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VARIATION IN CLINICAL PRESENTATIONS AND OUTCOMES OF HEAT STROKE VICTIMS IN THE MASS-CASUALTY SETTING

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Abstract—Background: Immigrants crossing the Southern U.S. border are particularly susceptible to heat illness. We review 3 patients from a heat-related mass-casualty incident with variations in heat stroke presentation, course, and outcome. **Case Report:** On July 23, 2017, emergency medical services responded to a trafficking-related mass-casualty incident in San Antonio, Texas, involving 39 migrants found inside an abandoned tractor trailer without air conditioning who had been trafficked from Laredo, Texas. Three victims exhibiting heat stroke symptoms were taken to the ED of a large academic teaching hospital. Patient 1 was a 42-year-old man who presented with seizing, vomiting, and a core temperature of 38.8°C (101.8°F). His 54-day hospital course was notable for 2 cardiac arrests, disseminated intravascular coagulation, prolonged lactic acidosis, and residual kidney disease. Patient 2 was a 32-year-old man who presented to the emergency department intubated in the field with a core temperature of 40.7°C (105.3°F). His 60-day hospital course was notable for disseminated intravascular coagulation, severely elevated troponin, prolonged lactic acidosis, and stroke. Patient 3 was a 20-year-old man who presented with seizing and decorticate posturing, with a core temperature of 40.5°C (104.9°F). His 6-day hospital course was notable for rapid clinical improvement and full recovery. **Why Should an Emergency Physician Be Aware of This?:** Emergency physicians will encounter heat stroke

victims. Our patients were exposed to an identical environment, and while each patient was otherwise healthy and differed significantly only in age, they exhibited a diversity of heat stroke presentations and sequelae. Treatment prioritizes cooling, but rapid deterioration requires intensive treatment of multiorgan failure. © 2019 Published by Elsevier Inc.

Keywords—heat stroke; human; immigrant; lactic acidosis; mass casualty; resuscitation; United States

INTRODUCTION

Amidst the U.S.–Mexico border controversy, the media have highlighted migrants and their travel through a hot and austere environment, either on foot or in large transportation vehicles. A recent study reviewing unauthorized U.S.–Mexico border crossings and migrant death found that >60% of the deaths were related to environmental heat exposure (1). Two variants of heat stroke are commonly highlighted in media exposure: exertional heat stroke, typically resulting from physical activity in high ambient temperatures, and nonexertional heat stroke, or “classic heat stroke,” most often seen in those who are susceptible to being confined in spaces without air cooling (i.e., the elderly and infants) (2–5).

A review of the published literature reveals many cases of heat stroke, but none illustrate a mass-casualty

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incident in the setting of a single, congruent environment. We review heat stroke presentation, management, and the hospital courses of 3 patients in a mass-casualty incident. More specifically, we aim to depict the variable clinical presentations of heat stroke and the significant spectrum of patient morbidity and duration of hospital stay.

CASE REPORT

Background

On July 23, 2017 at 00:26 CST, the San Antonio Police Department and emergency medical services (EMS) responded to a scene of 39 migrants found inside an abandoned tractor-trailer in a retail shopping center parking lot (6). Reports speculate that the tractor-trailer departed Laredo, Texas on July 22, 2017 at 22:00 CST and arrived at this location at 00:00 CST. Temperatures in San Antonio peaked at 38.3°C (101°F) just before 17:00 CST and did not fall below 32.2°C (90°F) until well past 22:00 CST (7,8). Approximately 100 immigrants from Mexico and Guatemala were transported in the trailer, though some fled from the vehicle after police and EMS arrived (6,7). Without working air conditioning or access to drinking water during transport, the ambient temperature of the compartment approached 40°C (104°F), and persons found in the tractor-trailer exhibited conditions related to prolonged heat exposure, dehydration, and asphyxiation (6,8). By 01:00 CST, EMS was in the process of triaging and initiating treatment. Eight people were deceased and 20 were in “very serious” or “critical” condition. Twenty-nine patients were transported to local hospitals within San Antonio, Texas, and 13 were transferred to level 1 trauma centers. Seven patients were taken to a large academic teaching hospital in San Antonio, where 3 had symptoms of heat stroke (6,7).

Patient 1

A 42-year-old man with no known medical history was removed from the tractor-trailer. He was unconscious, with blood pressure of 138/87 mm Hg and a heart rate of 97 beats/min. He had 1 seizure en route to the hospital. Upon arrival to the emergency department (ED), his core temperature, measured by urinary catheter, was 38.8°C (101.8°F), his heart rate was 139 beats/min, his blood pressure was 138/58 mm Hg, his respiratory rate was 16 breaths/min, his oxygen saturation was 100% on room air, and his Glasgow Coma Scale score was 3. He was ventilated by bag-valve mask and suctioned for vomitus and underwent rapid sequence intubation. He was cooled with a 3-L chilled normal saline (7.2°C [45.0°F] bolus infusion via pressure infusion bags through two 18-gauge antecubital IVs), ice packs to the groin and axillae, and

forced-air cooling blanket (Bair Hugger; 3M, St. Paul, MN). His core temperature was cooled to 37.4°C (99.3°F) in 84 minutes (0.02°C/min; Figure 1). His initial laboratory values were serum lactic acid 7.9 mmol/L (likely affected by the seizure en route), serum sodium 145 mmol/L, serum creatinine 2.8 mg/dL, venous blood pH 7.12, and troponin 20.99 µg/L. A urine drug screen and blood alcohol, salicylate, acetaminophen, and ethylene glycol levels all were within normal limits. He was admitted to the Medical Intensive Care Unit (MICU) at 3 h.

Patient 1 had a difficult hospital course. He developed disseminated intravascular coagulation (DIC) at 8 h that required 9 units of packed red blood cells, 4 units of platelets, 4 units of cryoprecipitate, and 7 units of thawed plasma. He remained in a prolonged comatose state and had continued hypotension requiring multiple pressor infusions. His lactic acid levels continued to rise after control of the seizures, peaking at 16.2 mmol/L at 24 h (Figure 2). The troponin level peaked at 94.59 µg/L and alanine aminotransferase at 990 U/L. His acute renal failure (ARF) and lactic acidosis required continuous renal replacement therapy and renal dialysis for a total of 47 days. He sustained 2 episodes of cardiac arrest with pulseless electrical activity at 71 and 73 h after admission suspected to be caused by metabolic derangements. After cardiopulmonary resuscitation and epinephrine, bicarbonate, calcium, and magnesium administration, he had return of spontaneous circulation. After 18 days in the MICU, he was extubated and downgraded to a monitored bed for a total hospitalization of 54 days. He made a full recovery except for non-dialysis-dependent renal insufficiency.

Patient 2

A 32-year-old man with no known medical history was extracted from the tractor-trailer and was unconscious, with a systolic blood pressure of 66 mm Hg and a heart rate of 160 beats/min. EMS began intravenous infusion of normal saline, and endotracheal intubation was performed en route to the hospital. On arrival, the patient

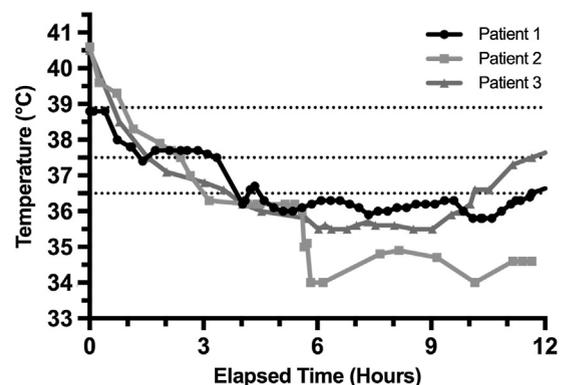


Figure 1. Core temperature of patients 1, 2, and 3 over 12 h.

had a core temperature, measured by urinary catheter, of 40.7°C (105.3°F), a heart rate of 174 beats/min, a blood pressure of 113/78 mm Hg, a respiratory rate of 16 breaths/min via bag-valve mask, an oxygen saturation of 91% on room air, and a Glasgow Coma Scale score of 3T. Cooling was instituted with 4 L of chilled normal saline infusion (7.2°C bolus via pressure infusion bags through two 18-gauge antecubital IVs), ice packs to the groin and axillae, and a forced-air cooling blanket. His core temperature was cooled to 38.3°C (100.9°F) in 69 min (0.03°C/min; [Figure 1](#)). His initial laboratory values included serum lactic acid of 6.1 mmol/L, serum creatinine of 2.8 mg/dL, serum sodium 145 mmol/L, venous blood pH 7.1, and 97 troponin of 5.16 µg/L. Urine drug screen, blood alcohol, salicylates, acetaminophen, and ethylene glycol levels all were within normal limits. Contusions to the head and face area were present, but head and maxillofacial computed tomography scans did not reveal signs of significant intracranial or other traumatic injury. While in the ED, he developed DIC and required 8 units packed red blood cells, 8 units of platelets, 8 units of cryoprecipitate, and 8 units of thawed plasma. At 12 h he was transferred to the MICU.

His MICU course was also difficult, with prolonged hypotension requiring vasopressor support, and hypoxic respiratory failure requiring prolonged mechanical ventilation. His pulmonary status was complicated by *Aspergillus* pneumonia and sepsis. He sustained an anterior circulation stroke with resultant hemiplegia. His severe metabolic acidosis, rhabdomyolysis, and ARF required 3 days of continuous renal replacement therapy and bicarbonate drip. His lactic acidosis peaked at 21.6 mmol/L at 48 h ([Figure 2](#)). He also had elevated troponin to 107.94 µg/L, and shock liver with an alanine aminotransferase peak of 1391 U/L. After 44 days in the MICU, he was extubated and downgraded to a monitored bed for a total hospitalization of 60 days. The patient was discharged to a rehabilitation facility for treatment of residual weakness from his stroke.

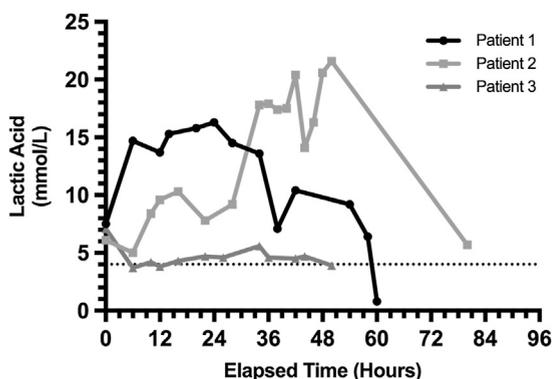


Figure 2. Lactic acid levels of patients 1, 2, and 3.

Patient 3

A 20-year-old man with no known medical history was also extricated from the same tractor-trailer while he was unconscious. His blood pressure was 73/65 mm Hg and his heart rate was 180 beats/min. He was transported seizing with decorticate posturing. On arrival, he had a core temperature, measured by urinary catheter, of 40.5°C (104.9°F), a heart rate of 178 beats/min, a blood pressure of 72/42 mm Hg, a respiratory rate of 10 breaths/min, oxygen saturation of 70% on room air, and a Glasgow Coma Scale score of 5. He underwent rapid sequence intubation. Cooling was initiated with 4 L of chilled normal saline infusion (7.2°C bolus via pressure infusion bags through two 18-gauge antecubital IVs), ice packs to the groin and axillae, and a forced-air cooling blanket. His core temperature was cooled to 38.5°C (101.3°F) in 47 min (0.04°C/min; [Figure 1](#)). Initial laboratory values included a serum lactic acid of 7.1 mmol/L (likely affected by seizure en route), serum sodium 154 mmol/L, serum creatinine 1.9 mg/dL, venous blood pH 7.06, and troponin of 1.22 µg/L. Urine drug screen, blood alcohol, salicylates, acetaminophen, and ethylene glycol levels all were within normal limits. Further blood pressure resuscitation required vasopressor infusions. Diazepam was administered followed by levetiracetam loading for seizure control. His lactic acidosis resolved by 6 h ([Figure 2](#)). Patient 3 remained in the ED for 35 h before being transferred to the MICU. His hospital course was complicated by hypoxic respiratory failure requiring ventilator support. He developed *Klebsiella* pneumonia and ARF with pH 7.06 but did not require renal dialysis. His troponin peaked at 7.46 µg/L and alanine aminotransferase at 476 U/L. He was downgraded from the MICU at 3 days, with a total hospitalization of 6 days. The patient made a full recovery without any appreciable deficits.

DISCUSSION

Historically, heat illness has been viewed on a continuum, with presentations varying in severity. It ranges from benign heat edema and heat cramps to heat syncope, heat exhaustion, and heat stroke (3,5,9,15). Heat stroke is a core temperature >40.0°C (104°F), central nervous system changes, and multiorgan dysfunction (10,11). At worst, it can manifest as DIC, shock liver, and ARF (2,5). Previous studies demonstrated that prolonged hyperthermia and hypotension with end-organ dysfunction indicate high likelihood of severe sequelae (5). Advanced age, endotracheal intubation, and altered coagulation are additional poor prognostic factors (12,13). Treatment focuses on lowering body temperature via evaporative cooling or cold-water immersion, providing

cardiopulmonary support, and correcting metabolic and hemostatic derangements (2,4,9,14,15). Even with the best treatment, mortality is 10–14% and can approach 80% if delayed (2,4,12,14).

In this mass-casualty incident, each patient presented in rapid succession, and initial communication between EMS and emergency physicians suggested a potential for 7 victims in need of emergent resuscitation. The intensity of this resuscitation effort coincided with overnight hospital staffing, which quickly exhausted hospital resources and made the standard of care, cold water immersion or evaporative cooling, unfeasible. However, in our cohort, a rapid rate of temperature correction similar to what is seen with evaporative cooling ($0.035^{\circ}\text{C}/\text{min}$), was achieved using forced air-cooling blankets, chilled normal saline, and ice packs to the groin and axillae (16).

Patients 1 and 2 suffered the most severe complications from their heat illness, both developing lactic acidosis, extremely elevated troponin, DIC, ARF, and shock liver. These complications correlated with both patients requiring hospitalization for >60 days. Patient 1 was discharged with chronic renal insufficiency, and patient 2 with residual anoxic brain injury. In contrast, patient 3 developed less severe lactic acidosis, troponinosis, ARF, and shock liver, and he did not develop DIC. His hospital course was one-tenth as long as patients 1 and 2, and he was discharged with no appreciable residual deficits. Of note, the stark contrast in hospital course does not appear correlated with the initial temperature of each patient at presentation, as patient 3 had a recorded core temperature of 40.5°C (104.9°F) while patient 1 presented with a core temperature lower than the diagnostic threshold for heat stroke.

It must be acknowledged that patient 1 presented to the ED with a core temperature of 38.8°C (101.8°F) and therefore did not meet the temperature criteria for heat stroke of 40.5°C (104.0°F). However, this patient met the other 2 diagnostic criteria of central nervous system and multiorgan dysfunction at presentation. Other differential diagnoses for this patient initially considered included acute intracranial process, cerebrovascular accident, acute coronary syndrome, electrolyte disturbance, and toxic ingestion. Ultimately, the congruence of this patient's history and clinical picture with patients 2 and 3 led to him being treated for presumed heat stroke. We suspect that patient 1's core temperature was higher in the field and that passive cooling efforts during EMS transport, such as air conditioning of the ambulance and disrobing of the patient, may have lowered his temperature to below the diagnostic threshold. Because of the patient 1's relatively cooler core temperature at presentation to the ED, less aggressive cooling measures were taken to avoid overcorrection and hypothermia. These measures explain the patient's relatively slow rate of cooling while in the ED at $0.02^{\circ}\text{C}/\text{min}$.

Historically, similar heat stroke incidents have occurred in Lyon, France, the U.S. states of Illinois and Texas, and the Middle East (17–24). In particular, heat illness has been a common insult for centuries to those making the Islamic, Makkah Pilgrimage (“Haji”). With >2.5 million participants and with temperatures that can exceed 45°C depending on the Islamic (Lunar) calendar year, the logistics of the Haji Pilgrimage poses a challenge for the Kingdom of Saudi Arabia and the Ministry for Health (22,23). A cross-sectional study of the 2016 Haji recruited 246 patients between 4 hospitals and reported 80 (29%) patients and 187 (67.75%) patients with the diagnosis of heat stroke and heat illness, respectively (22). However, unlike the victims of the tractor trailer incident, Haji pilgrims have variable access to food, water, and shade on their journeys, and some receive pretravel education about the importance of using umbrellas or performing rituals at night (24). In addition, the Saudi Ministry of Health, in collaboration with the Haji Committees, has made provisions for heat related illness by providing the necessary supplies and trained personnel to accommodate such heat-laden trek (22). The Makkah Pilgrimage, therefore, cannot be considered a single, congruent environment. Similarly, the previous incidents in Lyon, Illinois, and Texas affected individuals across entire cities and therefore constitute variable settings of insults (17–21).

To our knowledge, this case report is the first to detail heat stroke outcomes in patients from presumably the same set of environmental conditions, as all patients were confined to the same tractor trailer. Of course, our report is limited by sample size and multiple other variables, but it can provide some insight into how heat exposure can manifest differently in patients with varying age.

WHY SHOULD AN EMERGENCY PHYSICIAN BE AWARE OF THIS?

Heat stroke is a common phenomenon in the Southern United States, and with heat exposure incidents expected to increase because of rising global temperatures, all emergency physicians should be familiar with the range of initial presentations (25). In addition, providers near the U.S.–Mexico border should be prepared for mass-casualty heat-related incidents. These cases demonstrate some classic features of heat stroke, as well as the variability of clinical sequelae that can arise in unique patients exposed to identical environmental conditions. While initial treatment of heat stroke is directed toward the reduction of core body temperature, it will be influenced by prehospital cooling measures. Dysfunction of multiple organ systems should be expected, and even with meticulous resuscitation, patients may require ventilator support, trauma assessment, blood product

replacement, and correction of acidosis from lactate and intrinsic renal failure. Surveillance for superimposed infection may also be part of the complex recovery. The resuscitation of multiple victims of heat stroke will challenge all the skill sets of the emergency physician.

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