Hypothermia
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Hypothermia is a condition commonly seen in veterinary medicine. Animals with a temperature of <99.7°F may be considered hypothermic. Most cases are mild and associated with prolonged surgery or anesthesia. However, exposure to cold environments for an extended period of time or loss of ability to thermoregulate can lead to more severe hypothermia. Severe hypothermia may be underdiagnosed in clinical practice because most commonly used thermometers have a minimum temperature reading.

In hypothermic states, cardiac output decreases and blood viscosity increases, thereby diminishing oxygen delivery to tissues. However, the metabolic rate of cells also decreases, so the body is able to meet metabolic demand for a short period of time. As hypothermia progresses, peripheral vasoconstriction shunts blood flow to the vital organs. Eventually, tissue demand will exceed supply, resulting in cell death. Animals that present with severe hypothermia require rapid and intensive treatment to adequately rewarm the tissues. A comprehensive plan is required to manage the common, and often life-threatening, sequelae that may develop.

DIAGNOSTIC CRITERIA

Historical Information
Age Predisposition
Old and young animals are prone to loss of thermoregulation and development of hypothermia.

Other Historical Considerations/Predispositions
• Animals may present with a history of exposure to a cold environment. The duration and extent of exposure should be determined.
• Any history of underlying illness or injury, which may affect thermoregulation or may interfere with the animal’s ability to respond to cold conditions (i.e., prolonged recumbency, inadequate haircoat, etc.), should be determined.
• There may be a history of prolonged anesthesia or surgery.
• Primary neurologic disease may affect the hypothalamic set point for thermoregulation or interfere with the animal’s ability to respond to hypothermia.

Physical Examination Findings
Mild Hypothermia (Core Temperature 90° to 99°F)
• Tachycardia and tachypnea may initially be seen.
There is evidence of peripheral vasoconstriction with cold extremities and decreased peripheral pulses.

The animal is often lethargic and shivering; however, if the animal is anesthetized, the shivering response may be depressed or absent.

Mental dullness with an abnormal or ataxic gait may be seen.

Significant diuresis may occur in initial hypothermia, causing dehydration with signs of dry mucous membranes, skin tenting, or sunken eyes.

There may be progressive bradycardia, which is refractory to atropine administration.

**Moderate Hypothermia (Core Temperature 82˚ to 90˚F)**

- As the duration or extent of hypothermia increases, there is a progressive drop in the basal metabolic rate.
- Heart rate, respiratory rate, mean arterial blood pressure, and urine output will decrease.
- Cardiac arrhythmias can develop secondary to increased myocardial irritability.
- Atrial dysrhythmias or fibrillation may be seen as an early feature of hypothermia. The ventricles become gradually more irritable as body temperature decreases. Ventricular premature contractions may develop, which can progress to ventricular tachycardia and/or ventricular fibrillation.
- The animal may show signs of muscle stiffness, is unlikely to be ambulatory, and will no longer be shivering.
- The animal may appear depressed, semiconscious, or comatose.
- There are significant changes in the brain's electrical activity below 92˚F, and temperature-dependent enzymes in cerebral cells are unable to function.

**Severe Hypothermia (Core Temperature <82˚F)**

- Animals may be unconscious and nonresponsive.
- Pupils may be dilated and respiration may be decreased to 1 to 2 breaths/minute.
- Ventricular fibrillation is common and often unresponsive to electrical defibrillation until the animal is rewarmed.
- These animals may appear to be clinically dead.

**Laboratory Findings**

- Laboratory assessment of hypothermic animals is often confusing.
- The packed cell volume (PCV) should increase 1% for each 1˚F fall in body temperature. However, measured PCV is often higher than calculated due to fluid shifts caused by increased vascular permeability, cold-induced diuresis, and subsequent dehydration.
- A normal PCV reading in the presence of hypothermia should raise suspicion of blood loss or a preexisting anemia.
- Leukopenia and thrombocytopenia may occur due to sequestration of white blood cells and platelets in the splenic and perivascular tissue beds.
- Electrolyte abnormalities are common and unpredictable.

Hyperkalemia may occur secondary to metabolic acidosis, rhabdomyolysis, or acute renal failure.

Hyperglycemia may be present in the acute presentation of hypothermia due to stress-induced gluconeogenesis and inhibition of insulin. However, levels decline quickly due to diuresis and decreased gluconeogenesis as the condition progresses.

Blood urea nitrogen (BUN) and creatinine concentrations may increase as a result of fluid shifts, dehydration, or acute renal failure.

Urinalysis may show signs of glycosuria, proteinuria, or low urine-specific gravity secondary to diuresis or acute renal failure.

Carbon dioxide retention and subsequent respiratory acidosis may be present on blood gas evaluation. Metabolic acidosis can be seen secondary to increased lactic acid production in dehydration.

Disseminated intravascular coagulation (DIC) can occur in moderate to severe hypothermia. Normal prothrombin time (PT) and activated partial thromboplastin time (aPTT) do not rule out the presence of a coagulopathy because these tests are generally run at normal body temperatures.

Hypothyroidism should be ruled out by performing thyroid function tests because this condition may decrease the hypothalamic set point for thermoregulation.

**Other Diagnostic Findings**

- Electrocardiographic (ECG) monitoring may reveal arrhythmias.
- Thoracic radiography may be indicated to rule out bronchitis and bronchopneumonia.
  - Hypothermia causes a reduction in ciliary clearance, thereby promoting bronchiolar mucus plugs and atelectasis.
  - Hypothermia is also a risk factor for development of noncardiogenic pulmonary edema because increased vascular permeability may lead to fluid extravasation into the pulmonary parenchyma.

**Summary of Diagnostic Criteria**

- Low rectal or core temperature.
- History of prolonged exposure to cold environment, underlying illness, hypothyroidism, very old or very young animals, or prolonged anesthesia.
- Physical examination may reveal mental dullness that can progress to depression, stupor, and coma. Pupils may be dilated.
- Bradycardia may be noted, with an increased propensity for cardiac arrhythmias.
- Hemoconcentration, electrolyte abnormalities, hypoglycemia, acidosis, leukopenia, and thrombocytopenia may be present.
Differential Diagnoses

- Differentials for underlying disease include cardiac or pulmonary disease, neurologic abnormalities, or endocrine disorders.
- Exposure or accidental hypothermia is a diagnosis based on a history of exposure to a cold environment and elimination of an underlying cause.
- The history taken from the owner is very important to rule out prolonged anesthesia, trauma, or concurrent illness.
- Physical examination and diagnostic tests may be confounded by the presence of hypothermia.

TREATMENT RECOMMENDATIONS

Initial Treatment

- **Rewarming the animal** is the most important aspect of treatment. As tissues start to re-heat, vasodilation of the peripheral vasculature occurs. Cold blood, which has been sequestered in the periphery, circulates into the central organs, and a phenomenon known as “afterdrop” may occur. This is where the core body temperature continues to decline after the patient has been removed from the cold environment.
- **Rapid volume expansion** with warm (104 to 106°F) IV fluids is crucial for volume replacement and rewarming. Because the fluid shifts in hypothermia are due to absolute fluid loss from diuresis and subsequent dehydration, an isotonic crystalloid solution is preferred over administration of synthetic colloids. Synthetic colloid administration may also exacerbate an underlying coagulopathy. However, if total protein or albumin concentrations are normal or decreased in a hypothermic patient, administration of 10 mL/kg of fresh frozen plasma may be indicated to provide colloidal support. Lactated Ringer’s solution is not recommended because the hypothermic liver has decreased ability to metabolize lactate.
- **Fluid rates** will depend on the hydration status and degree of hypothermia of the patient. In moderate to severely affected animals, rates of 25 to 45 mL/kg/hr for dogs or 15 to 25 mL/kg/hr for cats (half of normal shock rates) may be indicated. Patients should be monitored closely because there is increased risk of fluid overload in hypothermic animals, especially in the presence of acute renal failure or pulmonary edema. Cats are less tolerant of volume overload than dogs, especially in the presence of acute renal failure or pulmonary disease.
- **Endpoints of fluid resuscitation** include a urine output of >2 mL/kg/hr or a CVP of 2 to 6 cm H₂O. The patient’s mucous membrane color, capillary refill time, heart rate, and arterial blood pressure would optimally return to normal limits, although these factors may not normalize until hypothermia is resolved.
- **Large volumes of warm fluid** should not be administered via a central line because a myocardial temperature gradient can develop, causing further cardiac irritability and increasing the risk for arrhythmias.
- **Empirical potassium supplementation** should be avoided until the animal is normothermic and rehydrated because impaired renal function in the hypothermic state may result in decreased potassium excretion. If potassium levels are <3 mEq/L, 20 to 30 mgEq/L of potassium chloride may be added to the IV fluids.
- **Supplementation of dextrose** may be required and should be based on blood glucose measurements.
- **Passive rewarming** may be adequate in cases of mild hypothermia. In this situation, the animal is wrapped in dry blankets and hypothermia is resolved by intrinsic heat production.
- **Active external rewarming** is used for moderate hypothermia, where hot water bottles, circulating hot water blankets, radiant heat, and other exogenous heat sources are used in addition to wrapping the patient. Ideally, these heating devices should be confined to the thorax to warm the heart and the blood supplying the extremities and to avoid peripheral vasodilation.
- **In cases of moderate or severe hypothermia**, active external rewarming may lead to sudden vasodilation and severe shock. Active external rewarming increases metabolic demands and further decreases the threshold for ventricular arrhythmias. Core rewarming is indicated in these cases.
- **Severe burns** may result if external heating devices are allowed to come into direct contact with the patient. — Caution is advised with all external heating devices because hypothermic patients have significant vasostriction within the skin and are unable to conduct heat away from the surface.
- Animals should be turned frequently to prevent prolonged contact of one area with external heating devices.
- **Oxygen supplementation** via oxygen cage, nasal cannulation, or hood may be required if there is evidence of pulmonary dysfunction. If the animal is hypoventilating or there is severe pulmonary disease, endotracheal intubation and positive pressure ventilation may be indicated. This should continue until there is resolution of the respiratory acidosis or hypoxemia and an adequate respiratory rate has been obtained.
- **Administration of heated and humidified air** via mask or endotracheal tube will allow warming of airways and prevent respiratory heat loss.

Alternative/Optional Treatments/Therapy

- Core rewarming is advised for any patient with moderate or severe hypothermia. In veterinary medicine, the most commonly used technique is rectal or colonic lavage with warm fluid, although this technique has variable efficacy in restoring core temperature.
Core rewarming via peritoneal dialysis involves the administration of heated dialysate into the abdominal cavity. Two abdominal catheters are placed. 10 to 20 mL/kg of crystalloid dialysate are administered via one catheter, and the second catheter provides outflow suction. This technique not only provides direct rewarming of abdominal organs but also allows for adjustment of serum potassium levels.

Gastric and urinary irrigation have been used to facilitate rewarming. These methods are hampered by the restricted amount of heat exchanged via these organs and the risk of organ perforation. Gastric lavage may cause cardiac irritation as well as increase the risk of aspiration in the lungs, which already have compromised ciliary clearance.

Closed pleural irrigation through thoracostomy tubes has been used to rewarm thoracic organs. Warm sterile saline is infused through one line, while active suction is provided through a second chest drain. Adverse effects of this technique include cardiac irritation and potentiating development of arrhythmias.

Patients that remain mentally dull despite increased body temperature may be developing cerebral edema. Mannitol can be administered at 0.25 to 0.5 g/kg IV bolus over 30 minutes to reduce brain swelling. Corticosteroids are not indicated in this situation.

Coagulopathies may resolve with rewarming. However, if coagulation abnormalities are seen after hypothermia has been resolved or if the hypothermic patient is clinically bleeding or hypoproteinemic, administration of fresh frozen plasma is indicated to provide exogenous coagulation factors and colloid support.

**Supportive Treatment**

Administration of medications should be avoided in hypothermic animals because they have significant vasoconstriction, depression of the cardiovascular system, and impaired hepatic and renal function. This means that metabolism and excretion of pharmaceuticals will be decreased and there will be variation in efficacy and duration of action of many drugs. The exception to this rule may be infusion of low-dose catecholamines to patients with hypotension, which is refractory to fluid therapy.

**Patient Monitoring**

- Hypothermic animals need very close monitoring during the rewarming phase.
- An indwelling rectal probe or thermometer is indicated, as is constant ECG monitoring.
- PCV, blood glucose, serum electrolyte levels, blood gas, and coagulation assays should be rechecked regularly during treatment.
- A urinary catheter should be placed to monitor urine output and fluid shifts during rewarming. The initial cold diuresis seen in hypothermic patients is often followed by a significant decrease in glomerular filtration rate, which may lead to oliguric or anuric renal failure.
- Blood pressure monitoring is advised. Ideally, direct blood pressures should be measured because these are more accurate in the presence of severe vasoconstriction; however, specialized techniques and equipment are required. Oscillometric or ultrasonographic techniques can be used to measure the indirect blood pressure, but these techniques tend to be dependent on adequate peripheral circulation.

**Home Management**

Animals that have recovered from a moderate to severe hypothermic episode should be monitored closely at home for the next 5 to 7 days. Complications of hypothermia such as bronchopneumonia, pulmonary edema, or cardiac arrhythmias may require further treatment and monitoring.
Milestones/Recovery Time Frames

- The main goal of treatment of the hypothermic patient is rapid rewarming. Mild to moderate hypothermia should resolve quickly and there should be significant improvement in body temperature within 8 to 12 hours in severe hypothermia.
- Many of the clinical conditions associated with hypothermia may not become apparent until the patient is warm enough to increase peripheral perfusion.
- Hypoglycemia, hyperkalemia, DIC, and metabolic acidosis may develop and require intensive treatment. Continued close monitoring of these parameters is required for a minimum of 24 to 48 hours after normothermia has been achieved.
- Cerebral or pulmonary edema is also common sequelae to hypothermia.
- “Afterdrop” may occur at the onset of rewarming. This effect can initiate a rapid decline in the patient’s clinical status and possibly lead to a state of refractory shock.
- Respiratory complications of hypothermia, such as bronchopneumonia, may not become apparent until 24 to 72 hours post-presentation.
- Radiographic evidence of pneumonia or pulmonary edema often lags 12 to 24 hours behind clinical signs.
- Cardiac dysfunction should improve with clinical status of the patient; however, arrhythmias may continue for 48 to 72 hours after the initial onset.

Treatment Contraindications

- Aggressive external rewarming of the extremities in moderate to severe hypothermia.
- Direct application of heating devices to skin.
- Administration of nonessential medications.
- Administration of large volumes of fluids to cats.

PROGNOSIS

Favorable Criteria

- Prognosis may be very difficult to predict based on presenting signs. Even animals that present with dilated pupils and no audible heart rate may respond to rapid rewarming and aggressive treatment.
- Mild hypothermia and rapid response to therapy are favorable signs for recovery.

Unfavorable Criteria

- Pre-hospital cardiac arrest.
- Severe hyperkalemia.
- Thromboembolism.
- Requirement for endotracheal intubation.
- Severe underlying disease.

RECOMMENDED READING


