### Factors Predisposing to Hypothermia

#### Decreased Heat Production

**Endocrinologic Failure**

- Hypopituitarism
- Hypoadrenalism
- Hypothyroidism
- Lactic acidosis
- Diabetic and alcoholic ketoacidosis

**Insufficient Fuel**

- Hypoglycemia
- Malnutrition
- Marasmus
- Kwashiorkor
- Extreme physical exertion

**Neuromuscular Physical Exertion**

- Age extremes
- Impaired shivering
- Inactivity
- Lack of adaptation

**Impaired Thermoregulation**

**Peripheral Failure**

- Neuropathies
• Acute spinal cord transection
• Diabetes

Central or Neurologic Failure

• Cardiovascular accident
• Central nervous system trauma
• Toxicologic effects
• Metabolic failure
• Subarachnoid hemorrhage
• Pharmacologic effects
• Hypothalamic dysfunction
• Parkinson disease
• Anorexia nervosa
• Cerebellar lesion
• Neoplasm
• Congenital intracranial anomalies
• Multiple sclerosis
• Hyperkalemic periodic paralysis

Increased Heat Loss

Environmental

• Immersion
• Nonimmersion

Induced Vasodilation

• Pharmacologic effects
• Toxicologic effects

Erythrodermas

• Burns
• Psoriasis
• Ichthyosis
• Exfoliative dermatitis

Iatrogenic
• Emergency childbirth
• Cold infusions
• Heatstroke treatment

Miscellaneous Associated Clinical States

• Multisystem trauma
• Recurrent hypothermia
• Episodic hypothermia
• Shapiro syndrome
• Infections: bacterial, viral, parasitic
• Pancreatitis
• Carcinomatosis
• Cardiopulmonary disease
• Vascular insufficiency
• Uremia
• Paget disease
• Giant cell arteritis
• Sarcoidosis
• Shaken baby syndrome
• Systemic lupus erythematosus
• Wernicke-Korsakoff syndrome
• Hodgkin's disease
• Shock
• Sickle cell anemia
• Sudden infant death syndrome

Decreased Heat Production

Thermogenesis is decreased at both extremes of age. In older adults, neuromuscular inefficiency and decreased physical activity impair shivering. Aging progressively diminishes homeostatic and cold adaptive capabilities. Although most older adults have normal thermoregulation, they tend to develop conditions that impair heat conservation. [283, 286]

Older adults are physiologically less adept at increasing heat production and the respiratory quotient (the ratio of the volume of carbon dioxide produced to the volume of oxygen consumed per unit of time). Impaired thermal perception, possibly caused by decreased resting peripheral blood flow, leads to poor adaptive behavior. Metabolic studies also demonstrate that in severely hypothermic older adults, lipolysis occurs in preference to glucose consumption. [256, 271]

Neonates have a large surface area–to–mass ratio, relatively deficient subcutaneous tissue layer, and virtually no behavioral defense mechanisms. Newborn “unadapted” infants attempt to thermoregulate with initial vasoconstriction and acceleration of metabolic rate. In contrast, “adapted” infants who are older than 5 days can increase lipolysis immediately and burn oxidative brown adipose tissue.
No cause-and-effect relationship has been found between hypothermia and the mortality rate of premature infants. Although the smaller infants in a neonatal intensive care unit are at the greatest risk for hypothermia, mortality is related to hypothermia only in larger neonates. Emergency deliveries and resuscitations are responsible for most acute neonatal hypothermia. Other common risk factors are prematurity, low birth weight, inexperienced mother, perinatal morbidity, and low socioeconomic status. In babies with more chronically induced subacute hypothermia, lethargy, a weak cry, and failure to thrive are common.

Many cold infants have “paradoxical rosy cheeks,” looking surprisingly healthy. After the first few days of life, hypothermia frequently indicates septicemia and carries a high mortality rate. Low weight and malnutrition are common. Hypothermia in a low-birth-weight neonate should suggest the possibility of intracranial hemorrhage; hypothermia is also observed in shaken baby syndrome.

Endocrinologic failure, including hypopituitarism, hypoadrenalism, and myxedema, commonly decreases heat production. Interestingly, congenital adrenal hyperplasia with mineralocorticoid insufficiency is more common in cold climates, possibly an adaptive response to prolonged exposure to cold temperatures, because “normal” cold diuresis is reduced in these patients.

Hypothyroidism is often occult, with no history of cold intolerance, dry skin, lassitude, or arthralgias. The physician should check for a thyroid scar or any history of thyroid hormone replacement. The degree of temperature depression correlates fairly directly with mortality. Eighty percent of patients in myxedema coma, which is several times more common in female patients, are hypothermic.

The effects of insufficient nutrition extend from hypoglycemia to marasmus to kwashiorkor. Kwashiorkor is less often associated with hypothermia than is marasmus, because of the insulating effect of hypoproteinemic edema. Central neuroglycopenia distorts hypothalamic function. Many alcoholic patients with hypothermia are hypoglycemic. Malnutrition decreases insulative subcutaneous fat and directly alters thermoregulation. Poor nutrition predisposes to hypothermia and its attendant clumsiness in older adult women with femoral neck fractures. Partly because of fuel depletion, hypothermia is as great a threat as hyperthermia in marathon races run in cool climates. Runners slowing from fatigue or injury late in a race are at serious risk of hypothermia.

Increased Heat Loss

Poorly acclimated and insulated individuals often have high diaphoretic, convective, and evaporative heat losses during exposure to cold. Because the skin functions as a radiator, any dermatologic malfunction increases heat loss. Such erythrodermas include psoriasis, exfoliative dermatitis, and toxic epidermal necrolysis. Hypothermia with hypernatremic dehydration is also seen in congenital lamellar ichthyosis. Burns and inappropriate burn treatment cause excessive heat loss, as do other iatrogenic factors, including massive cold intravenous (IV) infusions and overcooling heatstroke victims. When carbon dioxide is used for abdominal insufflation before laparoscopy, warming the gas before administration helps prevent hypothermia. Environmental immersion exposure is discussed in detail in Chapter 6.

Many pharmacologic and toxicologic agents both increase heat loss and impair thermoregulation. The most common is ethanol, which interacts with every putative thermoregulatory neurotransmitter. Although ingestion of ethanol produces a feeling of warmth and perhaps visible flushing, it is the major cause of urban hypothermia. In fatal cases of accidental hypothermia, many victims are under the influence of ethanol. In children with ethanol intoxication, hypothermia is under the influence of ethanol. In children with ethanol intoxication, hypothermia is common.

Ethanol is also a poikilothermia-producing agent that directly impairs thermoregulation at high or low temperatures. Body temperature is lowered both from cutaneous vasodilation with radiative heat loss and from impaired shivering thermogenesis. Chronic ethanol ingestion damages the mamillary bodies and posterior hypothalamus, which modulates shivering thermogenesis. Ethanol also increases the risk for being exposed to the environment, by modifying protective adaptive behavior. The ultimate example is paradoxical undressing, or removal of clothing in response to a cold stress. As an organic solvent, ethanol confers a few theoretically redeeming qualities in freezing cold injuries by lowering the cellular freezing point.

The neurophysiologic effects of ethanol are modified by duration and intensity of exercise, food consumption, and applied cold stress. Aging increases sensitivity to the hypothermic actions of ethanol in some primate experiments. Chronic ingestion yields tolerance to its hypothermic effects, and rebound hyperthermia may be seen during withdrawal. Conditions associated with ethanol ingestion that adversely affect heat balance include immobility and hypoglycemia. Inhibited hepatic gluconeogenesis coexists with malnutrition. Hypothermic alcoholic ketoacidosis is reported.
Intravenous thiamine is diagnostic and therapeutic for Wernicke's encephalopathy, another cause of reversible hypothermia. The acute triad of global confusion, ophthalmoplegia, and truncal ataxia is often masked by hypothermia, and temperature depression may persist for weeks.

**Impaired Thermoregulation**

Various conditions that impair thermoregulation can be considered as having central, peripheral, metabolic, and pharmacologic or toxicologic effects.

**Central**

Central conditions may directly affect hypothalamic function and mediate vasodilation. Traumatic lesions include skull fractures, especially basilar, and intracerebral hemorrhages, most commonly chronic subdural hematomas. Pathologic lesions include neoplasms, congenital anomalies, and Parkinson disease. Patients with Parkinson disease or Alzheimer's disease, because of global neurologic impairment, are particularly at behavioral risk. Finally, cerebellar lesions also impede heat production because of inefficient choreiform shivering.

Hypothermia can occur with Reye's syndrome. In Hodgkin's disease, hypothermia is seen only in previously febrile patients with advanced disease, independent of cell type. This seems to be a disease-associated functional disorder of thermoregulation, similar to that seen in anorexia nervosa. Centrally induced hypothermia is completely antagonized with thyrotropin-releasing hormone.

**Peripheral**

Peripheral thermoregulation fails after acute spinal cord transection. Victims are functionally poikilothermic as soon as peripheral vasoconstriction is extinguished. [242] Other peripheral impediments to thermostability include neuropathies and diabetes mellitus. Hypothermia is more common in older adult diabetics than in the general population, even after excluding patients with diabetic metabolic emergencies. The common denominator in metabolic derangements may be abnormal plasma osmolality that interferes with hypothalamic function. Similar causes of hypothermia include hypoglycemia, diabetic ketoacidosis, and uremia. Remarkably, the pH was 6.67 in one hypothermic survivor with lactic acidosis, and 6.41 in another. [253]

**Pharmacologic or Toxicologic**

Numerous medications and toxins in therapeutic or toxic doses impair centrally mediated thermoregulation and vasoconstriction. [172,272,377] The usual offenders are barbiturates, benzodiazepines, phenothiazines, and the cyclic antidepressants. Reduced core temperature may be a prodrome of lithium poisoning. Organophosphates, narcotics, glutethimide, bromocriptine, erythromycin, clonidine, fluphenazine, bethanechol, atropine, acetaminophen, and carbon monoxide all cause hypothermia. In experimental studies, hypothermia after acute carbon monoxide poisoning is associated with increased mortality.

**Recurrent Hypothermia**

Recurrent and episodic hypothermias are widely reported. The recurrent variety is more common and is usually secondary to ethanol abuse, with one person having survived 12 episodes. [56] Severe, recurrent presentations are also caused by self-poisoning and anorexia nervosa.

Persons with episodic hypothermia can be divided into two groups, albeit with significant overlap, as follows:

**Group 1:** Diaphoretic episodes precede the temperature decline, which lasts several hours. This group includes those with hypothalamic lesions and agenesis of the corpus callosum (Shapiro syndrome) and persons with spontaneous periodic hyperthermia. Resultant hyperhidrosis and hypothermia are successfully treated with clonidine, a centrally acting α-adrenergic agonist. The hypothermia of corpus callosum agenesis is also seen with hypercalcemia and status epilepticus. Because no hypothermia results from experimental sectioning of the corpus callosum, associated lesions, including lipomas, probably cause thermoinstability. Spontaneous periodic hypothermia may reflect a diencephalic autonomic seizure disorder and can accompany paroxysmal hypertension. Vasomotor and thermoregulatory mechanisms are successfully treated with anticonvulsants. Florid psychiatric symptoms often mask these intermittent hypothermic episodes.

**Group 2:** The second group consists of persons who remain cold for days to weeks, rather than hours. These people have more seizure disorders, and the central hypothalamic thermostat is set abnormally low.

Patients with intermittent hypothermia usually show some characteristics of both groups. [225] Circadian rhythm disturbances are also seen in persons with neurologic disorders who have chronic hypothermia.
**Predisposing Infections or Conditions**

Among the infestations and infections that may elevate or depress core temperature are septicemia, pneumonia, peritonitis, meningitis, encephalitis, bacterial endocarditis, typhoid, military tuberculosis, syphilis, brucellosis, and trypanosomiasis. Other diseases, in addition to cerebrovascular and cardiopulmonary disorders, that produce secondary hypothermia include systemic lupus erythematosus, carcinomatosis, pancreatitis, and multiple sclerosis. Hypothalamic demyelination may explain episodic hypothermia observed in some patients with multiple sclerosis.

Hypothermia can also result from low cardiac output after a major myocardial infarction, which can be reversed by intra-aortic balloon counterpulsation. Finally, causes include vascular insufficiency, giant cell arteritis, uremia, sickle cell anemia, Paget disease, sarcoidosis, and sudden infant death syndrome. Magnesium sulfate infusion during preterm labor can produce hypothermia with fetal and maternal bradycardia, and hypothyroidism can be manifested as hypothermia after preeclampsia (see Box 5-2).

**Trauma**

Hypothermia protects the brain from ischemia but can result in arrhythmias, acidosis, and coagulopathies, and it can extract a high metabolic cost during rewarming. Hypothermia hinders protective physiologic responses to acute trauma and affects pharmacologic and therapeutic maneuvers necessary to treat injuries. An inverse relationship usually exists between the Injury Severity Score (ISS) and core temperature of traumatized patients on arrival in the emergency department (ED). This observation does not settle whether hypothermia is just another risk factor for increased mortality or reflects the fact that the most severely injured patients are in hemorrhagic shock.

One study assessed the impact of hypothermia as an independent variable during resuscitation from major trauma. Patients not aggressively rewarmed with continuous arteriovenous rewarming (CAVR) had increased fluid requirements, increased lactate levels, and increased acute mortality. Of the clinical entities associated with hypothermia, traumatic conditions causing hypotension and hypovolemia most dramatically jeopardize thermostability. Hypothermia is often obscured by obvious hemorrhaging and injuries. Liberalized indications for Focused Assessment With Sonography for Trauma (FAST) ultrasound examinations can minimize unnecessary computed tomography (CT) imaging. On the other hand, traumatic neurologic deficits, including paresis and areflexia, can be misattributed to hypothermia. In trauma patients requiring surgery, the mean temperature loss was greater in the ED than in the operating room. Thermal insults are often added during a trauma resuscitation. The patient is completely exposed for examination, and resuscitative procedures cause further heat loss.

In a study stratifying subjects with the anatomic ISS, hypothermic patients had a higher mortality rate than did similarly injured patients who remained normothermic. Another study did not corroborate this finding, but those investigators stratified using trauma revised injury severity score (TRISS) methodology, which is probably less valid during hypothermia because its physiologic components overestimate injury severity. To illustrate this point, some component of hypotension is normal for a given degree of hypothermia.

Various adverse physiologic events accompany hypothermia with trauma. Decreased skin and core temperatures without compensatory shivering thermogenesis are reported in patients with major trauma as defined by the ISS. Hypothermia directly causes coagulopathies in trauma patients through at least three avenues (see Coagulation, earlier). The cascade of enzymatic reactions is impaired, and plasma fibrinolytic activity is enhanced, producing a clinical presentation similar to that of DIC. Also, platelets are poorly functional and become sequestered.

Hypothermia is protective only when induced before shock occurs. This reduces adenosine triphosphate (ATP) utilization while ATP stores are still normal, as during elective surgery. ATP stores in traumatized patients are already depleted. Hypothermia worsens the effects of endotoxins on clotting time in vitro and may synergistically exacerbate the coagulopathy seen in trauma. The average temperature of 123 initially normothermic trauma patients in whom lethal coagulopathies developed was 31.2°C (88.2°F). In another study, postinjury life-threatening coagulopathy in the seriously injured who require massive transfusion was predicted by persistent hypothermia and progressive metabolic acidosis. The appropriate target core temperature for a hypothermic patient with an isolated severe head injury may be 32°C to 33°C (89.6°F to 91.4°F). This target temperature balances neuroprotection against the adverse hematologic and physiologic consequences of hypothermia (see Cerebral Resuscitation, later.)

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