocols provide for continued cooling through the use of skin lavage with ice water slurry and adjunctive use of chilled i.v. saline (3). During the period between April and November 2017, this method was used to successfully reduce the elevated core body temperatures of over 200 patients suffering from moderate to severe heat-related illnesses, including 52 cases of EHS (4). We report a case of EHS that was successfully treated using an endovascular cooling device after prolonged attempts at cooling with ice sheets, ice slurry, and chilled i.v. fluids failed to achieve satisfactory reduction in core body temperature.

CASE REPORT

A previously healthy 24-year old white male Army Ranger participating in the Ranger Assessment and Selection Program (body mass index 27.7) collapsed while performing a 12-mile foot march while carrying a 40-pound backpack. Upon initial evaluation by onsite medical personnel, his rectal temperature was 43.1°C (109.6°F). He was immediately stripped of all gear and clothing and ice sheets were applied. EMS arrived 19 min after the initial application of ice sheets; his repeat rectal temperature was 42.4°C (108.4°F). He was transported by ground ambulance to the ED. The patient was fanned, chilled i.v. fluids were administered, and ice sheets and ice water slurry were continuously applied during transport.

Due to the remote location of the training event, it took a total of 50 min to arrive at the ED after cooling measures were initiated in the field. Upon ED arrival, the patient's rectal temperature had marginally decreased to 41.2°C (106.2°F), and his Glasgow Coma Scale (GCS) score was 4. His vital signs included a blood pressure of 93/54 mm Hg, heart rate of 149 beats/min, respiratory rate of 37 breaths/min, and oxygen saturation of 100% on 15 L/min of oxygen via nonrebreather mask. Large-bore peripheral i.v. access had been established by EMS during transport, and 1 L of chilled saline had been infused.

Initial resuscitation efforts in the ED included rapid sequence intubation due to his depressed mental status, with simultaneous placement of a Quattro endovascular cooling catheter (Thermogard XP system; Asahi Kasei ZOLL Medical, Tokyo, Japan). The cooling catheter was placed into the inferior vena cava via the right femoral vein. Both of the above interventions were completed within 10 min of arrival, and x-ray study confirmed proper catheter placement. Although x-ray study is not typically indicated for confirmation of femoral central line placement, it is recommended with this product because the catheter is 45 cm in length and can inadvertently enter the right atrium or ventricle (5). Endovascular cooling was initiated with an initial target temperature of 36.6°C (98°F). After 42 min of endovascular cooling, at an average rate of 0.08°C/min (0.16°F/min), the patient's core temperature had reached 37.5°C (99.6°F). Initial laboratory studies revealed injury to multiple organ systems, including acute kidney injury (creatinine of 2.4 mg/dL), early acute liver injury with aspartate transaminase (AST) of 91 U/L and alanine transaminase (ALT) of 32 U/L, troponin of 0.108 ng/mL, creatine kinase of 3804, and a slightly elevated lipase of 107 U/L. A computed tomography scan of the head was unremarkable, and an electrocardiogram showed sinus tachycardia with right axis deviation.

He was admitted to the Intensive Care Unit (ICU), where he was successfully extubated later that same day with a GCS score of 15. He was started on N-acetylcysteine due to rising liver enzymes. He was found to have a very high fibrin D-dimer (>5000 ug/mL), low fibrinogen (175 mg/dL), and abnormal coagulation studies (prothrombin time 39.8 s, activated partial thromboplastin time 53 s, international normalized ratio 4.29) After 2 days in the ICU, he was transferred to a regional liver transplant center for hepatology and hematology consultation due to worsening liver failure (AST 3509 U/L, ALT 3846 U/L) and concern for possible disseminated intravascular coagulation. He remained in the ICU for another 6 days, during which time he was treated with vitamin K, zinc, and rifaximin for acute liver failure vs. disseminated intravascular coagulation. His AST and ALT peaked at 6687/4979 U/L prior to trending back to normal. His creatinine also returned to normal, and his creatine kinase peaked at 20,000 prior to trending downward. During his ICU stay he developed thrombocytopenia, with a platelet nadir of 22,000/mL, but he had no major bleeding events and did not require transfusion. He was subsequently transferred to a step-down unit and was later discharged with no permanent organ damage, neurological deficits, or cognitive impairment aside from mild diplopia. Review of his medical records at 6 months post injury showed normalization of all laboratory work. During a telephone follow-up, the patient reported that he had returned to his previous state of strength and cardiovascular endurance.

DISCUSSION

EHS is defined as an elevated core temperature, generally > 40°C (104°F), with associated encephalopathy in a patient who has been participating in strenuous exercise (6). These individuals require immediate and rapid cooling and continuous monitoring. Rapid cooling is best accomplished by full body (except the head) immersion in an ice water bath, which produces cooling rates up to 0.35°C/min (1,7,8). There have been reports of successfully treating EHS with CWI in the field and at endurance race events (9,10). However, CWI may be impractical or unavailable due to constraints and limitations in both hospital and field environments. At Martin Army Community Hospital (MACH), Fort Benning, Georgia, a heat and hyponatremia policy has been developed that recognizes the limitations of CWI and provides protocols to rapidly cool patients suffering from environmental injuries (11). This comprehensive set of protocols addresses the management of exertional heat injuries and associated conditions, and includes guidance for nonmedical personnel at the point of injury, prehospital EMS care, management in the ED, inpatient management, hospital discharge, and return to duty. These policies also address recognition and management of exercise-associated hyponatremia, which can appear almost clinically identical to EHS. Several of these protocols entail the application of ice sheets at the point of injury, which has become the preferred method of treatment for EHS due to safety, efficacy, decreased logistical concerns, minimal cost, portability, and availability. Intravenous administration of chilled saline is also used, along with ice sheets as an adjunctive cooling treatment during EMS transport.

Between April and November of 2017, the MACH ED cared for 52 patients diagnosed with EHS with a documented core temperature of 40°C (104°F) or greater in the field. Of these, only 5 patients (9.8%) arrived to the ED with core temperatures above 40°C (104°C) after being cooled using a combination of ice sheets, fans, and chilled saline (4). As one of these patients, the present case presented with a core temperature of 41.2°C (106.2°F). The decision to initiate endovascular cooling was based on the patients' failure to cool adequately despite 50 min of standard intervention, and his profoundly altered mental state (GCS 4). Endovascular cooling was initiated within minutes of arrival in the ED and effectively cooled the patient to < 38.9°C (102°F) within 30 min, and to 37.5°C (99.6°F) within 45 min, achieving a cooling rate of 0.08°C/min (0.16°F/min). Cooling with the endovascular device was slower than rates achieved with CWI, but it was able to achieve core temperature cooling where ice sheets and chilled saline had not been effective. External cooling measures and chilled saline produced a cooling rate of only 0.038°C/min (0.068°F/min) in this case. Furthermore, even if CWI had been available in the ED it would have been very difficult to use on this patient, who was unresponsive and required immediate advanced airway management as well as continuous cardiovascular monitoring.

In our review of the literature, there are only four other case reports of endovascular cooling being used in the management of EHS (12–15). This case is the second published report in which this technique has been used in the United States. The patient recovered fully, but did have significant complications including rhabdomyolysis, acute kidney injury, acute liver injury, and transient coagulopathy during his hospital course. Similar complications have been reported in previously published cases and were likely due to significant exertion leading to prolonged elevation in core body temperatures. Because these are well-known reported complications of EHS, it is unclear if endovascular cooling attenuates or exacerbates multisystem organ damage. In this case, the patient was cooled to 37.5°C (99.6°F) rather than stopping active cooling at 102°F, as recommended in the literature, which may have added to his complications (7). Further study is needed to determine whether or not there is a causal relationship between rapid endovascular cooling and complications related to EHS.

WHY SHOULD AN EMERGENCY PHYSICIAN BE AWARE OF THIS?

There are very few case reports detailing the use of endovascular cooling in EHS. In this case, standard cooling methods yielded only a marginal decrease of 1.9°C over a 50-min period. Cold water immersion in the ED was neither available nor would it have been practical in this unstable patient. The implementation of endovascular cooling rapidly lowered the patient's core temperature to normal range within 30 min of initiation and is only the second published use of this application in the United States for this condition. The authors believe that the rapid initiation of endovascular cooling is largely responsible for the intact neurological survival of this patient. As previously stated, further study is required to define the exact indications, cooling parameters, and complications.

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