

# HEAT EMERGENCIES

REPRESENT A SPECTRUM OF DISORDERS, INCLUDING HEAT CRAMPS, HEAT SYNCOPE, HEAT EXHAUSTION AND HEAT STROKE.

- The differentiation is somewhat blurred & patients can rapidly progress from relatively benign to life-threatening disease.

HEAT STROKE IS SEEN LESS AMONG PERSONS WHO LIVE IN COUNTRIES WHERE HOT SUMMERS ARE COMMON BECAUSE OF PHYSIOLOGICAL ACCLIMATISATION

## **PATHOPHYSIOLOGY:**

### **MECHANISMS OF HEAT TRANSFER:**

- Body temperature is regulated through the delicate balance of HEAT PRODUCTION, ACCUMULATION AND DISSIPATION

### **METHODS OF DISSIPATION:**

- RADIATION;
  - transfer by electromagnetic waves from warmer object to cooler one
- CONDUCTION;
  - heat exchange between two surfaces in direct contact
- CONVECTION;
  - heat transfer by air or liquid moving across the surface of an object
- EVAPORATION;
  - heat loss by vaporisation of water

When temperature is  $<35^{\circ}\text{C}$ , radiation accounts for ~60% of heat dissipation and evaporation for 30%

EFFECT OF WIND ON HEAT LOSS --> approximately proportional to square root of the wind velocity

When temperature rises to  $>35^{\circ}\text{C}$ , the body can no longer radiate heat to the environment and becomes dependent on evaporation for heat transfer.

AS HUMIDITY INCREASES, THE POTENTIAL FOR EVAPORATIVE HEAT LOSS DECREASES

- Hence the combination of HIGH TEMPERATURE AND HIGH HUMIDITY blocks the two main physiologic mechanisms that the body uses to dissipate heat.

### **RESPONSE TO HEAT STRESS:**

- Native thermal regulation mechanisms begin to fail at core temperatures  $>35-40^{\circ}\text{C}$ 
  - It is possible to maintain a core temperature of  $40-42^{\circ}\text{C}$  for short periods without adverse effects

- **PHYSIOLOGIC RESPONSE TO HEAT STRESS OCCURS THROUGH FOUR PRIMARY MECHANISMS:**
  - Dilatation of blood vessels
    - Especially in the skin
  - Increased sweat production
  - Decreased heat production
  - Behavioural changes --> find a cool environment
- As body temperature rises, the sympathetic outflow of the posterior hypothalamus is inhibited;
  - unopposed anterior hypothalamic sympathetic outflow
  - decreased vascular tone throughout the body, especially in the cutaneous circulation
  - substantial CV stress from this response, because CO increases by ~3L/minute for each 1°C above core temperature
  - Can result in myocardial ischaemia, arrhythmias & CHF

### **ACCLIMATISATION:**

- Human body has incredible capacity to respond to heat stress
- Primary acclimatisation involves changes in onset and volume of sweating, improvement in cutaneous vascular flow and overall CV function (Can be achieved over 7 days)

### **PATH TO HEAT INJURY:**

- Heat exhaustion and heat stroke occur when the body's thermoregulatory responses are impaired or **OVERWHELMED** and are no longer capable of maintaining homeostasis
- Excessive heat is **DIRECTLY TOXIC TO CELLS**;
  - Causes an acute phase reaction and release of inflammatory cytokines, heat-shock proteins & stress proteins.
  - Proteins are denatured & cellular processes are interrupted.
  - Damages vascular endothelium
- Massive activation of clotting-cascade occurs --> DIC.
- Classic heat injury occurs during high environmental heat stress.
  - Takes hours --> days.
- **HIGH RISK POPULATIONS:**
  - Elderly
  - The young
  - Psychological, physiologic & pharmacologic impairments.
- Exertional heat injury usually affects individuals who are physically fit and participating in athletic events or performing jobs under conditions of high heat stress (military, firefighters)
- Without an efficient cooling mechanism, progressive dehydration and hyperpyrexia continue to the level of **CARDIOVASCULAR & METABOLIC FAILURE**.

## **CLINICAL FEATURES AND TREATMENT:**

### **HEAT OEDEMA:**

- Self-limited. Mild swelling of feet, ankles and hands that appears in first few days of hot weather.
- Due to cutaneous vasodilatation and orthostatic pooling of interstitial fluid
- Oedema is exacerbated by heat-induced release of ADH and aldosterone
- No special treatment is necessary. Diuretics not effective

### **PRICKLY HEAT:**

- A pruritic, maculopapular, erythematous rash over normally clothed areas (aka. heat rash)
- It is an acute inflammation of the sweat ducts caused by blockage of the sweat pores by macerated stratum corneum
- Wearing clean, light and loose-fitting clothing is the cure



### **HEAT CRAMPS:**

- Painful, involuntary and spasmodic contractions of skeletal muscles, usually those of the calves (can effect thighs & shoulders)
- Usu. occur in those who are SWEATING PROFUSELY and replace fluid losses with water or other hypotonic solutions
- Most often occur during a rest period after several hours of vigorous physical activity.
- Do not involve enough muscle mass to cause rhabdomyolysis.
- Check electrolytes: May have *hyponatraemia* & *hypokalaemia*.
- TREATMENT: fluid and salt replacement (PO or IV) and rest in a cool environment. Consider sports drinks.

### **HEAT TETANY:**

- Consists of typical *hyperventilation* resulting in:
  - Respiratory alkalosis
  - Paraesthesia of the extremities
  - Circumoral paraesthesia
  - Carpopedal spasm
- Remove from heat and decrease the RR.

### HEAT SYNCOPE:

- A *variant of postural hypotension* & results from the cumulative effect of:
  - VOLUME DEPLETION
  - PERIPHERAL VASODILATATION
  - DECREASED VASOMOTOR TONE
- Occurs early in heat exposure
- Elderly most at risk.
- Exclude metabolic, CV and neurologic disorders that cause syncope.
- Remove from heat and rehydrate.

### HEAT EXHAUSTION:

- Occurs in two different ways --> water depletion or sodium depletion, but is **OFTEN A COMBINATION OF BOTH**
- Presents with headache, N+V, malaise, dizziness and muscle cramps as well as signs of dehydration such as tachycardia and orthostatic hypotension.
- **DIAGNOSIS OF EXCLUSION**
- On exam; temperature may be normal or elevated, BUT NOT > 40°C.
  - Patients **DO NOT MANIFEST CNS IMPAIRMENT !**
- Lab studies;
  - Haemoconcentration, specific electrolyte abnormalities depending on fluid and electrolyte losses to intake
  - No fluid intake --> hypernatraemia
  - Partially rehydrate with salt-containing solutions --> isotonic hypovolaemia
  - Hyponatraemia if rehydration with hypotonic solution
- TREATMENT:
  - Volume and electrolyte replacement and removal from heat-stressed environment
  - If patients do not respond to 30 minutes of fluid replacement, aggressive cooling is mandated.

**Table 204-1 Signs and Symptoms of Heat Emergencies**

| Heat Cramps                                                        | Heat Exhaustion                                                                                                                                                                                                   | Heat Stroke                                                                                                                                                                                                                                               |
|--------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Muscle cramps<br>Normal to mildly elevated temperature<br>Sweating | Symptoms seen in heat cramps plus:<br><br>Normal to elevated temperature [ $<40^{\circ}\text{C}$ ( $<104^{\circ}\text{F}$ )]<br><br>Nausea, vomiting, headache, malaise, dizziness<br><br>Orthostatic hypotension | Symptoms seen in heat exhaustion plus:<br><br>Elevated temperature [ $>40^{\circ}\text{C}$ ( $>104^{\circ}\text{F}$ )]<br><br>Neurologic abnormalities: inappropriate behavior, confusion, delirium, ataxia, coma, seizures<br><br>Anhidrosis or sweating |

## HEAT STROKE:

An acute, life-threatening emergency with mortality rates as high as 30-80% and is  
**UNIVERSALLY FATAL IF LEFT UNTREATED**

### **CARDINAL FEATURES OF HEAT STROKE:**

- HYPERTHERMIA ( $> 40^{\circ}\text{C}$ )
- ALTERED MENTAL STATUS
  - Absence of sweat is NOT DIAGNOSTIC as sweat is present in over half patients with heat stroke.
- CNS is particularly vulnerable to heat stroke, esp the CEREBELLUM
  - Ataxia is an early finding
  - Virtually any neurologic abnormality can be ascribed to heat stroke
  - SEIZURES ARE QUITE COMMON (esp. during cooling)
  - Neurologic injury is a function of maximum temperature reached and the duration of exposure
  - Can progress to plantar responses, decorticate and decerebrate posturing, hemiplegia, status epilepticus and coma
- Medications often interfere with heat-removal mechanisms
  - Anticholinergic drugs, diuretics, phenothiazines,  $\beta$ -blockers, CCB & sympathomimetic agents are most notable
- IMMEDIATE COOLING AND SUPPORT OF ORGAN SYSTEM FUNCTION IS THERAPEUTIC
  - A delay in cooling increases the mortality rate
- Evaluation needs to EXCLUDE OTHER PROCESSES:
  - *See DDx list below.*

**Table 204-2 Differential Diagnosis of Heat Stroke**

| <b>Table 204-2 Differential Diagnosis of Heat Stroke</b> |                                                            |
|----------------------------------------------------------|------------------------------------------------------------|
| <b>Infectious</b>                                        | <b>Neurologic</b>                                          |
| Sepsis syndrome                                          | Hypothalamic bleeding or infarct                           |
| Meningitis                                               | Cerebrovascular accident                                   |
| Encephalitis                                             | Status epilepticus                                         |
| Malaria                                                  | <b>Toxicologic</b>                                         |
| Typhoid                                                  | Anticholinergic toxidrome                                  |
| Tetanus                                                  | Sympathomimetic overdose                                   |
| <b>Endocrine</b>                                         | Salicylate overdose                                        |
| Thyroid storm                                            | Serotonin syndrome                                         |
| Pheochromocytoma                                         | Malignant hyperthermia                                     |
| Diabetic ketoacidosis                                    | Neuroleptic malignant syndrome                             |
|                                                          | Withdrawal syndromes—alcohol and benzodiazepine withdrawal |

## LABORATORY EVALUATION:

- Diagnostic studies are directed toward detecting end-organ damage & excluding other disease processes
- ABG, CK, coagulation profile, ECG, CXR
- Patients with exertional heat stroke often have a *lactic acidosis*
- Hypoglycaemia may occur

## TREATMENT OF HEAT STROKE:

Goals of therapy are IMMEDIATE COOLING AND SUPPORT OF ORGAN SYSTEM FUNCTION

### PREHOSPITAL;

- Remove from the environment while standard resuscitation measures are undertaken.
- Cooling with removal of clothing and spray with warm water and place wet towels or sheets over the patient's body or ice packs over groin, neck and axilla.

### ED MANAGEMENT;

- IV fluids that ensures adequate urine output.
- Check glucose on arrival.
- COOLING TECHNIQUES:
  - ONLY PHYSICAL METHODS (NO ROLE FOR ANTIPYRETICS)
    - They may be deleterious, dantrolene has no role.
- With all cooling methods (summarised below), the goal is to reduce the core temperature to 39C and then stop to avoid overshoot hypothermia

**Table 204-3 Summary of Cooling Techniques**

| Cooling Method                                                    | Advantages                            | Disadvantages                                      | Recommendations                                         |
|-------------------------------------------------------------------|---------------------------------------|----------------------------------------------------|---------------------------------------------------------|
| Evaporative methods                                               | Provides effective cooling            | Can cause shivering                                | Strongly recommended                                    |
|                                                                   | Readily available                     | Less effective in humid environments               |                                                         |
|                                                                   | Practical                             | Makes it difficult to maintain electrode positions |                                                         |
|                                                                   | Well tolerated                        |                                                    |                                                         |
| Ice water immersion                                               | Provides effective cooling            | Can cause shivering                                | Recommended                                             |
|                                                                   |                                       | Poorly tolerated                                   |                                                         |
|                                                                   |                                       | Not compatible with resuscitation settings         |                                                         |
| Ice packs on neck, axillae, and groin                             | Practical                             | Has limited cooling efficacy                       | Can be used as adjunct cooling method                   |
|                                                                   | Can be added to other cooling methods | Poorly tolerated                                   |                                                         |
| Cardiopulmonary bypass                                            | Provides fast and effective cooling   | Invasive                                           | Recommended in severe or resistant cases when available |
|                                                                   |                                       | Not readily available                              |                                                         |
|                                                                   |                                       | Setup is labor intensive                           |                                                         |
| Cooling blankets                                                  | Easy to apply                         | Has limited cooling efficacy                       | Not recommended when other methods available            |
|                                                                   |                                       | Impedes use of other cooling methods               |                                                         |
| Cold water gastric, urinary bladder, rectal, or peritoneal lavage | —                                     | Invasive                                           | Not recommended                                         |
|                                                                   |                                       | Labor intensive                                    |                                                         |
|                                                                   |                                       | May lead to water intoxication                     |                                                         |
|                                                                   |                                       | Human experience is limited                        |                                                         |
| Cold water IV infusion                                            | —                                     | Carries unjustified complication rate              | Not recommended                                         |

- Use warm water when spraying, as when the skin temperature drops below 30C, shivering will resulting more heat production and peripheral vasoconstriction will impair evaporation
- Cold water urinary bladder lavage and rectal lavage are adjuncts but are labour intensive and have the potential for water intoxication
- Bypass is invasive and is reserved for refractory cases

| <b>Table 204-4 Complications of Heat Stroke</b> |                       |                                        |
|-------------------------------------------------|-----------------------|----------------------------------------|
|                                                 | <b>Early</b>          | <b>Late</b>                            |
| Vital signs                                     | Hypotension           | —                                      |
|                                                 | Hypothermic overshoot |                                        |
|                                                 | Hyperthermic rebound  |                                        |
| Muscular                                        | Rhabdomyolysis        | —                                      |
| Neurologic                                      | Delirium/coma         | Cerebral edema                         |
|                                                 | Seizure               | Encephalopathy                         |
|                                                 |                       | Persistent neurologic deficit          |
| Cardiac                                         | Heart failure         | Myocardial injury                      |
| Pulmonary                                       | Pulmonary edema       | Acute respiratory distress syndrome    |
| Renal                                           | Oliguria              | Renal failure                          |
| GI                                              | —                     | Intestinal ischemia or infarction      |
|                                                 |                       | Pancreatic injury                      |
|                                                 |                       | Hepatic dysfunction                    |
| Metabolic                                       | Hypokalemia           | Hyperkalemia                           |
|                                                 | Hypernatremia         | Hypocalcemia                           |
|                                                 | Hyponatremia          | Hyperuricemia                          |
| Hematologic                                     | —                     | Thrombocytopenia                       |
|                                                 |                       | Disseminated intravascular coagulation |

## **TREATMENT OF COMPLICATIONS OF HEAT STROKE:**

- Both early and late complications can occur with heat stroke.
- HYPOTENSION is common initially.
  - Usually responds to IV fluid bolus.
  - Inotropes that cause severe vasoconstriction impede cooling by redirecting blood flow away from the skin
    - use DOBUTAMINE INSTEAD.
- FLUID & ELECTROLYTE ABNORMALITIES
  - Vary depending on type of onset and duration of the disorder and underlying disorders/medications
- DEHYDRATION AND VOLUME DEPLETION
  - May not occur in classic heat stroke but are common findings in heat exhaustion
  - Hypokalaemia due to total-body depletion
  - Hypernatraemia --> free water deficit.
  - Hyponatraemia can be seen in those who hydrate with oral hypotonic solutions
- ABNORMAL HAEMOSTASIS
  - Purpura, petechia and haemorrhage.
  - Occurs due to thermal deactivation of plasma proteins resulting in a decreased level of clotting factors, DIC and fibrinolysis
- THERMAL INJURY TO THE LIVER is common
  - Peaks at 24-72 hours, but does not result in jaundice frequently.
  - CENTRIOLOBULAR NECROSIS.
  - Glucose homeostasis and clotting are affected. Almost always reversible with a full recovery expected.
- RENAL FAILURE
  - Direct thermal injury, rhabdomyolysis or volume depletion
  - Manifest with oliguria.
  - Early, aggressive volume expansion is the key to avoidance.
- ADULT RESPIRATORY DISTRESS SYNDROME
  - May occur and require respiratory support while cooling occurs.
- MYOCARDIAL INJURY
  - Cardiac muscle injury, low cardiac output, with falling cardiac index and hypotension is associated with a poor prognosis
- SEIZURES.
  - May occur during cooling and can be controlled with benzodiazepines.
  - Persistent neurologic deficits occur in ~20% patients and are associated with high mortality