Hypothermia and Frostbite in the Canine

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CONTENTS

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HYPOTHERMIA

Hypothermia results when heat loss exceeds heat production, and core body temperature falls below the established normal range in a homeothermic animal.

About Taking Temperatures

Of all possible ways to take a temperature in a dog, rectal and core (esophageal) remain the most accurate. Ear thermometers, however more convenient for you, have proven unreliable (and not every dog likes a probe stuck in their ear).

A. Classifications of Hypothermia

1. Primary or accidental – prolonged exposure to cold environmental temperatures where normal physiologic responses are unable to maintain normal body temperature
2. Secondary – severe illness, injury, and/or drugs that alter heat production and thermoregulation, causing hypothermia in normal environmental temperatures

B. Conditions Surrounding Hypothermia

- Hypothermia may occur in any condition which increases heat loss, decreases heat production, or impairs thermoregulation.

1. Increases in heat loss via conduction, convection, radiation, evaporation
    a) Conduction – Cold water/cold air immersion, cold solution infusion, lying on cold non-insulated surface, over-aggressive treatment of hyperthermia
    b) Convection – depilation, environmental wind, artificial ventilation
    c) Radiation – cold environment, cold room, induced vasodilation
    d) Evaporation – wet body surface, open/exposed body cavities
2. Decreases in heat production
    a) Diminished muscular activity from any cause
    b) Diseases - hypopituitarism, hypoadrenalism, myxedema
    c) Anesthesia - depresses metabolism and hypothalamic thermoregulation
3. Disruptions of normal thermoregulatory function
    a) Drugs - Phenothiazines, dipyrone
    b) CNS disease - trauma, neoplasia, edema
    c) End-stage visceral organ failure - decompensatory shock, though some forms of shock can lead to measured (rectal temperature) hypothermia secondary to peripheral vasoconstriction but the core may be normal.

C. Degrees of Hypothermia – based on core body temperatures

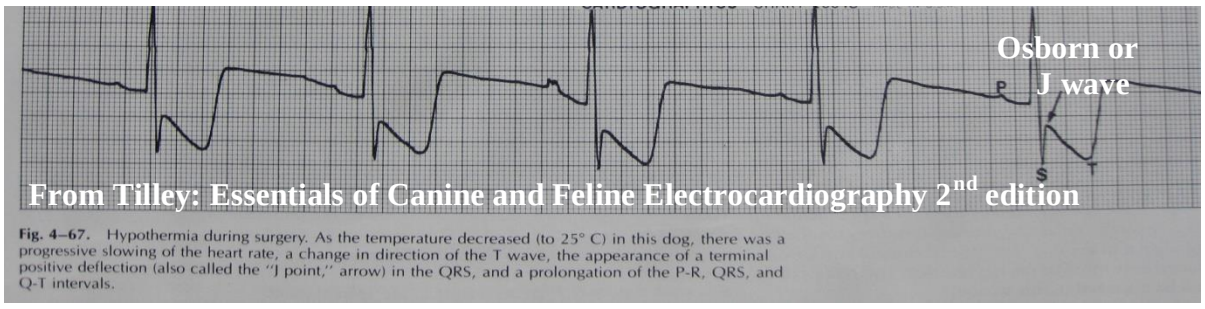
1. Mild 90-99 ^{o}F (32-37 ^{o}C)
2. Moderate 82-90 ^{o}F (28-32 ^{o}C)
3. Severe <82 ^{o}F (28 ^{o}C)

D. Thermoregulatory Responses to Hypothermia - Thermoregulation is the balancing of heat production and heat loss. Heat generation in canines is via basal metabolism, oxidation of nutrients, and muscular activity. Heat loss is mainly via conduction and convection. Humans' main heat loss is via radiation.

1. Hypothalamic Thermoregulatory Center - Maintains the narrow range of core body temperature, activating physiologic responses if temperatures vary outside established range
    a) Primary receptors located in pre-optic and anterior nuclei
    b) Secondary receptors within skin and body tissues (spinal cord, abdominal viscera, great veins)
2. Behavioral Response
    a) Curling up
    b) Seeking shelter
3. Physiologic Response
    a) Piloerection which traps insulating layer of air close to skin
    b) Vasoconstriction which shunts blood from periphery to core
    c) Shivering increases basal metabolic rate 2-5 times normal
    d) Sympathetic nervous system activation, thyroid gland thyroxin release

E. Physiologic Effects of Hypothermia – All body systems are affected by hypothermia, increasing in severity as the core temperature decreases. The most profound effects are seen in cardiovascular, respiratory, and neurologic systems

1. Cardiovascular Effects
    a) Sympathetic NS stimulation→ tachycardia, peripheral vasoconstriction
    b) Decreased alpha$_1$ response to norepinephrine → loss of vascular contractility, vasodilation, and decreased arterial blood pressure
    c) Decreased cardiac pacemaker cell depolarization → bradycardia and the Osborn or 'J' wave (seen at 90 ^{o}F/32 ^{o}C in canines and humans)
    d) Further cardiac conduction issues with atrial and ventricular irritability ensue: atrial fibrillation, VPCs, ventricular tachycardia and fibrillation
    e) Core body temperature <82^{o}F/28^{o}C ventricular fibrillation common, typically unresponsive to electrical defibrillation



From Tilley: Essentials of Canine and Feline Electrocardiography 2nd edition

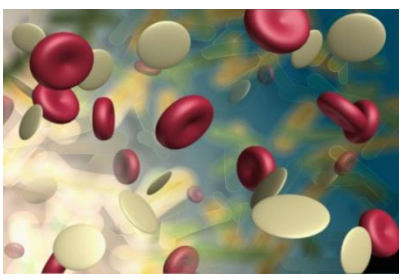
Fig. 4–67. Hypothermia during surgery. As the temperature decreased (to 25° C) in this dog, there was a progressive slowing of the heart rate, a change in direction of the T wave, the appearance of a terminal positive deflection (also called the "J point," arrow) in the QRS, and a prolongation of the P-R, QRS, and Q-T intervals.

2. Respiratory Effects
    a) Initial increase in respiratory rate
    b) Decreased cellular metabolism and CO_2 production → progressive decrease in respiratory rate and tidal volume
    c) CO_2 production decreases 50% with a 10.8° F (8° C) fall in body temp
    d) Shift of the oxyhemoglobin curve to the left increase O_2 affinity for hemoglobin, exacerbating tissue hypoxia
    e) Pulmonary edema, bronchopneumonia, decreased mucociliary activity → acute respiratory distress syndrome (ARDS)

3. Neurologic Effects
    a) Decreases in cerebral metabolism (6-7% per 1°C drop in core body temp) → alterations in mental status, from depression to comatose
    b) Impaired cerebral autoregulation → cerebral blood flow entirely dependent on mean arterial blood pressure
    c) Ischemic injury → cerebral edema (so use of hyperosmotic agents are considered, like mannitol, in suspected high ICP)
    d) Profound hypothermia → EEG flat line, and along with asystole leads to a misguided diagnosis of death; keep in mind:
    "The hypothermic animal is not dead until they are warm and dead."

4. Clinical Pathologic Effects

    a) Primary hemostasis effects:
        - Thrombocytopenia from reversible hepatosplenic platelet sequestration
        - Decreased platelet aggregation and function
    b) Secondary hemostasis effects
        - Prolonged prothrombin time and activated thromboplastin time
    c) Fibrinolysis and disseminated intravascular coagulation (DIC)
    ♬*Interpret coagulation tests with caution, as they are run at 37°C and may not reflect abnormal hemostasis status.*
    d) Leukopenia due to sequestration
    e) High packed cell volume (PCV), ↑ 2% per 1°C drop in core body T°
    f) Metabolic acidosis and cell lysis → hyperkalemia
    g) Potassium entry into muscle cells → hypokalemia
    h) Hypertnatremia and hyponatremia (mechanism?)
    i) Hyperglycemia from catecholamine release in mild hypothermia; ↓ insulin secretion and insulin resistance in worsening hypothermia
    j) Hypoglycemia with hepatic glycogen depletion and impaired gluconeogenesis



5. Other Systems
    a) Gastrointestinal system: splanchnic vasoconstriction may lead to gastric ulcers and pancreatitis
    b) Urinary system: initial diuresis: peripheral vasoconstriction increases plasma blood volume which increases glomerular filtration rate; then "cold diuresis" may occur due to decreased renal tubular reabsorption of sodium and water and altered sensitivity of the collecting tubules to ADH. This increases hypovolemia, worsens vasoconstriction.
    c) Immune system: compromised wound healing and immune function due to decreased oxygen tension from subcutaneous vasoconstriction, which impairs neutrophil phagocytic ability

F. Quick Summary - General Signs Indicative of Hypothermia

- Diminished consciousness, from depression to coma
- Delayed, diminished reflexes
- Low BP (weak/absent pulses)
- Shivering (lost at <88^{o}F/31^{o}C)
- Bradycardia (HR <70 bpm)
- Cardiac arrhythmias (V tach, VPCs, V fib, A fib)
- Cyanotic/pale body part
- Shallow, infrequent respirations
- Increased muscle tone/no shiver
- Dilated pupils, +/- unresponsive
- Anesthesia of frozen tissue

G. Treatment of Hypothermia – Prompt recognition and aggressive therapy are paramount to successful treatment. Therapy consists of

Initial triage examination
History
ABCs: assess respiratory, cardiovascular, mentation
Body temperature

♫ ***Note***: Most thermometers do not register below 89-95^{o}F. Soft rectal probes, which can be inserted 8-15 cm for better temperature accuracy, will read very high and low values

Treatments based on exam and needs: rewarming techniques, cardiovascular and respiratory support, and identification of complications (neurological, blood parameters) and current disease.

1. Mild degrees of hypothermia >96 ^{o}F (>36 ^{o}C) have minimal detrimental effects. Treatment consists of:
    a) Passive rewarming: placing patient in a warm environment and preventing further heat loss
        - Remove canine from the cold
        - Dry them if they are wet
        - Place in warm environment
        - Wrap with insulating blankets

    b) Active rewarming (see 2c)
        - If passive fails to increase core body temp
        - If hypovolemic, treat with warm fluid therapy first

2. Moderate (82-90 ^{o}F/28-32 ^{o}C) to Severe (<82 ^{o}F/28 ^{o}C) hypothermia – may present as an emergent situation
    a) Transport
        - Avoid further heat loss by covering with insulating blanket
        - Dry if wet
        - Keep canine horizontal
        - ***Do not rub or massage*** as may lead to vasodilation, cardiovascular collapse, and suppression of shivering
        - Avoid direct heating of the skin and periphery, i.e. warm water bottles and heating pads, at this time
        - Transport cautiously, movement may lead to ventricular fibrillation

    b) Technical support at medical/veterinary facility
        - IV catheter placement for warm IV fluid and drug therapy
        - Blood drawn for minimum data base, electrolytes, acid-base
        - Complete blood work is for after rewarming as some parameters are reversible (WBCs, PLTs)

    c) Active External Rewarming
        - Direct transfer of heat to patient facilitated by hot water blankets, heat lamps, forced air warmers
        - Avoid direct skin contact with warming devices to avoid burn injury if possible, otherwise:
            - If water bottles placed on skin, water temp < 106^{o}F (42^{o}C)
            - If electric blanket used, place thermometer between animal and blanket and do not exceed 106^{o}F (42^{o}C)
            - Maintain heat in water bottles, or body heat will flux out
        - Application of direct heat to the trunk recommended to avoid all of the following:
            - Peripheral vasodilation of extremities and subsequent hypotension
            - Surface rewarming decreases neuronal feedback to thermostatic centers and may decrease thermogenic response
            - Re-establishing perfusion to hypoxemic tissues may flush noxious metabolites into system, further burdening an already compromised heart
        - Immersion in warm water has been described but is not recommended as it impedes resuscitation and patient monitoring
        - Monitor rectal temperature continuously; rectal probe placed 8-15 cm in considered most accurate
        - Rewarming rate should be limited to < 2^{o}F (1^{o}C) per hour

GOAL is 98^{o}-99^{o}F/37^{o}C
AVOID HYPERTHERMIA

d) Active Internal/Core Warming
- Warm IV fluids (104-106^{o}F/40-42 ^{o}C)
- Heated humidified air by oxygen mask
- Body cavity lavage (pleural, peritoneal) extremely effective (isotonic crystalloid warmed to 104-113^{o}F/40-45^{o}C infused aseptically via large bore catheter @ 10-20 ml/kg per exchange)
- Warm fluid gastric/rectal lavage (gastric only if awake, swallows) but will impair rectal temperature monitoring)
- Bladder lavage
- Monitor rectal temperature; if unconscious esophageal temperature measured at heart base even more accurate than rectal temperatures

♬ **After Drop**

A patient's temperature initially drops after warming treatments are started. This occurs secondary to countercurrent cooling of the blood which is perfusing cold tissues. Once the gradient between core blood and peripheral blood equalizes, core body temperature should rise.

e) Respiratory Support

- As in any emergency, airway and breathing are assessed initially and this is no exception; in severe hypothermic patients the respiratory rate can be depressed or absent
- If breathing give 100% oxygen, warm humidified ideal
- If not breathing, intubate and positive pressure ventilation
- Monitor pulse oximetry, arterial blood gases if available
- Hypoxemia may result from several factors: respiratory depression, increased airway secretions, atelectasis, bronchopneumonia, and ARDS (consider antimicrobial therapy)

f) Cardiovascular Support

- Hypovolemic shock is due to fluid diuresis:
  - Peripheral vasoconstriction/centralize blood volume $\rightarrow$Increased GFR $\rightarrow$ decreased renal Na^{+} and H_2O absorption (cold diuresis),altered renal sensitivity to ADH
- Bolus warm IV fluids (104-106^{o}F/40-42 ^{o}C) @ 10-30 ml/kg/hr, reassessing every 15 minutes until clinical signs of shock have improved
- Monitor heart rate and rhythm via continuous ECG. Cardiac arrhythmias are minimized by immobilizing the patient as much as possible until rewarming has occurred
- Monitor blood pressure, direct via arterial if possible
- Normal urine output 1-2 ml/kg/hr, adjust for fluid administration

g) Neurologic Support
- Altered mentation - Cerebral edema
  - Hypertonic fluids - 7% NaCl @ 3-5 ml/kg IV
  - Colloids – hetastarch @ 5 ml/kg increments IV
  - Mannitol – 0.5-1.0 G/kg IV
  - Follow hyperosmotic agents with crystalloids
- Warming patient important, but not too warm!

♬ NOTE: With evidence that hypothermia is neuroprotective, some institute therapeutic hypothermia. At the very least, avoid over-warming the patient

- Oxygen – 100% (warm, humidify if possible)
- Elevate head 30^{o} to minimize intracranial pressure
- Seizures
  - Diazepam 0.25-0.5 mg/kg IV
  - Phenobarbital

h) Drugs – minimize drug intervention, as liver metabolism is decreased and protein binding is increased. Slow steady proper rewarming is the best, and may be all that is needed for some abnormalities

- Analgesics:
  - **Butorphanol** 0.1-0.5 mg/kg IV q 1-4 h, 0.2-0.8 mg/kg SC,IM,PO q 1-6 h
  - **Buprenorphine** 0.005-0.03 mg/kg IV,IM,SC q 4-12h
  - **Morphine**0.05-0.1 mg/kg IV q1-4 h, 0.2-2 mg/kg IM,SC q2-6h
  - **Oxymorphone** 0.05-0.1 mg/kg IV q 2-4 h, 0.05-0.2 mg/kg IM,SC q 2-6 h
  - **Fentanyl** 40-48 .g/kg IV,IM
- Antibiotics
  - **Ampicillin** 20 mg/kg IV,IM,SC,PO q8h
  - **Cephalosporin** 20mg/kg IV,IM,PO q8h
  - **Enrofloxacin** 2.5-5 mg/kg IV,IM,PO q12h or 5-10 mg/kg IV,IM,PO q24h

H. Prevention Techniques

1. Check canine frequently for signs of hypothermia
   - Shivering
   - Slow responses
   - Diminished mentation
   - Slow heart rate
   - Cold, pale, cyanotic body part
   - Slow respiration
   - Dilated pupils
   - Taut muscles, no shivering
2. Limit cold exposure
3. Protective clothing – coat, booties, head gear
4. Provide shelter from wind
5. Acclimation plays a role in what is needed for prevention

FROSTBITE

Frostbite is a condition of avascular necrosis caused by the freezing of body tissue

A. Conditions in which frostbite may occur include:

1. Body temperatures below 93°F/34°C
2. Freezing of an exposed body part
3. After contact with cold liquid, glass, or metal

B. Signs of frostbite include:

1. Pale to cyanotic tissue appearance
2. Tissue palpates as cool to cold to the touch
3. Hyperesthetic to hypoesthetic, depending on the depth of damage
4. Thawing causes erythema, pain, edema and swelling

C. Treatment of frostbite: minimal handling

1. Remove patient from the cold source
2. Warm tissue with compresses or immerse in warm water 102-104°F/39-40°C as long as refreezing is not a possibility
3. DO NOT RUB the affected areas, which causes tissue damage
4. Gently dry, apply bandaging, avoid pressure bandages
5. Topical antibiotics, aloe vera applied before protective bandages
6. Prophylactic antibiotics and analgesics may be given; +/- NSAIDs
7. Prevent self trauma and re-freezing of affected areas
8. Give time for tissues to heal before excising apparent dead tissue, as much may return to normal over the next few days

D. Prevention of frostbite

1. Protect sensitive areas from the cold: ears, face, tail, scrotum, feet
2. Limit exposure
3. Check canine often

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