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Pediatric Heat-Related Illness: Recommendations for Prevention and Management

Abstract

Infants, children, and adolescents are at increased risk for heat-related illness due to their inability to remove themselves from dangerous environments. Evidence shows that morbidity and mortality from heat illness is related to the length of time core temperature is elevated, so rapid reduction and accurate serial measurements are crucial to prevention of organ system damage and death. The primary methods of patient cooling are conduction (ice-water immersion, cold packs) and convection (moisture and moving air). The choice of method used may depend on availability of equipment, but there is evidence that can guide optimal use of resources. This issue presents evidence-based recommendations and best practices in heat-illness resuscitation, including managing children who are obese, have special needs or take medications, and advocacy for prevention strategies.

August 2017
Volume 14, Number 8

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Case Presentations

On a hot summer day, an obese 15-year-old adolescent boy presents to the ED after a week of two-a-day football practices. He has completed 10 practices to date. He presents with headache, muscle aches, nausea, and 2 episodes of vomiting. The patient denies any trauma or injury. His past medical history includes ADHD, and his home medications include methylphenidate. His physical examination is remarkable for a fatigued-appearing obese boy with flushed, sweaty skin. The patient's vital signs are: heart rate, 120 beats/min; respiratory rate, 24 breaths/min; blood pressure, 128/76 mm Hg; rectal temperature, 39°C (102.2°F); and oxygen saturation, 98% on room air. You begin to wonder how severe his heat-related illness is and whether diagnostic studies need to be ordered. What treatment needs to be initiated immediately, or can treatment wait while you see another patient?

While you are considering these questions, EMS brings in a lethargic 8-month-old infant. The paramedic reports that a bystander found the infant in a locked vehicle. The parents could not be located, and the amount of time the child was in the car is unknown. The physical examination demonstrates an obtunded infant with no evidence of sweating. The infant's vital signs are: heart rate, 192 beats/min; respiratory rate, 20 breaths/min; blood pressure, 70/45 mm Hg; rectal temperature, 41°C (105.8°F); and oxygen saturation, 92% on room air. You consider whether this is heat exhaustion or a more severe case of heat stroke. You begin to think about the diagnostic studies that you will need to order to confirm the diagnosis and when you should begin treatment.

The following day, you are volunteering as a clinician on the medical team for a marathon. Bystanders bring over a 16-year-old adolescent girl with altered mental status. Her temperature is 40°C (104°F). She is responding to questions, but is confused to place and time. You decide to contact EMS for transport to the ED and plan to initiate cooling measures. While waiting for EMS to arrive, you look around to see what resources are available and consider what cooling measure would be most effective.

Introduction

Heat-related illness is the result of inadequate thermoregulation during excessive heat exposure and/or exertion.[1] Heat-related illness varies in clinical presentation depending on the severity of illness, which ranges from mild heat stress to life-threatening heat stroke. The variability in presentation requires emergency clinicians to include this diagnosis in their differential for any patient who presents with hyperthermia.

Heat-related illness does not occur only in summer months or in hot climate regions. Zeller et al found that while most exertional heat-related illness in the United States does occur during the hotter months of May to September, a few occurred during the winter months.[2] Local and federal health services record fatal and nonfatal heat illness incidents, noting correlations to weather conditions.[3,4] From 1997 to 2006, 54,983 patients were treated for exertional heat-related illness in emergency departments (EDs) in the United States, with a 133% increase in that time frame. Pediatric patients aged < 19 years accounted for the largest proportion of heat-related illness, at 47%.[5] Heat stroke has the highest mortality of all heat-related illnesses, with a mortality rate ranging from 6.4% to 33%.[1,2] To reduce morbidity and mortality in patients with heat illness, it is essential that emergency clinicians recognize heat-related illness and implement resuscitation quickly. This issue of *Pediatric Emergency Medicine Practice* provides an overview of heat-related illness and offers recommendations for prevention and management in the pediatric population.

Critical Appraisal of the Literature

A systematic literature search was performed in PubMed for articles on heat-related illness in patients aged 0 to 18 years, with limitations to articles published in English from 1996 to 2017. The following search terms were used: *exertional heat illness*, *heat stress*, *heat cramp(s)*, *heat exhaustion*, and *heat stroke*. A total of 121 articles were selected as being relevant to this issue, including case reports, epidemiological studies, clinical reviews, retrospective and prospective observational studies, canine experimental studies, simulation studies, and a few small randomized controlled studies.

Etiology and Pathophysiology

Core body temperature is maintained by the body's ability to balance heat exposure and heat production with heat dissipation to the environment. Heat-related illness occurs when the body is unable to regulate its core temperature in response to excess heat exposure and heat production, coupled with decreased heat dissipation.

Heat Exposure

Nontrauma visits to the ED from mass gathering events (such as amusement parks and county fairs) indicate that 11% to 25% of all visits are due to heat-related illness.[6,7] The majority of heat-related illness cases are seen during the summer months.[8,9] During heat waves, ED visits, hospitalizations, and daily mortality rates are increased.[10-13] Toloo et al found a significant increase in heat-related illness in children on heat-wave days in Australia, with a relative risk (RR) of 3.0 for days when the temperature was > 34°C (93.2°F) and a RR of 29.8 for days when the temperature was > 37°C (98.6°F).[14]

A preventable source of heat exposure occurs when infants and children are left unattended in vehicles. Over a 13-year period, the United States National Highway Traffic Safety Administration reported 556 vehicular child hyperthermia deaths due to children being locked in cars.[15] Other studies have confirmed the frequency of this highly preventable cause of death, with reports ranging from 384 to over 600 fatalities related to vehicular heat exposure.[16,17] Grundstein et al performed a model simulation of a 1-year-old child left in a car and compared the expected heat stress on the model in 4 astronomical seasons. In the simulation, a model could reach 42°C (107.6°F) in as little as 125 minutes in the summer and 355 minutes in the winter.[17]

McLaren et al found that the rate of temperature increase inside an enclosed vehicle was not significantly different when environmental temperatures ranged from 22.2°C to 35.6°C (72°F-96°F). An average mean increase of 1.8°C (3.2°F) per 5-minute interval was reported, with 80% of the increase occurring in the first 30 minutes. The final internal vehicular temperature reached 47.2°C (117°F), even at the cooler environmental temperature of 22°C. They also found that leaving the windows open slightly did not decrease the rate of temperature increase.[18] Duzinski et al studied daily vehicular temperature measurements in Austin, Texas. Vehicular temperature rose to > 41°C (106°F) in all months except January and December, and during the days with the hottest temperatures, vehicular temperature reached a maximum of 58°C (137°F). Even with environmental temperatures of 20°C (68°F), vehicular temperature still reached > 41°C (106°F).[16]

Case reports have also shown excessive heat exposure and heat-related illness in infants exposed to electric blankets; infants swaddled tightly in several blankets with and without recent illnesses; infants wrapped in 4 blankets and placed within a few feet of a fire; infants sleeping next to a radiator; infants left in an unplugged, closed icebox; and infants exposed to an electric foot warmer.[19-21]

Heat Production

During exertion, heat is generated by muscle contractions that elevate core body temperature.[22] Nonacclimated athletes, obese athletes, athletes with certain chronic medical conditions (eg, diabetes or cystic fibrosis), and those taking certain medications (eg, methylphenidate [Ritalin®, Concerta®, Aptensio®, etc]) have an increased risk for exertional core body temperature rise.[23-27] Yeo reported that exertion in temperatures > 26.1°C (79°F) with humidity > 59% increases the risk of developing a heat-related illness.[28]

Exertional heat stroke in high school athletes has been described in case reports.[29,30] Studies of the National High School Sports-Related Injury Surveillance System data found that 90% of exertional heat-related illness occurred during preseason training, with football being 11 times more likely to be associated with a heat-related illness than all other sports combined.[31,32]

Heat Dissipation

The body uses the mechanism of heat dissipation to balance the effects of excess heat exposure (environmental heat) or excess heat production (exertion). Effective heat dissipation depends on the rapid transfer of heat from the core of the body to the skin and from the skin to the external environment.

There are 4 mechanisms of heat dissipation: radiation, evaporation, convection, and conduction. Under normal physiologic conditions, radiation and evaporation account for most heat transfer in humans.

- **Radiation** involves heat transfer through infrared rays. It occurs when the environmental temperature is below body temperature, and it accounts for 65% of heat transfer under normal physiologic conditions. Once the environmental temperature reaches 35°C (95°F), radiation becomes less effective. When the environmental temperature exceeds body temperature, heat is gained instead of lost.[33-35]
- **Evaporation** involves heat transfer through the conversion of sweat from liquid to gas at the skin surface, and it is the main mechanism of heat dissipation at higher environmental temperatures, when radiation is less effective. When the humidity level exceeds 75%, heat transfer by evaporation begins to decrease.[33-35]
- **Convection** involves heat transfer through the movement of air or water over the skin surface. Under normal physiologic conditions, about 10% of heat transfer occurs by convection.
- **Conduction** involves heat transfer through physical contact of the body with another cooler surface or object. Conduction allows for approximately 2% of heat loss under normal physiologic conditions.[1,33-35]

As the environmental temperature increases, the body's ability to dissipate heat through radiation decreases, and convection and evaporation gain greater importance in preventing heat-related illness. Convection and evaporation are directly controlled by circulatory dynamics and sweating.[35] The hypothalamus compensates for each 1°C (1.8°F) increase in core temperature by promoting cutaneous vasodilatation and increasing the rate of sweating. Vasodilatation dissipates heat by convection, and sweat dissipates heat by evaporation.[22,34,36,37]

Thermoregulation in Children

It has been postulated that children are at increased risk for heat-related illness due to several physiologic reasons. These include greater body surface area-to-body mass ratio, production of more metabolic heat per kilogram of body weight, a slower rate and volume of sweat production, a higher temperature required to stimulate the sweating mechanism, and a lower cardiac output at a given metabolic rate.[35,36,38-40] However, recent studies have revealed that children and adults have similar rectal and skin temperatures, cardiovascular responses, and exercise tolerance times during exercise in neutral-to-moderate heat,[41-45] although in extreme environmental conditions, children may thermoregulate less effectively.[46] Falk et al compared thermoregulatory responses to exercise in prepubertal, midpubertal, and late-pubertal boys. They found sweating and evaporative cooling rates were lower in prepubertal boys, but there was no difference in sweat production per kilogram of weight between them and the other 2 groups. The authors concluded that the overall thermoregulatory response was effectively similar between the groups.[47] Inbar et al compared the thermoregulatory response to exercise in prepubertal boys, young adult men, and elderly adult men. The rise in temperature was found to be similar in all age groups, but the sweating rate and volume was found to be lower in the prepubertal group. However, since prepubertal boys were more efficient thermoregulators, the thermoregulatory response to exercise was found to be similar to the other groups.[42]

Differential Diagnosis

Heat-related illness occurs along a continuum from heat stress, to heat exhaustion, to heat stroke. The signs and symptoms of the different stages of the illness can overlap.

- **Heat stress** is characterized by perceived discomfort and physiologic strain, including heat cramps, while a normal core temperature is maintained.[48-50]
- **Heat exhaustion** is characterized by a rise in body temperature usually associated with dehydration, with a core body temperature < 40°C (104°F). Signs and symptoms of heat exhaustion include fatigue, weakness, dizziness, nausea, vomiting, myalgias, profuse sweating, intense thirst, tachycardia, syncope, and headache, with the absence of severe neurological symptoms.[48-53]
- **Heat stroke** is a life-threatening failure of thermoregulation characterized by a body temperature ≥ 40°C (104°F), with central nervous system abnormalities such as confusion, convulsions, or coma. It is associated with severe dehydration, endotoxemia, circulatory failure, and, potentially, multisystem organ failure.[48-53]

It is imperative that the emergency clinician be able to differentiate hyperthermia from fever. In hyperthermia, the hypothalamus has a normal set point and the body is unable to dissipate enough heat to match the set point, resulting in an elevated core temperature. In contrast, fever occurs when the hypothalamic set point is increased by circulating cytokines, and the body attempts to conserve and generate heat until the core temperature rises to the new set point.[37,49]

The differential diagnosis of heat-related illness includes any disease process that causes hyperthermia from excess heat exposure or production. Causes of hyperthermia include toxins and associated toxidromes such as anticholinergic and serotonin syndromes. Another drug-related cause of hyperthermia includes neuroleptic malignant syndrome, most notably associated with antipsychotic drugs. Malignant hyperthermia is an autosomal-dominant condition that results in an elevation in core temperature following exposure to medications such as inhalational anesthetic agents and paralytic agents, and it causes skeletal muscle rigidity and a rapid increase in core temperature.[50] There are similarities between exertional heat stroke and malignant hyperthermia; although the inciting etiology is different, both lead to excessive heat production.[54,55] A thorough history of exposures will lead to easy differentiation between these diseases.

Prehospital Care

Prior to emergency medical service (EMS) provider arrival, prehospital care for a patient with exertional heat-related illness may include immediate care provided by coaches and athletic trainers on the scene. Once a heat-related illness is suspected, the patient should be removed from the environmental heat source and placed in a cool, shaded area. If applicable, the equipment, uniform, or clothing should be removed and oral rehydration initiated while waiting for EMS arrival. If available, rapid cooling with immersion in a tub of ice water should be considered. In an online survey of 1142 athletic trainers, most were compliant with therapeutic interventions for heat-related illness in removing equipment (98%) and placing the patient in a shaded area (91%), but few had active strategies for calling EMS (29%).[56] In an online survey of 38 coaches regarding knowledge of exertional heat stroke, most coaches were unaware of potential causes or symptoms of heat stroke, but they had levels of self-confidence in their management abilities higher than was indicated by their knowledge level.[57]

Basic Life Support (BLS) interventions for patients with heat-related illness include immediate assessment of airway, breathing, and circulation (ABC). After initial assessment of the ABCs, the BLS unit should remove the patient's clothing (if not already done), obtain a rectal temperature, if possible, and begin cooling interventions. If Advanced Life Support (ALS) medical providers are available, additional interventions include performing an electrocardiogram with interpretation, placing an advanced airway, if indicated, administering intravenous (IV) fluids, and managing seizure activity. Prompt and appropriate prehospital care can greatly improve patient outcomes. If transportation is prolonged, immediate cooling measures should be considered.

Emergency Department Evaluation

History

When a patient presents with signs and symptoms of a heat-related illness, there are certain key questions the emergency clinician should ask when taking the history. Has the patient been involved in exertional activities in a hot or humid environment? Is the patient new to the physical activity? Is the patient taking any type of stimulant medication, either prescribed or recreational? How long has the patient been exposed to heat?

Physical Examination

The physical examination in a suspected heat-related illness should be problem-focused. The emergency clinician needs to be observant of vital signs, and abnormal vital signs should be addressed. Either rectal or esophageal temperature should be obtained to estimate core temperature, as all other external temperatures are inadequate at predicting core temperature and may be falsely depressed.[58,59] Poor prognosis is likely if the patient's core temperature is > 42°C (107.6°F).[50]

A neurologic examination and Glasgow Coma Scale (GCS) score will not only allow the emergency clinician to address the severity of the injury and diagnose heat stroke, but also to determine the need for immediate intervention and resuscitation. A cardiac examination should be completed to evaluate for tachycardia and/or dysrhythmias and to evaluate for adequate perfusion. An increase or decrease in respiratory effort can be a presenting abnormality in heat-related illness. Both profuse sweating or a lack of sweating can provide necessary information to the emergency clinician that a patient may have a heat-related illness.

Diagnostic Studies

The diagnosis of heat stroke is based on clinical symptoms and does not require any laboratory abnormalities. Laboratory test results for patients with heat stress or heat exhaustion are usually normal or consistent with dehydration; other organ systems are usually not involved. Nonetheless, heat stroke has been found to be associated with multisystem organ dysfunction as well as myocardial injury,[60] so although diagnostic studies are not needed to verify the diagnosis and should not delay immediate treatment, diagnostic studies may assist with managing complications associated with a heat-related illness. **(See Table 1.)**

In patients with heat stroke, laboratory tests can reveal an elevated lactate level from poor perfusion. In addition, hepatic injury is a common finding in patients with heat stroke. Aspartate aminotransferase (AST) and alanine aminotransferase (ALT) elevations peak approximately 48 to 72 hours after exposure to heat and gradually return to normal in 10 to 14 days. Elevation of bilirubin levels as well as prothrombin time have been reported secondary to liver injury. Rhabdomyolysis with an elevated creatine kinase can be associated with heat-related illness. Acute renal injury leading to renal failure can also occur with heat stroke, but it generally responds well to rehydration and usually corrects in a few days. Hematologic findings can include anemia from red blood cell membrane osmotic fragility. Thrombocytopenia and findings of disseminated intravascular coagulation with prolongation of prothrombin time, partial thromboplastin time, and D-dimer are also found with heat stroke.[50]

Treatment

The initial care of the patient with a heat-related illness should focus on evaluation and support of the ABCs. Dehydration is often associated with heat-related illness and attention should be given to adequate fluid resuscitation. As heat-related illness progresses, attention to complications associated with heat exhaustion and heat stroke need to be addressed, including electrolyte abnormalities, mul-

Table 1. Potential Organ System Affected and Suggested Diagnostic Studies

Organ System	Diagnostic Studies
Circulatory	Basic metabolic panel, lactate
Cardiac	Troponin, CK, ECHO, ECG
Hepatic	AST, ALT, bilirubin, PT, PTT, INR
Renal	BUN, Cr, UA
Hematologic	CBC, PT, PTT, INR, D-dimer
Musculoskeletal	CK, urine myoglobin
Neurologic	Head CT

Abbreviations: ALT, alanine aminotransferase; AST, aspartate aminotransferase; BUN, blood urea nitrogen; CBC, complete blood cell count; CK, creatine kinase; Cr, creatinine; CT, computed tomography; ECG, electrocardiogram; ECHO, echocardiogram; INR, international normalized ratio; PT, prothrombin time; PTT partial thromboplastin time; UA, urinalysis.

tisystem organ failure, disseminated intravascular coagulation, seizures, and coma.

The key to management is the initiation of rapid cooling, because morbidity and mortality are directly related to the duration and intensity of the hyperthermia.[61] A retrospective study concluded that hyperthermic patients with a higher initial temperature, hypotension, or a low GCS score had a higher mortality rate.[62] Decreasing the temperature to below 40°C (104°F) is critical and more important than how high the initial temperature was.

Decreasing the core temperature prevents protein denaturation, and complications associated with heat stroke can be reduced if cooling is initiated within the first 30 to 60 minutes after the onset of heat stroke symptoms.[1,61] Bouchama et al reported a heat stroke mortality rate of 15% if cooling was initiated within 60 minutes, and 33% if it was initiated after more than 60 minutes.[1] In a study of adults, if the temperature was reduced to < 40°C (104°F) within 30 minutes, then mortality from heat stroke approached 0%.[63,64] Core temperature must be continuously monitored with either a rectal or esophageal probe, and cooling measures must be stopped once the core temperature has decreased. There is no evidence of a specific end point to stop cooling measures, but a rectal temperature of 38°C to 39°C (100.4°F-102°F) appears to be a safe temperature range to avoid hypothermic overshoot.[36,65]

The most-recommended methods of cooling utilize the property of heat dissipation. When core temperatures are high, cooling measures utilizing the properties of conduction and evaporation are used to rapidly decrease the core temperature.

Cooled Fluid Administration/Lavage

Historically, cooled IV normal saline (0.9%) or iced lavage fluids have been used as conductive cooling methods to reduce core temperature in patients with heat-related illness. There is no literature to support the use of cooled IV saline for the treatment of hyperthermia in children, and this method is associated with discomfort and shivering. Hostler et al showed that, in patients who received cold normal saline, high-dose diazepam (20 mg) compared to low-dose diazepam (10 mg) or placebo control showed improved reduced core body temperature without oxygen consumption or shivering.[66]

There are no human studies that compare iced gastric or bladder lavage to other cooling measures; however, studies in animals have shown mixed results. Iced gastric lavage was studied in a canine model and yielded a cooling rate that was 5 times faster than controls in ambient air temperature; (0.15°C/min vs 0.03°C/min).[67] In another canine experiment, White et al found that iced gastric lavage was not advantageous compared to evaporative cooling.[68]

Due to the lack of evidence for the use of cooled IV or iced lavage fluids, it is not routinely recommended for heat-related illness, but consideration should be given to its use in children with severe heat stroke. No studies have evaluated the effect of more-invasive cooling measures (such as peritoneal or thoracic lavage) in the treatment of heat-related illness in children; therefore, they are not recommended for the management of heat-related illness, as they are invasive, time consuming, and difficult to perform.

Conductive Cooling Measures

Cooling measures using conductive heat dissipation include water immersion, ice pack application, cooling blankets, and more-invasive iced peritoneal or gastric lavage.

With water immersion, the patient is submerged into either cold water or ice water. With ice water, a steeper temperature gradient can be obtained and can potentially increase the rate of heat dissipation, but it is postulated that aggressive cooling with ice water may secondarily cause shivering and peripheral vasoconstriction, thereby impeding the efficacy of ice-water immersion.[69] However, several studies have shown superior efficacy of ice-water immersion. Casa et al reviewed published literature on cooling rates of different cooling modalities and found cooling via ice-water immersion to be superior to all other modalities.[70] Flouris et al compared ice-water immersion to natural recovery and found ice-water immersion had a faster cooling rate.[71] Armstrong et al compared ice-water immersion to air-exposed wet towels and noted the cooling rate in ice water was twice as rapid compared to wet towels, 0.2°C/min compared to 0.11°C/min.[72] Proulx et al showed the cooling rate after immersion in 2°C water was about 2 times faster (0.35°C/min) compared to water at 8°C (0.19°C/min), 14°C (0.15°C/min), or 20°C (0.19°C/min).[73] Clements et al compared the cooling rate of runners with exercise-induced hyperthermia of 39.3°C to 39.6°C (102.7°F-103.3°F). They found that 12 minutes of immersion in either ice or water was more effective than passive cooling, but the cooling rates were similar for immersion in ice or water.[74]

Monitoring vital signs and temperature can be difficult with water immersion; therefore, this can be a challenge to perform in the ED setting. Practically, the lack of a tub can also prevent this treatment in the ED, but this method of cooling can be considered on-scene for patients with hyperthermia, such as a football locker room or sporting event treatment unit. Ice-water immersion is best utilized with a patient who is awake and alert, but it can be performed with patients with altered mental status.

Ice-pack application usually involves placing ice packs over the large vessels of the body, such as the neck, axillae, and groin. Shibasaki et al found greater blood flow over the chest and back of boys with heat exposure, which suggests that other potential sites for ice application should include the chest and back.[75,76] Ice-pack cooling promotes heat exchange adjacent to areas of increased blood flow by convection and conduction, but used alone, it is not as effective as other cooling measures.[65] Indeed, evaporative cooling was found to have a higher cooling rate compared to ice packs.[77] The least effective of all conductive cooling measures is probably cooling blankets.

Evaporative Cooling Measures

The most recognized and recommended method of cooling in the ED setting is evaporative cooling. Evaporative cooling requires all clothing to be removed from the patient, followed by spraying water over the skin in a setting where there is continuous airflow. Hadad et al suggested that a warm environment is crucial for the evaporative process, which can be accomplished with either warm forced air and/or by warming the water sprayed on the body.[65] As an alternative method of evaporative cooling, Al-Harthi et al showed that a sheet wetted with tap water and placed over the body in a setting with fans was as effective as spraying warm water.[78]

Comparison of the Efficacy of Different Cooling Measures

Studies demonstrate conflicting results regarding whether water immersion or evaporative cooling is more effective. Hadad et al reported a significantly higher cooling rate with evaporative cooling compared to immersion in 14°C (57°F) water.[65] In contrast, Armstrong et al reported a significant decrease in rectal temperature when a patient was immersed in ice water compared to using evaporative cooling.[72] Hadad et al summarized the cooling rate of available methods in healthy subjects and reported that evaporative cooling (0.027°-0.31°C/min) and conductive cooling with ice-water immersion (0.16°-0.35°C/min) appear to have the fastest cooling rates, followed by tap-water immersion (0.04°-0.16°C/min) and cooling with locally applied ice packs (0.03°-0.09°C/min). In studies evaluating patients with heat stroke, evaporative cooling appeared to have a faster cooling rate (0.05°-0.34°C/min) than ice-water immersion (0.15°-0.23°C/min).[65] Casa et al also found evaporative cooling to be effective, but immersion in 2°C (35.6°F) water was superior to all other modalities of cooling.[70]

Medications

Pharmacologically induced cooling measures have little role in the management of heat-related illness. Due to the normal set point of the hypothalamus and the pathophysiology associated with heat-related illness, antipyretics should not be used in the treatment of hyperthermia, as the etiology of the hyperthermia with heat-related illness is not related to circulating cytokines.[65] However, benzodiazepines can be considered to decrease shivering if cooled IV fluids are used for a patient with heat stroke.[66]

Special Populations

Children Left in Cars

The risk for heat-related illness in infants and young children is mostly attributed to their inability to remove themselves from high-heat environments, such as a locked vehicle. Guard et al found that over 70% of fatalities were children who were left in cars by adults[79] and Ferrara et al found that 75% of children were intentionally left in a car.[80] Balbus et al studied the effects of climate change on hot-car deaths and found that mortality rates for infants and children increased by 4.9% per 5.6°C (10°F) increase in mean daily temperature.[81] These studies highlight the importance of educating parents and caregivers about the dangers of leaving children in cars, even for short periods of time.

Children Who Take Medications, Drugs, or Supplements

Other at-risk populations who need special consideration are children and athletes who take regularly scheduled medications and/or use recreational drugs, as some medications are associated with an increased risk of heat stroke. A list of medications and drugs that can contribute to hyperthermia is included in **Table 2**. There are multiple case reports of patients who used methylphenidate who experienced heat stroke induced by exertion.[27,82,83] Other medications (eg, zonisamide [Zonegran®]) have been reported to cause heat stroke-like episodes when used to treat a child with seizures.[84] Previous recommendations included the avoidance of caffeine, as it was believed to have a diuretic effect and thereby increase the risk of exertional heat-related illness, but studies on caffeine intake in adults have shown little to no influence on heat stress during exertion.[85,86] Illicit recreational drug use also has been associated with heat-related illness,

Table 2. Medications That Contribute to Hyperthermia

- Alcohol
- Cocaine
- Amphetamines and derivatives
- Atropine
- Alpha-adrenergic agonists
- Diuretics
- Laxatives
- Neuroleptic agents
- Phenothiazines
- Thyroid agonists
- Tricyclic antidepressants
- Typical and atypical antipsychotics

especially in combination with decreased fluid intake, increased physical activity, and drug use during mass events such as raves.[87,88]

Patients With High Body Mass Index

Athletes who have a high body mass index should be monitored, as they have an increased risk for heat-related illness.[89,90] In a review of 243 high school and college football player fatalities over a 20-year period, obesity was found to be a risk factor for heat-related fatality. Patients who are obese have increased heat production and relatively low surface area for heat dissipation via evaporation.[23] Kerr et al found exertional heat-related illness in football players to be most frequent among offensive linemen, defensive linemen, and linebackers.[31] Bedno et al found an increased risk of heat-related illness among adult male military recruits with excess body fat; the RR for heat exhaustion was 3.3 and the RR for heat stroke was 21.4.[91] Dougherty et al studied the effects of light-to-moderate intensity exercise in heat-acclimated obese boys compared to lean boys. They determined a significant difference in obese boys, with a decrease in sweating rate and volume at all temperatures, a lower water vapor pressure between skin and air, and a higher subjective response for rating of perceived exertion and thermal sensation. They suggested exertion modification guidelines at different climatic heat stress levels that are tailored for obese boys.[92,93]

Patients With Chronic Medical Conditions

Patients with certain chronic medical conditions are at increased risk for heat-related illness. A 2012 case-control study based on a surveillance system for heat illness found that patients with certain pre-existing conditions were at greater risk for developing heat stroke (40% vs 24%). Neuropsychiatric disorders were associated with an odds ratio (OR) of 7.6.[94] Wang et al found an OR of 3.6 for heat-related hospital admission for children with renal disease on heat wave days.[95] Over a 5-year period, Hess et al analyzed data from the Nationwide Emergency Department Sample of the Healthcare Cost and Utilization Project that included patients of all ages. They evaluated factors associated with hospital admission or deaths in the ED that were related to heat illness and found that men, the elderly, and patients who were chronically ill were at greatest risk for admission or death in the ED. They also noted that, among the subgroup with heat stroke, adjusted odds of death in the ED were highest for the patients who were aged 0 to 17 years, boys/men, patients from low-income Zip codes, and patients with chronic circulatory conditions.[96] Patients with sweat and temperature instability, such as in familial dysautonomia, hypohidrotic ectodermal dysplasia, sickle cell disease, and cystic fibrosis are at a higher risk for heat-related illness.[97-102] Patients with type 1 diabetes are also believed to have an associated impairment in heat dissipation during exercise and should be monitored closely during exertion on days with high heat or humidity.[24]

Controversies and Cutting Edge

Given the similar physiologic processes of exertional heat stroke and malignant hyperthermia, there is a theoretical benefit for the skeletal muscle relaxant, dantrolene. Although dantrolene reduces muscular heat in malignant hyperthermia, there have been mixed recommendations for its use in heat illness. In a case series of patients with heat-related illness, dantrolene was not found to be effective.[103] There is no evidence for the recommendation of dantrolene for the treatment of exertion-related heat illness. The mainstay treatment for heat stroke remains aggressive cooling measures and IV fluid resuscitation.[1,54]

A few case reports support the use of more aggressive measures in patients with heat stroke who are not responsive to standard supportive therapy. Sixteen patients with heat stroke who were treated with continuous venovenous hemofiltration were retrospectively reviewed. All 16 patients had significant improvement and there were no deaths.[69] In a retrospective study conducted by Chen et al, the clinical effects of continuous renal replacement therapy (CRRT) versus routine therapy in adults and a few adolescent patients with heat shock were reviewed, with the conclusion that patients with CRRT treatment in combination with current treatment had a higher discharge rate. These patients also had a faster return to baseline body temperature, acidosis correction, and decreased serum levels of biomarkers for liver and kidney dysfunction. Furthermore, these patients had a more extensive improvement and recovery from organ dysfunction. While CRRT is not appropriate for everyone, especially those diagnosed with heart/lung edema, CRRT in combination with routine therapy has been shown to be successful in decreasing heat stroke-related mortality.[104]

Kawanami et al studied the analysis of urine temperature as a surrogate for rectal temperature and found urine temperatures correlated closely with rectal temperatures.[105] Further studies will need to be conducted to evaluate the accuracy of urine temperature before recommendations can be made for this noninvasive method for estimating the core temperature of patients with hyperthermia.

Disposition

Patients with mild heat-related illness (eg, heat stress or exhaustion) whose vital signs have returned to normal and who are no longer symptomatic during their ED stay may be discharged home. There is no consensus on the duration of monitoring after stabilization of vital signs in asymptomatic patients.

Most children have lower odds of hospitalization from the ED compared to adults; OR of 0.25 for children aged 0 to 14 years and OR of 0.64 for children aged 15 to 19 years.[106] Discharge instructions should include education on strategies to prevent future heat-related illness, including proper hydration prior to and during exertion, cooling in shade with the onset of heat-related illness symptoms, and proper acclimatization during the preseason.

Patients with heat exhaustion whose vital signs or symptoms have not returned to normal or patients with major laboratory test abnormalities should be admitted until they are stabilized. Patients with heat stroke and those who required intubation, exhibited signs of shock, or had evidence of multisystem end-organ damage should be admitted to the intensive care unit.

Prevention Strategies

As frequent providers of emergency care at schools, sporting events, mass outdoor events, and in EDs during extreme heat weather events, emergency clinicians are uniquely positioned to offer patients strategies for prevention of heat-related illness. The primary strategies include acclimatization, hydration, and practice modification.

Acclimatization

The goal of heat acclimatization is to gradually increase exertional heat tolerance and enhance the ability to exercise safely in a warm or hot environment. Although most recommendations for acclimatization protocols are derived from preseason football training, we recommend that coaches and trainers consider acclimatization for all outdoor activities conducted in hot, humid environments. Acclimatization should begin on the first day of conditioning in the preseason and usually follows a 14-day plan.[107] Some acclimatization recommendations specific to football include no two-a-day practices in the first week and introducing protective equipment in stages, starting with the helmet and progressing to a full uniform.[108] In an online questionnaire of 1142 high school athletic trainers, only 2.5% reported full compliance with acclimatization guidelines.[109] McGarr et al studied heat adaptation among cyclists using short-term endurance and sprint interval training over a 2-week period and found improvements in cardiovascular strain, but did not find improved thermal responses; they thus concluded that this did not replace the need for heat acclimatization.[110]

Hydration

Hydration plays a key role in the prevention of heat-related illness. Adequate thermal regulation requires adequate hydration, to allow for blood flow to dissipate heat by convection and evaporation. During intense practice and competitive play, sweat losses in junior tennis players ranged from 1 liter per hour up to 2.5 liters per hour in older adolescents.[111] In a study evaluating 8 healthy, fit adolescent male tennis athletes, Bergeron et al found that players who did not begin well-hydrated had progressively increasing thermal strain, and playing multiple matches on the same day posed the greatest risk to thermal strain.[112] In a survey of preseason football injuries, Luke et al noted that athletic programs had routine planned hydration only 45% of the time and 7% provided no water breaks.[113]

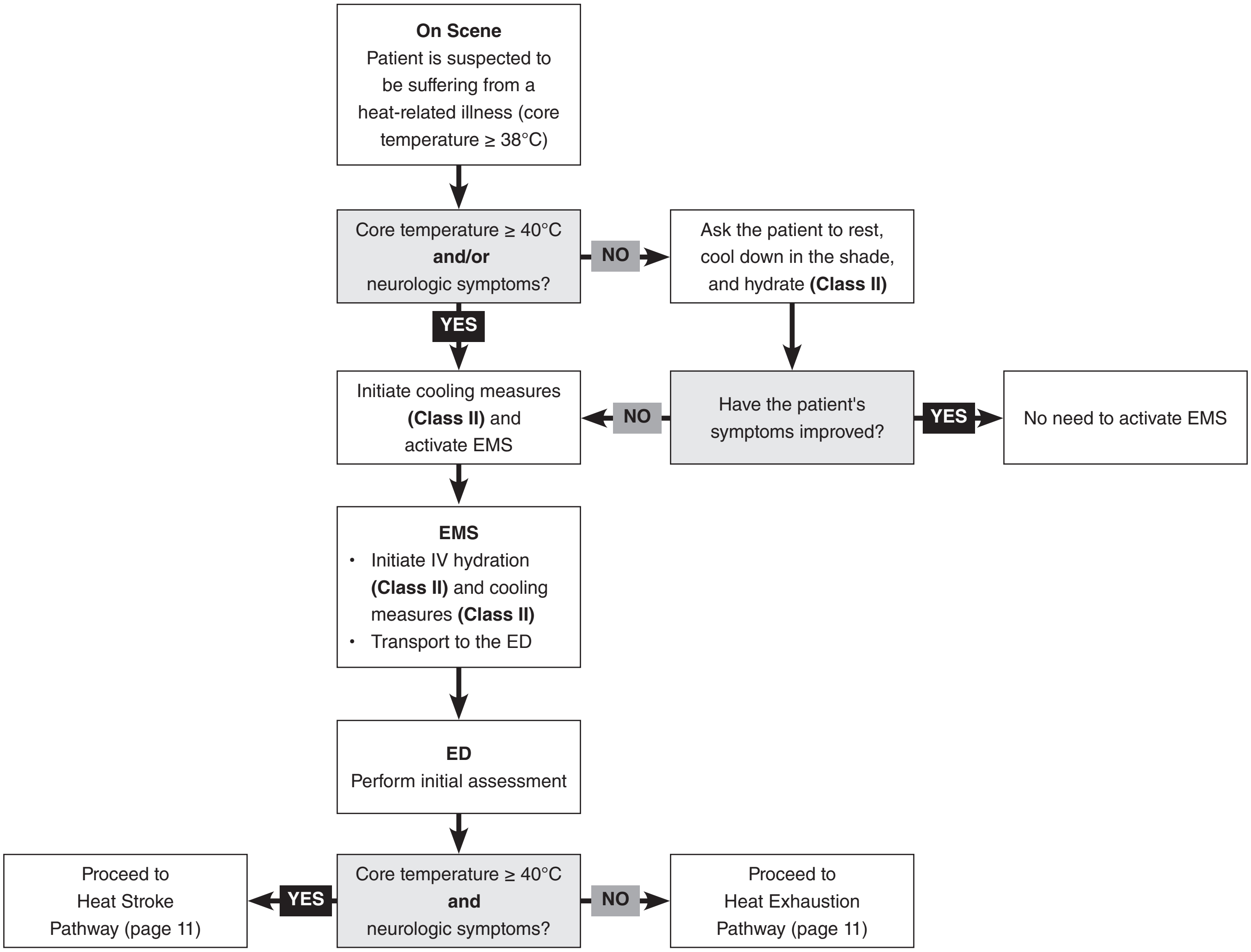
Several strategies may increase motivation to hydrate: marching band participants who had access to water via a water belt showed a subjective improvement in heat-related illness from previous years;[114] cold water compared to room-temperature drinks has been found to extend endurance to exhaustion;[115] and adding flavoring as well as carbohydrates to water was shown to enhance voluntary drinking and prevent dehydration.[116-118]

Practice Modification

Practice modification during hot and humid days can decrease the rate of heat-related illness among athletes. Administrators, event coordinators, coaches, and athletic trainers need to be aware of the risk associated with hot and humid days and make appropriate modifications to protect athletes from experiencing heat-related illness.[119] A study of preseason football programs found that on hot and humid days, only 31% eliminated all equipment, 57% eliminated the helmet only, and 33% eliminated the helmet and shoulder pads.[113] In a study of 24 young athletes, 1 hour of complete rest with cool-down and rehydration following 80 minutes of strenuous activity in heat was effective in eliminating any apparent residual or carryover effects that would result in thermal and cardiovascular strain during an identical exercise bout.[120]

In a panel consensus statement by Bergeron et al, recommendations were made for practice modification to reduce the risk of heat exhaustion and heat stroke. The practice modification called for recognition of the levels of heat and humidity, monitoring players during practice, and recognition of players who are not acclimated or aerobically fit.[108] Rav-Acha et al showed that implementing guidelines in military force training based on individual limiting factors, environmental factors, and training factors showed a marked reduction in the rate of heat-related casualties in following years.[121]

Clinical Pathway for Initial Management of Pediatric Patients With Heat-Related Illness



Abbreviations: ED, emergency department; EMS, emergency medical services; IV, intravenous.

Class of Evidence Definitions

Each action in the clinical pathways section of *Pediatric Emergency Medicine Practice* receives a score based on the following definitions.

Class I
- Always acceptable, safe
- Definitely useful
- Proven in both efficacy and effectiveness

Level of Evidence:
- One or more large prospective studies are present (with rare exceptions)
- High-quality meta-analyses
- Study results consistently positive and compelling

Class II
- Safe, acceptable
- Probably useful

Level of Evidence:
- Generally higher levels of evidence
- Nonrandomized or retrospective studies: historic, cohort, or case control studies
- Less robust randomized controlled trials
- Results consistently positive

Class III
- May be acceptable
- Possibly useful
- Considered optional or alternative treatments

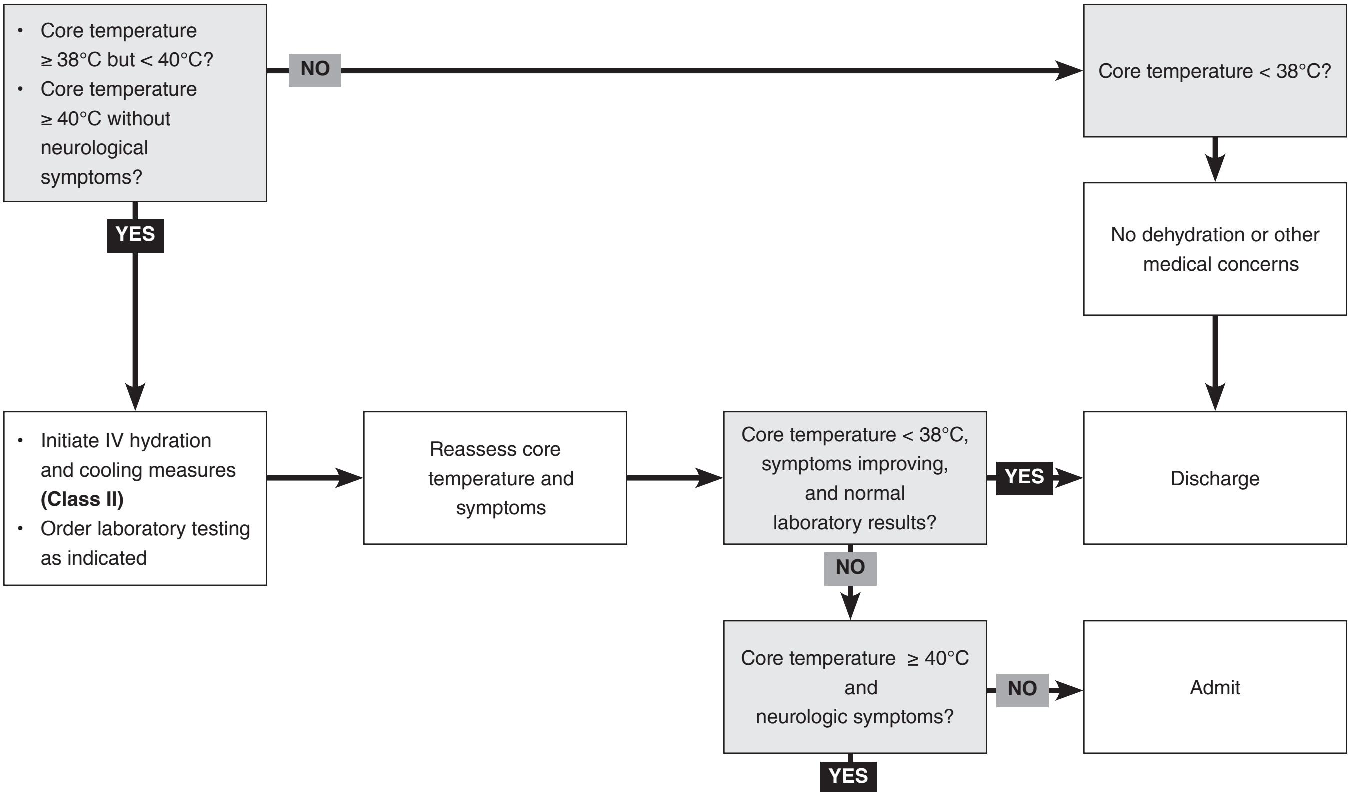
Level of Evidence:
- Generally lower or intermediate levels of evidence
- Case series, animal studies, consensus panels
- Occasionally positive results

Indeterminate
- Continuing area of research
- No recommendations until further research

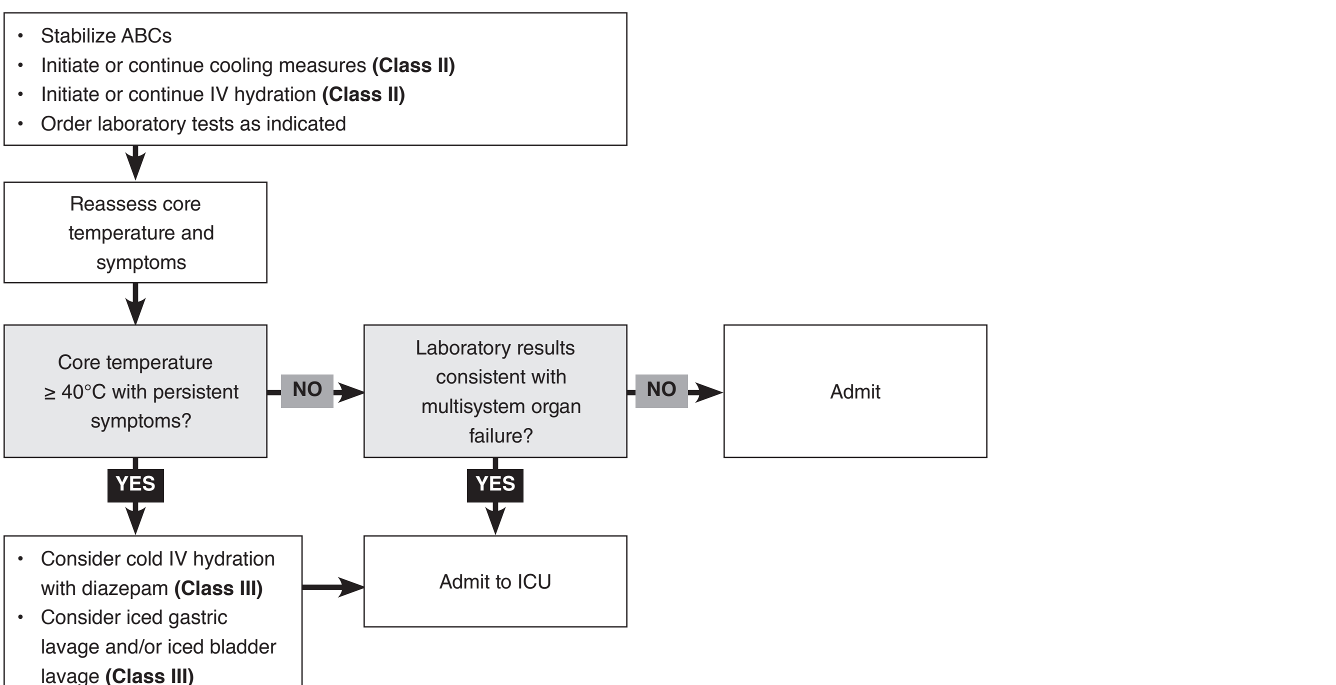
Level of Evidence:
- Evidence not available
- Higher studies in progress
- Results inconsistent, contradictory
- Results not compelling

This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient's individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

Clinical Pathway for Management of Heat Exhaustion



Clinical Pathway for Management of Heat Stroke



Abbreviations: ABC, airway, breathing, and circulation; ICU, intensive care unit; IV, intravenous.
For Class of Evidence definitions, see page 10.

Risk Management Pitfalls in Pediatric Patients With Heat-Related Illness

1. **"The outside temperature was only 26.7°C (80°F). There's no way that the baby's elevated temperature was related to being left in the car."**
   Even in mild-to-moderate environmental temperatures, the temperature inside a car can reach dangerous levels. McLaren showed environmental temperature ranges of 22.2°C to 35.6°C (72°F-96°F) can increase the internal car temperature to 47.2°C (117°F).[18]

2. **"The patient's rectal temperature was not high enough for her to be considered to have a heat-related illness."**
   The diagnosis of heat exhaustion includes temperatures < 40°C (104°F). When considering the diagnosis of a heat-related illness, history of signs and symptoms and examination findings are important in diagnosis and initiating management.

3. **"The boy's axillary temperature was only 39°C (102.2°F), so heat stroke could not be a possible diagnosis."**
   Only core temperature measurements utilizing rectal or esophageal probes should be used for diagnosis and management of a patient with a heat-related illness, as other external temperature measurements are inaccurate and often underestimate core temperature.

4. **"It was only 26.1°C (79°F) with 80% humidity outside, so I didn't consider a heat-related illness as a source of hyperthermia."**
   The body's ability to dissipate heat is related to both environmental temperature and humidity. When the humidity level reaches or exceeds 75%, heat loss by evaporation begins to decrease and the risk of heat-related illness during exertion increases.

5. **"I didn't stress preseason acclimatization conditioning to the patient's football coach, as the temperatures do not exceed 32.2°C (90°F) in our area."**
   Exertional heat illness among football athletes is 11 times more likely than in athletes in all other sports combined. Most heat-related illness occurs during the preseason, when athletes are unconditioned and it is the hottest time of the year. Humidity as well as temperature should be considered as risks for heat-related illness. It is therefore important that athletes are acclimated prior to full participation in preseason practice.

6. **"Near the end of the championship game, the football player was experiencing nausea and fatigue. His oral temperature was 38°C (100.4°F). Since this was an important game and his temperature was not too high, we rehydrated him and allowed him to return to the game."**
   When treating an athlete with heat exhaustion, in addition to rehydration, it is imperative to remove football equipment and place the patient in a shaded area to prevent progression to heat stroke.

7. **"The patient had a temperature of 41°C (105.8°F) in the ED after football practice, so I asked the nurse to initiate cooling measures by placing ice packs on his body and turning fans on him."**
   Evaporative cooling has been shown to be more effective than cooling with ice packs. Evaporative cooling is accomplished by spraying warm water over the skin with forced continuous airflow. Warm forced air or warm water is crucial for the evaporative process in order to maintain good peripheral perfusion and to minimize vasoconstriction.

8. **"I ordered a dose of dantrolene prior to initiating cooling measures, as the patient's temperature was 40.5°C (105°F)."**
   Although dantrolene is standard therapy for medication-induced malignant hyperthermia, there is no convincing evidence for the use of dantrolene in the management of exertional heat stroke. Initial management should be focused on rapid cooling measures.

9. **"The patient is an offensive linemen. Since they don't run as much as other football athletes, I thought he was less at risk for heat stroke."**
   Athletes with a high body mass index are at increased risk for exercise-induced heat-related illness, due to their increased heat production, increased insulation, and decreased sweating rate, which prevents evaporative heat dissipation.

10. **"I initiated rapid cooling measures in my patient whom I suspected had heat stroke. I instructed the nurse to stop once the patient's core body temperature dropped below 37°C (98.6°F)."**
    To avoid hypothermia, it is recommended that cooling measures be stopped when the core temperature drops below 38°C to 39°C (100.4°F-102.2°F).

Summary

Heat-related illness occurs as a result of excess heat exposure and heat production combined with decreased heat dissipation, and it can be potentially life-threatening. A history of excess heat exposure or exertion with physical examination findings consistent with hyperthermia are needed to make the clinical diagnosis of heat-related illness. To avoid a missed diagnosis, it is important to consider special populations that are particularly at risk, including infants, children with chronic diseases, obese patients, and patients on medications that put them at risk for hyperthermia. Early recognition and treatment are critical to reduce morbidity and mortality. A rectal or esophageal thermometer should be utilized to measure temperature, as external temperatures can underestimate core temperature. Laboratory studies have no role in the diagnosis of heat-related illness, but do assist with managing associated complications. When heat-related illness is suspected, immediate cooling measures must be initiated if they have not already been started by EMS. Conductive cooling (such as immersion in ice water) or evaporative cooling are treatment options to rapidly cool core temperature in the ED. Because immersion in ice water is often not feasible in the ED setting, evaporative cooling is the preferred method of cooling and has been found to be equal or superior to other cooling measures. There is no clear end point temperature to stop cooling measures, but 38°C to 39°C (100.4°F-102°F) appears to be safe to avoid hypothermic overshoot. Most children with heat exhaustion can be safely discharged from the ED with adequate hydration, but those with persistent symptoms, abnormal laboratory values, or signs or symptoms of heat stroke need to be admitted for further observation and management.

Case Conclusions

Given the history and physical examination findings, you diagnosed the 15-year-old football player with heat exhaustion; the patient's weight, methylphenidate use, as well as poor acclimatization were likely contributors. Treatment with IV fluid hydration and evaporative cooling was initiated within the first hour of arrival to avoid further progression and complications associated with heat exhaustion. CBC, CMP, and CK levels were ordered and showed no findings that would suggest multiorgan involvement. When you rechecked the patient's rectal temperature, it was 37.4°C (99.3°F). Since all of the patient's symptoms had improved, he was discharged home and given discharge instructions on prevention strategies for heat-related illness.

The 8-month-old infant that had been in a hot car was evaluated and determined to have heat stroke. You immediately established an airway and IV access for fluid resuscitation. After initial stabilization of the ABCs, immediate cooling measures were initiated with evaporative cooling as well as cooled IV fluids with a dose of diazepam. Continuous rectal temperature monitoring was performed. Diagnostic studies for this patient revealed elevated AST, ALT, and total bilirubin levels, as well as acute kidney injury. The infant was admitted to the pediatric intensive care unit.

The 16-year-old marathon runner was experiencing the onset of heat stroke. The medical unit on scene had a tub available for ice-water immersion, so you immediately placed her in the ice-water tub to avoid further progression and complications related to heat stroke. The patient was then transported to the ED. Upon arrival to the ED, her temperature had decreased to 38°C (100.4°F) and her mental status had also improved. Diagnostic studies were unremarkable except mild elevation of creatine kinase. The patient was admitted for further monitoring.

References

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study is included in bold type following the references, where available. The most informative references cited in this paper, as determined by the authors, are noted by an asterisk (*) next to the number of the reference.

1.* Bouchama A, Dehbi M, Chaves-Carballo E. Cooling and hemodynamic management in heatstroke: practical recommendations. *Crit Care*. 2007;11(3):1-10. **(Review)**

2.* Zeller L, Novack V, Barski L, et al. Exertional heatstroke: clinical characteristics, diagnostic and therapeutic considerations. *Eur J Intern Med*. 2011;22(3):296-299. **(Retrospective; 32 patients)**

3. Moore R, Mallonee S, Sabogal RI, et al. From the Centers for Disease Control and Prevention. Heat-related deaths-four states, July-August 2001, and United States, 1979-1999. *JAMA*. 2002;288(8):950-951. **(Case reports and review)**

4. Noe RS, Choudhary E, Cheng-Dobson J, et al. Exertional heat-related illnesses at the Grand Canyon National Park, 2004-2009. *Wilderness Environ Med*. 2013;24(4):422-428. **(Descriptive epidemiological study)**

5. Nelson NG, Collins CL, Comstock RD, et al. Exertional heat-related injuries treated in emergency departments in the U.S., 1997-2006. *Am J Prev Med*. 2011;40(1):54-60. **(Descriptive epidemiology study)**

6. Grant WD, Nacca NE, Prince LA, et al. Mass-gathering medical care: retrospective analysis of patient presentations over five years at a multi-day mass gathering. *Prehosp Disaster Med*. 2010;25(2):183-187. **(Retrospective; 2075 visits)**

7. Olympia RP, Brady J, Rupp V, et al. Emergency department visits from a local amusement park. *J Emerg Med*. 2011;41(1):14-20. **(Retrospective; 296 visits)**

8. Choudhary E, Vaidyanathan A. Heat stress illness hospitalizations – environmental public health tracking program, 20 states, 2001-2010. *Morb Mortal Wkly Rep*. 2014;63(13):1-10. **(Descriptive epidemiology study)**
9. Frieden TR, Jaffe HW, Stephens JW, et al. Nonfatal sports and recreation heat illness treated in hospital emergency departments--United States, 2001-2009. *Morb Mortal Wkly Rep*. 2011;60(29):977-980. **(Descriptive epidemiology study)**
10. Almeida S, Casimiro E, Analitis A. Short-term effects of summer temperatures on mortality in Portugal: a time-series analysis. *J Toxicol Environ Health A*. 2013;76(6):422-428. **(Retrospective descriptive)**
11. Bai L, Ding G, Gu S, et al. The effects of summer temperature and heat waves on heat-related illness in a coastal city of China, 2011-2013. *Environ Res*. 2014;132:212-219. **(Retrospective)**
12. Xu Z, Sheffield PE, Su H, et al. The impact of heat waves on children's health: a systematic review. *Int J Biometerorol*. 2014;58(2):239-247. **(Systematic review)**
13. Zhang K, Chen T, Begley CE. Impact of the 2011 heat wave on mortality and emergency department visits in Houston, Texas. *Environ Health*. 2015;14:11. **(Retrospective)**
14. Toloo GS, Yu W, Aitken P, et al. The impact of heatwaves on emergency department visits in Brisbane, Australia: a time series study. *Crit Care*. 2014;18(2):2224-2233. **(Retrospective)**
15. Patek GC, Thoma TG. National Highway Traffic Safety Administration (NHTSA) notes. *Ann Emerg Med*. 2013;61(6):703-704. **(Commentary)**
16. Duzinski SV, Barczyk AN, Wheeler TC, et al. Threat of paediatric hyperthermia in an enclosed vehicle: a year-round study. *Inj Prev*. 2014;20(4):220-225. **(Observational study)**
17. Grundstein AJ, Duzinski SV, Dolinak D, et al. Evaluating infant core temperature response in a hot car using a heat balance model. *Forensic Sci Med Path*. 2015;11(1):13-19. **(Simulation experimental study)**
18.* McLaren C, Null J, Quinn J. Heat stress from enclosed vehicles: moderate ambient temperatures cause significant temperature rise in enclosed vehicles. *Pediatrics*. 2005;116(1):109-112. **(Prospective observational)**
19. Alunni V, Crenesse D, Piercecchi-Marti MD, et al. Fatal heat stroke in a child entrapped in a confirmed space. *J Forensic Leg Med*. 2015;34:139-44. **(Case report)**
20. Krous HF, Nadeau JM, Fukumoto RI, et al. Environmental hyperthermic infant and early childhood death: circumstances, pathologic changes, and manner of death. *Am J Forensic Med Pathol*. 2001;22(4):374-382. **(Case series)**
21. Zhou Y, Li L, Liu L, et al. Heat stroke deaths caused by electric blankets: case report and review of literature. *Am J Forensic Med Pathol*. 2006;27(4):324-327. **(Case report)**
22. Rowland T. Thermoregulation during exercise in the heat in children: old concepts revisited. *J Appl Physiol*. 2008;105(2):718-724. **(Review)**
23. Boden BP, Breit I, Beachler JA, et al. Fatalities in high school and college football players. *Am J Sports Med*. 2013;41(5):1108-1116. **(Descriptive epidemiology study)**
24. Carter MR, McGinn R, Barrera-Ramirez J, et al. Impairments in local heat loss in type 1 diabetes during exercise in the heat. *Med Sci Sports Exerc*. 2014;46(12):2224-2233. **(Prospective case-control; 16 subjects)**
25. Fortes MB, Di Felice U, Dolci A, et al. Muscle-damaging exercise increases heat strain during subsequent exercise heat stress. *Med Sci Sports Exerc*. 2013;45(10):1915-1924. **(Prospective crossover design; 13 male subjects)**
26. Kritikou-Pliota E, Galanakis E, Alfadaki SA, et al. Cystic fibrosis presenting as heat stroke. *Acta Paediatr*. 2000;89(1):121-122. **(Case report)**
27. Thoenes MM. Heat-related illness risk with methylphenidate use. *J Pediatr Health Care*. 2011;25(2):127-132. **(Case report)**
28. Yeo TP. Heat stroke: a comprehensive review. *AACN Clinical Issues*. 2004;15(2):280-293. **(Review)**
29. Trujillo MH, Bellorin-Font E, Fragachan CF, et al. Multiple organ failure following near fatal exertional heat stroke. *J Intensive Care Med*. 2009;24(1):72-78. **(Case report)**
30. Wagner C, Boyd K. Pediatric heatstroke. *Air Med J*. 2008;27(3):118-122. **(Case report)**
31. Kerr ZY, Casa DJ, Marshall SW, et al. Epidemiology of exertional heat illness among U.S. high school athletes. *Am J Prev Med*. 2013;44(1):8-14. **(Descriptive epidemiology study)**
32. Huffman EA, Yard EE, Fields SK, et al. Epidemiology of rare injuries and conditions among United States high school athletes during the 2005-2006 and 2006-2007 school years. *J Athl Train*. 2008;43(6):624-630. **(Prospective cohort)**
33. Bailes BK, Reeve K. Prevention of heat-related illness. *J Nurse Pract*. 2007;3(3):161-168. **(Review)**
34. Gordon S. Heat illness in Hawai'i. *Hawaii J Med Public Health*. 2014;73(11):33-36. **(Review)**
35. Grubenhoff JA, du Ford K, Roosevelt GE. Heat-related illness. *Clin Pediatr Emerg Med*. 2007;8(1):59-64. **(Review)**
36. Bytomski JR, Squire DL. Heat illness in children. *Curr Sports Med Rep*. 2003;2(6):320-324. **(Review)**
37. Simon HB. Hyperthermia. *N Engl J Med*. 1993;329(7):483-487. **(Review)**
38. Falk B, Dotan R. Children's thermoregulation during exercise in the heat: a revisit. *Appl Physiol Nurt Metab*. 2008;33(2):420-427. **(Review)**
39. Gomes LH, Carneiro-Junior MA, Marins JC. Thermoregulatory responses of children exercising in a hot environment. *Rev Paul Pediatr*. 2013;31(1):104-110. **(Review)**
40. Naughton GA, Carlson JS. Reducing the risk of heat-related decrements to physical activity in young people. *J Sci Med Sport*. 2008;11(1):58-65. **(Review)**
41. Armstrong LE, Maresh CM. Exercise-heat intolerance of children and adolescents. *Pediatr Exerc Sci*. 1995;7(3):239–252. **(Review)**
42. Inbar O, Morris N, Epstein Y, et al. Comparison of thermoregulatory responses to exercise in dry heat among prepubertal boys, young adults and older males. *Exp Physiol*. 2004;89(6):691-700. **(Prospective; 24 subjects)**
43. Kravchenko J, Abernethy AP, Fawzy M, et al. Minimization of heatwave morbidity and mortality. *Am J Prev Med*. 2013;44(3):274-282. **(Review)**
44. Rivera-Brown AM, Rowland TW, Ramirez-Marrero, et al. Exercise tolerance in a hot and humid climate in heat-acclimatized girls and women. *Int J Sports Med*. 2006;27(12):943-950. **(Prospective case-control; 18 subjects)**
45. Rowland T, Hagenbuch S, Pober D, et al. Exercise tolerance and thermoregulatory responses during cycling in boys and men. *Med Sci Sports Exerc*. 2008;40(2):282-287. **(Prospective case-control; 16 subjects)**
46. Falk B. Effects of thermal stress during rest and exercise in the paediatric population. *Sports Med*. 1998;25(4):221-240. **(Review)**
47. Falk B, Bar-Or O, Macdougall JD. Thermoregulatory responses of pre-, mid-, and late-pubertal boys to exercise in dry heat. *Med Sci Sports Exerc*. 1992;24(6):688-694. **(Prospective; 31 subjects)**
48.* Bergeron MF, Devore C, Rice SG. Policy statement – climatic heat stress and exercising children and adolescents. Council on Sports Medicine and Fitness and Council on School Health. American Academy of Pediatrics. *Pediatrics*. 2011;128(3):e741-e747. **(Policy statement)**

49. Bouchama A, Knochel JP. Heat stroke. *N Engl J Med*. 2002;346(25):1978-1988. **(Review)**
50.* Jardine DS. Heat illness and heat stroke. *Pediatr Rev.* 2007;28(7):249-258. **(Review)**
51. Frank B, Fields SA. Heat exhaustion and heat stroke. In: Domino FJ, ed. *The 5-Minute Clinical Consult Standard 2016*. Philadelphia, PA: Wolters Kluwer Health/Lippincott Williams & Wilkins; 2015:470-471. **(Textbook chapter)**
52. Mandt MJ, Grubenhoff JA. Emergencies & injuries. In: Hay WW, Levin MJ, Deterding RR, et al, eds. *Current Diagnosis & Treatment: Pediatrics*. New York, NY: McGraw-Hill Medical; 2014:351-352. **(Textbook chapter)**
53. Solari PB, Wright PL, Woodward GA. Heat stroke and related illnesses. In: *The 5-Minute Pediatric Consult 2013*. Philadelphia, PA: Wolters Kluwer Health/Lippincott Williams & Wilkins; 2012:392-393. **(Textbook chapter)**
54. Hopkins PM. Is there a link between malignant hyperthermia and exertional heat illness? *Br J Sports Med*. 2007;41(5):283-284. **(Review)**
55. Muldoon S, Deuster P, Brandom B, et al. Is there a link between malignant hyperthermia and exertional heat illness? *Exerc Sport Sci Rev.* 2004;32(4):174-179. **(Review)**
56. Kerr ZY, Marshall SW, Comstock RD, et al. Exertional heat stroke management strategies in United States high school football. *Am J Sports Med*. 2014;42(1):70-77. **(Cross sectional survey; 1142 athletic trainers)**
57. Adams WM, Mazerolle SM, Casa DJ, et al. The secondary school football coach's relationship with the athletic trainer and perspectives on exertional heat stroke. *J Athl Train*. 2014;49(4):469-477. **(Online questionnaire; 38 participants)**
58. Coris E, Walz S, Konin J, et al. Return to activity considerations in a football player predisposed to exertional heat illness: a case study. *J Sport Rehabil*. 2007;16(3):260-270. **(Case study)**
59. Pryor RR, Seitz JR, Morley J, et al. Estimating core temperature with external devices after exertional heat stress in thermal protective clothing. *Prehosp Emerg Care*. 2012;16(1):136-141. **(Prospective; 50 subjects)**
60. Muniz AE. Ischemic electrocardiographic changes and elevated troponin from severe heat stroke in an adolescent. *Pediatr Emerg Care*. 2012(1);28:64-67. **(Case report)**
61. Casa DJ, Armstrong LE, Kenny GP, et al. Exertional heat stroke: new concepts regarding cause and care. *Curr Sports Med Rep*. 2012;11(3):115-123. **(Review)**
62. LoVecchio F, Pizon AF, Berrett C, et al. Outcomes after environmental hyperthermia. *Am J Emerg Med*. 2007;25(4):442-444. **(Retrospective; 52 patients)**
63. Casa DJ, McDermott BP, Loe EC, et al. Cold water immersion: the gold standard for exertional heat stroke treatment. *Exerc Sport Sci Rev*. 2007;35(3):141-149. **(Review)**
64. O'Connor FG, Williams AD, Blivin S, et al. Guidelines for return to duty (play) after heat illness: a military perspective. *J Sport Rehabil*. 2007;16(3):227-237. **(Review)**
65.* Hadad E, Rav-Acha M, Heled Y, et al. Heat stroke: a review of cooling methods. *Sports Med*. 2004;34(8):501-511. **(Review)**
66. Hostler D, Northington WE, Callaway CW. High-dose diazepam facilitates core cooling during cold saline infusion in healthy volunteers. *Appl Physiol Nutr Metab*. 2009;34(4):582-586. **(Prospective randomized controlled; 15 subjects)**
67. Syverud SA, Barker WJ, Amsterdam JT, et al. Iced gastric lavage for treatment of heatstroke: efficacy in a canine model. *Ann Emerg Med*. 1985;14(5):424-432. **(Experimental canine model; 11 animals)**
68. White JD, Riccobene E, Nucci R, et al. Evaporation versus iced gastric lavage treatment of heatstroke: comparative efficacy in a canine model. *Crit Care Med*. 1987;15(8):748-750. **(Experimental canine model; 9 animals)**
69. Zhou F, Song Q, Peng Z, et al. Effects of continuous venous-venous hemofiltration on heat stroke patients: a retrospective study. *J Trauma*. 2011;17(6):1562-1568. **(Retrospective; 16 patients)**
70. Casa DJ, Armstrong LE, Ganio MS, et al. Exertional heat stroke in competitive athletes. *Curr Sports Med Reports*. 2005;4(6):309-317. **(Review)**
71. Flouris AD, Wright-Beatty HE, Friesen BJ, et al. Treatment of exertional heat stress developed during low or moderate physical work. *Eur J Appl Physiol*. 2014;114(12):2551-2560. **(Prospective; 9 subjects)**
72. Armstrong LE, Crago AE, Adams R, et al. Whole-body cooling of hyperthermic runners: comparison of two field therapies. *Am J Emerg Med*. 1996;14(4):355-358. **(Observational; 21 subjects)**
73. Proulx CI, Ducharme MB, Kenny GP. Effect of water temperature on cooling efficiency during hyperthermia in humans. *J Appl Physiol*. 2003;94(4):1317-1323 **(Experimental; 7 subjects)**
74. Clements JM, Casa DJ, Knight J, et al. Ice-water immersion and cold-water immersion provide similar cooling rates in runners with exercise-induced hyperthermia. *J Athl Train*. 2002;37(2):146-150 **(Prospective crossover; 17 subjects)**
75. Shibasaki M, Inoue Y, Kondo N. Mechanisms of underdeveloped sweating responses in prepubertal boys. *Eur J Physiol Occup Physiol*. 1997;76(4):340-345. **(Prospective; 19 subjects)**
76. Shibasaki M, Inoue Y, Kondo N, et al. Relationship between skin blood flow and sweating rate in prepubertal boys and young men. *Acta Physiol Scand*. 1999;167(2):105-110. **(Prospective; 19 subjects)**
77. Kielblock AJ, Van Rensburg JP, Franz RM. Body cooling as a method for reducing hyperthermia: an evaluation of techniques. *S Afr Med J*. 1986;69(6):378-380. **(Prospective; 5 subjects)**
78. Al-Harthi SS, Yaqub BA, Al-Nozha MM, et al. Management of heat stroke patients by rapid cooling at Mecca pilgrimage. *Saudi Med J*. 1986;7:369. **(Prospective randomized controlled trial; 16 subjects)**
79. Guard A, Gallagher SS. Heat related deaths to young children in parked cars: an analysis of 171 fatalities in the United States, 1995-2002. *Inj Prev*. 2005;11(1):33-37. **(Retrospective; 171 subjects)**
80. Ferrara P, Vena F, Caporale O, et al. Children left unattended in parked vehicles: a focus on recent Italian cases and a review of literature. *Ital J Pediatr*. 2013;39:71. **(Review)**
81. Balbus JM, Malina C. Identifying vulnerable subpopulations for climate change health effects in the United States. *J Occup Environ Med*. 2009;51(1):33-37. **(Review)**
82. Allen SB, Cross KP. Out of the frying pan, into the fire. A case of heat shock and its fatal complications. *Pediatr Emerg Care*. 2014;30(12):904-910. **(Case report)**
83. Perrin AE, Jotwani VM. Addressing the unique issues of student athletes with ADHD. *J Fam Pract*. 2014;63(5):1-9. **(Review)**
84. Shimizu T, Yamashita Y, Satoi M, et al. Heat stroke-like episode in a child caused by zonisamide. *Brain Dev*. 1997;19(5):366-368. **(Case report)**
85. Armstrong LE, Casa DJ, Maresh CM, et al. Caffeine, fluid-electrolyte balance, temperature regulation, and exercise-heat tolerance. *Exerc Sport Sci Rev*. 2007;35(3):135-140. **(Review)**
86. Suvi S, Timpmann S, Tamm M, et al. Effects of caffeine on endurance capacity and psychological state in young females and males exercising in the heat. *Appl Physiol Nutr Metab*. 2017;42(1):68-76. **(Prospective; 23 subjects)**
87. Gunja N. Teenage toxins: recreational poisoning in the ado-

lescent. *J Pediatr Child Health.* 2012;48(7):560-566. **(Review)**

88. Levine M, LoVecchio F, Ruba AM, et al. Influence of drug use on morbidity and mortality in heat stroke. *J Med Toxicol.* 2012;8(3):252-257. **(Case-control; 78 patients)**
89. Fink E, Brandom BW, Torp KD. Heatstroke in the super-sized athlete. *Pediatr Emerg Care*. 2006;22(7):510-513. **(Case report)**
90. Raj VM, Alladin A, Pfeiffer B, et al. Therapeutic plasma exchange in the treatment of exertional heat stroke and multiorgan failure. *Pediatr Nephrol*. 2013;28(6):971-974. **(Case report)**
91. Bedno SA, Li Y, Han W, et al. Exertional heat illness among overweight U.S. Army recruits in basic training. *Aviat Space Environ Med*. 2010;81(2):107-111. **(Prospective case-control; 9667 subjects)**
92. Dougherty KA, Chow M, Kenney WL. Critical environmental limits for exercising heat-acclimated lean and obese boys. *Eur J Appl Physiol*. 2010;108(4):779-789. **(Prospective case-control; 14 subjects)**
93. Dougherty KA, Chow M, Kenney WL. Responses of lean and obese boys to repeated summer exercise in the heat bouts. *Med Sci Sports Exerc*. 2009;41(2):279-289. **(Prospective case-control; 14 subjects)**
94. Kim S, Jo S, Myung H, et al. The effect of pre-existing medical conditions on heat stroke during hot weather in South Korea. *Environ Res*. 2014;133:246-252. **(Retrospective; 968 patients)**
95. Wang X, Barnett A, Guo Y, et al. Increased risk for emergency hospital admissions for children with renal diseases during heatwaves in Brisbane, Australia. *World J Pediatr*. 2014;10(4):330-335. **(Retrospective; 1565 patients)**
96. Hess JJ, Saha S, Luber G. Summertime acute heat illness in US emergency departments from 2006 through 2010: analysis of a nationally representative sample. *Environ Health Perspect*. 2014;122(11):1209-1215. **(Retrospective; 326,497 visits)**
97. Howorth PJN. The biochemistry of heat illness. *J R Army Med Corps*. 1995;141(1):40-41. **(Review)**
98. Kritikou-Pliota E, Galanakis E, Alfadaki SA, et al. Cystic fibrosis presenting as heat stroke. *Acta Paediatr.* 2000;89(1):121-122. **(Case report)**
99. Prasun P, Karmarkar SA, Agarwal A, et al. Unusual physical features and heat stroke presentation for hypohydrotic ectodermal dysplasia. *Clin Dysmorphol.* 2012;21(1):24-26. **(Case report)**
100. Ray S, Sharma S, Maheshwari A, et al. Heat stroke in an infant with hypohidrotic ectodermal dysplasia: brain magnetic resonance imaging findings. *J Child Neurol*. 2013;28(4):538-540. **(Case report)**
101. Tirosh I, Hoffer V, Finkelstein Y, et al. Heat stroke in familial dysautonomia. *Pediatr Neurol*. 2003;29(2):164-166. **(Case report)**
102. Wirthwein DP, Spotswood SD, Barnard JJ, et al. Death due to microvascular occlusion in sickle-cell trait following physical exertion. *J Forensic Sci.* 2001;46(2):399-401. **(Case report)**
103. Watson JD, Ferguson C, Hinds CJ, et al. Exertional heat stroke induced by amphetamine analogues. Does dantrolene have a place? *Anaesthesia*. 1993;48(12):1057-1060. **(Case series)**
104. Chen G, Chen Y, Zhang W, et al. Therapy of severe heat-shock in combination with multiple organ dysfunction with continuous renal replacement therapy. *Medicine (Baltimore)*. 2015;94(31):1-8. **(Retrospective case-control; 33 patients)**
105. Kawanami S, Horie S, Inoue J, et al. Urine temperature as an index for the core temperature of industrial workers in hot or cold environments. *Int J Biometeorol*. 2012;56(6):1025-1031. **(Prospective; 31 subjects)**
106. Pillai SK, Noe RS, Murphy MW, et al. Heat illness: predictors of hospital admissions among emergency department visits- Georgia, 2002-2008. *J Community Health*. 2014;39:90-98. **(Retrospective case-control; 13,562 cases)**
107. Casa DJ, Csillan D. Preseason heat-acclimatization guidelines for secondary school athletics. *J Athl Train*. 2009;44(3):332-333. **(Guidelines)**
108.* Bergeron MF, McKeag DB, Casa DJ, et al. Youth football: heat stress and injury risk. *Med Sci Sports Exerc*. 2005;37(8):1421-1430. **(Consensus statement)**
109. Kerr ZY, Marshall SW, Comstock RD, et al. Implementing exertional heat illness prevention strategies in US high school football. *Med Sci Sports Exerc.* 2014;46(1):124-130. **(Cross sectional survey; 1142 athletic trainers)**
110. McGarr GW, Hartley GL, Cheung SS. Neither short-term sprint nor endurance training enhances thermal response to exercise in a hot environment. *J Occup Environ Hyg*. 2014;11(1):47-53. **(Prospective pre-post paired sample; 16 subjects)**
111. Bergeron MF. Hydration and thermal strain during tennis in the heat. *Br J Sports Med.* 2014;48(1):1-7. **(Review)**
112. Bergeron MF, McLeod KS, Coyle JF. Core body temperature during competition in the heat: National Boys' 14s Junior Championships. *Br J Sports Med*. 2007;41(11):779-783. **(Observational study; 80 subjects)**
113. Luke AC, Bergeron MF, Roberts WO. Heat injury prevention practices in high school football. *Clin J Sport Med*. 2007;17(6):488-493. **(Web-based survey)**
114. Vepraskas C. Beat the heat: managing heat and hydration in marching band. *J Sch Nurs*. 2002;18(4):237-243. **(Review)**
115. Lee JK, Shirreffs SM, Maughan RJ. Cold drink ingestion improves exercise endurance capacity in the heat. *Med Sci Sports Exerc.* 2008;40(9):1637-1644. **(Prospective case-control; 8 subjects)**
116. Rivera-Brown A, Ramirez-Marrero FA, Wilk B, et al. Voluntary drinking and hydration in trained, heat-acclimatized girls exercising in a hot and humid climate. *Eur J Appl Physiol*. 2008;103(1):109-116. **(Prospective; 12 subjects)**
117. Wilk B, Bar-Or O. Effect of drink flavor and NaCl on voluntary drinking and hydration in boys exercising in the heat. *J Appl Physiol*. 1996;80(4):1112–1117. **(Observational study; 24 subjects)**
118. Wilk B, Rivera-Brown A, Bar-Or O. Voluntary drinking and hydration in non-acclimatized girls exercising in the heat. *Eur J Appl Physiol*. 2007;101(6):727-734. **(Prospective; 12 subjects)**
119. Bergeron MF. Youth sports in the heat: recovery and scheduling considerations for tournament play. *Sports Med.* 2009;39(7):513-522. **(Review)**
120. Bergeron MF, Laird MD, Marinik EL, et al. Repeated-bout exercise in the heat in young athletes: physiological strain and perceptual responses. *J Appl Physiol.* 2009;106(2):476-485. **(Prospective; 24 athletes)**
121. Rav-Acha M, Hadad E, Epstein Y, et al. Fatal exertional heat stroke: a case series. *Am J Med Sci*. 2004;328(2):84-87. **(Case series)**

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1. **What is the outside temperature that puts an infant who is left in a car at risk for heat stroke?**
   a. 24°C (75.2°F)
   b. 32°C (89.6°F)
   c. 38°C (100.4°F)
   d. All of the above

2. **Which athlete is most at risk for a heat-related illness?**
   a. A 14-year-old who plays soccer
   b. A 16-year-old who plays football
   c. A 15-year-old who plays tennis
   d. A 13-year-old who plays basketball

3. **A 16-year-old girl presents with dizziness and fatigue after a softball tournament on a hot, humid day. Her temperature is 39°C (102.2°F) and she has a normal neurologic examination. What is the most likely diagnosis?**
   a. Heat stress
   b. Heat exhaustion
   c. Heat stroke
   d. Malignant hyperthermia

4. **On a hot, humid day, a 12-year-old boy presents with altered mental status (GCS score, 12) after soccer practice. His vital signs are significant for a temperature of 41°C (105.8°F). What is the most likely diagnosis?**
   a. Heat stress
   b. Heat exhaustion
   c. Heat stroke
   d. Malignant hyperthermia

5. **What is the preferred route of measuring temperature during management of a patient with heat stroke?**
   a. Rectal thermometer
   b. Axillary thermometer
   c. Temporal thermometer
   d. Tympanic membrane thermometer

6. **What heat dissipation methods are utilized for optimal treatment of a patient with a heat-related illness?**
   a. Radiation and evaporation
   b. Radiation and convection
   c. Conduction and evaporation
   d. Conduction and convection

7. **What is the preferred method of cooling in the ED setting?**
   a. Tap-water immersion
   b. Evaporative cooling
   c. Iced peritoneal lavage
   d. Administration of dantrolene

8. **What is the recommended technique for performing evaporative cooling for a heat-related illness?**
   a. Spraying ice water over the body in a setting with continuous airflow
   b. Wrapping the body with towels that are soaked in ice water in a setting with continuous airflow
   c. Spraying warm water over the body in a setting with continuous airflow
   d. Wrapping the body with towels that are soaked in warm water in a setting with continuous airflow

9. **Which medication increases the risk of a heat-related illness?**
   a. Nonsteroidal anti-inflammatory drugs
   b. Stimulant medications
   c. Antipyretic medications
   d. Beta-adrenergic medications

10. **What pre-existing medical condition places a child at an increased risk of a heat-related illness?**
    a. Asthma
    b. Hydrocephalus
    c. Supraventricular tachycardia
    d. Cystic fibrosis

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Erratum

In the “Nonaccidental Injury in Pediatric Patients: Detection, Evaluation, and Treatment” article in *Pediatric Emergency Medicine Practice,* Vol. 14, No. 7, an arrow on the “Clinical Pathway for Evaluation of Nonaccidental Injuries in Children” on page 12 connected to the wrong box.

The "NO" arrow that connected the “Is the injury concerning for abuse?” box to the “Does evaluation reveal a medical etiology for presentation?” should have connected to the “Perform usual care” box.

The correct version of this article appears on our website at: www.ebmedicine.net/NAI

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Needs Assessment: The need for this educational activity was determined by a survey of medical staff, including the editorial board of this publication; review of morbidity and mortality data from the CDC, AHA, NCHS, and ACEP; and evaluation of prior activities for emergency physicians.

Target Audience: This enduring material is designed for emergency medicine physicians, physician assistants, nurse practitioners, and residents.

Goals: Upon completion of this activity, you should be able to: (1) demonstrate medical decision-making based on the strongest clinical evidence; (2) cost-effectively diagnose and treat the most critical ED presentations; and (3) describe the most common medicolegal pitfalls for each topic covered.

CME Objectives: Upon completion of this article, you should be able to: (1) identify pediatric patients at risk for heat-related illness; (2) recognize physical findings of pediatric patients suffering from a heat-related illness; (3) appropriately treat heat-related illness in pediatric patients; and (4) educate patients and peers regarding prevention of heat-related illness.

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