TABLE 479e-2 TYPICAL MANIFESTATIONS OF HEATSTROKE

Classic	Exertional
Older patient	Younger patient
Predisposing health factors/medications	Healthy condition
Epidemiology (heat waves)	Sporadic cases
Sedentary	Exercising
Anhidrosis (possible)	Diaphoresis (common)
Central nervous system dysfunction	Myocardial/hepatic injury
Oliguria	Acute renal failure
Coagulopathy (mild)	Disseminated intravascular coagulation
Mild lactic acidosis	Marked lactic acidosis
Mild creatine kinase elevation	Rhabdomyolysis
Normoglycemia/calcemia	Hypoglycemia/calcemia
Normokalemia	Hyperkalemia

The definitive diagnosis should be reserved until the other potential causes of hyperthermia are excluded. Many of the usual laboratory abnormalities seen with heatstroke overlap with other conditions. If the patient's mental status does not improve with cooling, toxicologic screening may be indicated, and cranial CT and spinal fluid analysis can be considered.

The premonitory clinical characteristics may be nonspecific and include weakness, dizziness, disorientation, ataxia, and gastrointestinal or psychiatric symptoms. These prodromal symptoms often resemble heat exhaustion. The sudden onset of heatstroke occurs when the maintenance of adequate perfusion requires peripheral vasoconstriction to stabilize the mean arterial blood pressure. As a result, the cutaneous radiation of heat ceases. At this juncture, the core temperature rises dramatically. Since many patients with heatstroke also meet the criteria for systemic inflammatory response syndrome and have a broad differential diagnosis, rapid cooling is essential during the extensive diagnostic evaluation (Table 479e-1).

There are two forms of heatstroke with significantly different manifestations (Table 479e-2). Classic (epidemic) heatstroke (CHS) usually occurs during long periods of high ambient temperature and humidity, as during summer heat waves. Patients with CHS commonly have chronic diseases that predispose to heat-related illness, and they may have limited access to oral fluids. Heat dissipation mechanisms are overwhelmed by both endogenous heat production and exogenous heat stress. Patients with CHS are often compliant with prescribed medications that can impair tolerance to a heat stress. In many of these dehydrated CHS patients, sweating has ceased and the skin is hot and dry. If cooling is delayed, severe hepatic dysfunction, renal failure, disseminated intravascular coagulation, and fulminant multisystem organ failure may occur. Hepatocytes are very heat sensitive. On presentation, the serum level of aspartate aminotransferase (AST) is routinely elevated. Eventually, levels of both AST and alanine aminotransferase (ALT) often increase to >100 times the normal values. Coagulation studies commonly demonstrate decreased platelets, fibrinogen, and prothrombin. Most patients with CHS require cautious crystalloid resuscitation, electrolyte monitoring, and—in certain refractory cases—consideration of central venous pressure (CVP) measurements. Hypernatremia is secondary to dehydration in CHS. Many patients exhibit significant stress leukocytosis, even in the absence of infection.

Patients with exertional heatstroke (EHS), in contrast to those with CHS, are often young and previously healthy, and their diagnosis is usually more obvious from the history. Athletes, laborers, and military recruits are common victims. Unlike those with CHS, many EHS patients present profusely diaphoretic despite significant dehydration. As a result of muscular exertion, rhabdomyolysis and acute renal failure are more common in EHS. Studies to detect rhabdomyolysis and its complications, including hypocalcemia and hyperphosphatemia, should be considered. Hyponatremia, hypoglycemia, and coagulopathies are frequent findings. Elevated creatine kinase and lactate dehydrogenase levels also suggest EHS. Oliguria is a common finding. Renal failure can result from direct thermal injury, untreated rhabdomyolysis, or volume depletion. Common urinalysis findings include microscopic hematuria, myoglobinuria, and granular or red cell casts.

With both CHS and EHS, heat-related reversible increases in cardiac biomarker levels are often present. Heatstroke often causes thermal cardiomyopathy. As a result, the CVP may be elevated despite significant dehydration. In addition, the patient often presents with potentially deceptive noncardiogenic pulmonary edema and basilar rales despite being significantly hypovolemic. The electrocardiogram commonly displays a variety of tachyarrhythmias, nonspecific ST-T wave changes, and heat-related ischemia or infarction. Rapid cooling—not the administration of antiarrhythmic medications—is essential.

Above 42°C (107.6° F), heat can rapidly produce direct cellular injury. Thermosensitive enzymes become nonfunctional, and eventually there is irreversible uncoupling of oxidative phosphorylation. The production of heat-shock proteins increases, and cytokines mediate a systemic inflammatory response. The vascular endothelium is also damaged, and this injury activates the coagulation cascade. Significant shunting away from the splanchnic circulation produces gastrointestinal ischemia. Endotoxins further impair normal thermoregulation. As a result, if cooling is delayed, severe hepatic dysfunction, permanent renal failure, disseminated intravascular coagulation, and fulminant multisystem organ failure may occur.

COOLING STRATEGIES

Before cooling is initiated, endotracheal intubation, CVP determination, and continuous core-temperature monitoring should be considered. Hypoglycemia is a frequent finding and can be addressed by glucose infusion. Since peripheral vasoconstriction delays heat dissipation, repeated administration of discrete boluses of isotonic crystalloid for hypotension is preferable to the administration of α-adrenergic agonists.

Evaporative cooling is usually the most practical and effective technique. Rapid cooling is essential in both CHS and EHS, and an immediate improvement in vital signs and mental status may prove valuable for diagnostic purposes. Cool water (15°C [60° F]) is sprayed on the exposed skin while fans direct continuous airflow over the moistened skin. Cold packs applied to the axillae and groin are a useful cooling adjunct. If cardiac electrodes will not adhere, they can be applied to the patient's back. To avoid "overshoot hypothermia," active cooling should be terminated at ~38°–39°C (100.4°–102.2°F).

Immersion cooling in cold water is an alternative option in EHS but induces peripheral vasoconstriction and intense shivering. This technique presents significant monitoring and resuscitation challenges in most clinical settings. The safety of immersion cooling is best established for young, previously healthy patients with EHS (but not for those with CHS).

Cooling with commercially available cooling blankets should not be the sole technique used, since the rate of cooling is far too slow. Other methods are less efficacious and rarely indicated, such as IV infusion of cold fluids and cold irrigation of the bladder or gastrointestinal tract. Cold thoracic and peritoneal lavage are efficient maneuvers but are invasive and rarely necessary. Cardiopulmonary bypass provides fast and effective cooling but is labor intensive and is rarely available on a stat basis.

RESUSCITATION

Aspiration and seizures commonly occur in heatstroke, and endotracheal intubation is usually necessary. The metabolic demands are high, and supplemental oxygenation is essential due to hypoxemia induced by thermal stress and pulmonary dysfunction. Pneumonitis, pulmonary infarction, hemorrhage, edema, and acute respiratory distress syndrome occur frequently in heatstroke patients.

The circulatory fluid requirements, particularly in CHS, may be deceptively modest. Aggressive cooling and modest volume repletion usually elevate the CVP to 12–14 mmHg. The reading, however,