Hyperthermia and Heatstroke in the Working Canine

Lori E. Gordon, DVM

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Massachusetts Task Force 1
Urban Search and Rescue
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INTRODUCTION

Hyperthermia

This is defined as an elevation in body temperature that results when heat production exceeds heat loss. Core body temperature rises above the established normal range of 99.8-102.8^{o}F (37.6-39.3^{o}C) in the homeothermic (resting) canine.*

***For working dogs, we must redefine 'normal'.**

Military Working Dogs (MWDs), Police Dogs, and Search & Rescue K9s frequently have a working body temperature ranging from 104-108^{o}F or higher (40-42^{o}C) during moderate activity without adverse effects.

- University study of hyperthermic patients concluded temperatures of >106^{o}F (41.1^{o}C) taken at time of admission were fatal.
  - *Concern*: Was temperature higher at injury point?
  - Had temperature decreased during transport?
  - Had cooling measures been instituted before hospital arrival?
- Dr. Janice Baker has documented MWD temperature of 111^{o}F(43.9^{o}C)
  - Dog was tired, but otherwise healthy and did well
- Iditarod 2017 had 3 sled dogs arrive a veterinary hospital with temperatures of 108^{o}F(42^{o}C) and 109^{o}F(42.8^{o}C) and 110^{o}F(43.3^{o}C)
  - The first 2 dogs survived; the third did not but had aspiration in addition to the high body temperature

What we can learn from this

There is more to defining heat stress, heat exhaustion, and heat stroke than simply a body temperature. Different dogs respond differently to heat and exertion based on their risk factors. These include fitness level, body weight, environmental acclimation, and medical issues. What is thought of as heat injury body temperature for one dog is not necessarily the same for other dogs.

If working dogs can handle higher body temperatures, why is this important?
According to statistics:

- #1 cause of accidental death overall in MWDs
- #2 cause of non-hostile action death in Police K9s
- #3 cause of death in MWDs in combat zones

TYPES OF HYPERTHERMIA

Pyrogenic

Fever occurs when endogenous or exogenous pyrogens (e.g. virus, bacteria, and cytokines) act on the hypothalamus to raise body temperature, creating a higher set point. As a normal acute phase response to infection and inflammation, this rarely raises body temperature higher than 105.5 ^{o}F/ 40.8^{o}C, not putting the patient at a severe health risk, and may be beneficial in mitigating morbidity and mortality of infectious diseases.

Non-pyrogenic

A more severe form of heat-induced illness, this may range from thermal stress to heat exhaustion to heat stroke. Severe effects may include central nervous dysfunction and multi-systemic tissue injury secondary to a systemic inflammatory response.

*This is the type of situation referenced throughout the rest of this paper.

There are 2 types:

1. **Non-exertional** –environmental heat injury, which can be the weather or a confined space (vehicle). Weather-related is more common during seasonal changes before acclimatization has occurred (late spring/early summer in New England). Confined space can be in any weather, but more common when it is warm as the heat rises faster.

2. **Exertional** – exercise induced heat injury, which is exacerbated by the environment as well as the physical fitness of the dog. Even an athletically fit dog can have trouble if they train in the cold but deploy to a warm environment without time to acclimate. Health conditions also influence their tolerance (anatomy, obesity, diseases)

RISK CONDITIONS

Factors that inhibit heat dissipation

- Rapid change in ambient temperature - lack of acclimatization. Dogs begin acclimatization around 4 days, but may require up to 20 days to complete
- High/hot ambient temperatures, especially in sun, no breeze
- Humidity
- Confinement with poor ventilation
- Water deprivation, dehydration – associated with vasoconstriction and may interfere with hypothalamic function
- Brachycephalic breeds (Pugs, Boston Terriers, English Bulldogs) with compromised upper respiratory anatomy (stenotic nares, elongated soft palate, laryngeal edema/collapse, everted saccules, trachea hypoplasia)
- Obesity
- Extremes of age – very young, very old
- Thick, dense coat – insulating effect, although this also reflects short-wave radiation better and protects body surface from heat radiation exposure
- Muzzling
- Drugs – antihistamines
- Medical conditions – laryngeal paralysis, malignant hyperthermia, epiglottis entrapment (increased incidence in Belgian Malenois)

Factors that contribute to heat production

- Simple exposure to excessive environmental temperatures
- Exercise - muscle metabolism accounts for up to 80% of the body's overall heat production during exercise.
- Anxiety
- Drugs – aspirin, thyroid supplements

Medical Conditions – Apparent healthy dogs may not be clinical or yet diagnosed

- Cardiovascular disease
- CNS disease, hypothalamic disease, seizures
- Laryngeal paralysis
- Hypokalemia
- Endocrine disorders: hyperthyroidism, diabetes mellitus, Addisonian crisis, pheochromocytoma
- Rebound hyperthermia following hypothermia episode

Other

- Fatigue - canine not moving as efficiently, must work harder to perform job.
- Ground surface – higher ground temperature, especially asphalt or sand which also reflect heat back up to canine
- Underestimation of fitness or long period off work
- Muzzle work

THERMOREGULATORY RESPONSE

Physiologic Responses

Rise in core body temperature stimulates central and peripheral temperature receptors, which activate the hypothalamus (Hypothalamic Thermoregulatory Center). Cooling measures are via physiologic responses, *how the body works to keep cool*:

- Evaporative cooling – panting for evaporation of saliva and fluid in upper respiratory tract, may account for up to 60% of heat dissipation
- Peripheral vasodilation and increased cardiac output – contributes to cooling via conduction, convection, and radiation. More than 70% of a dog's body surface heat loss may occur by these mechanisms, up to 40% via radiation alone
- Release of pro-inflammatory and anti-inflammatory cytokines – an acute phase response
- Heat shock proteins – play a role in protecting cells from heat damage

Behavioral Responses

Observation of the following is an indication of heat stress in a dog:

- Seek cool surfaces to lie upon
- Seek shade, getting out of direct sun
- Seek water
- Seek breezes
- Minimize/avoid activity

In working dogs, trained to obey, consider the following signs of heat stress:

- Uncontrolled panting that distraction (ball, toy, food) cannot stop (the 'smile')
- Seeking shade or lying down without command. Remember, you may be a source of shade so K9 may move with you to stay in your shadow.
- Reluctance to work or delayed return – working search, patrol, chase of a toy, or return from retrieving a toy; they seem like they are not listening to command but are actually trying to lie down or seek shade during work or play that is causing their rise in body temperature
- Voluntarily releases reward – cannot pant with something in their mouth

These are the early signs of thermal stress.

Actual body temperature may vary depending on the dog.

Mild Heat Stress - <104°F (<40°C)
Moderate Heat Exhaustion – 104-106°F (40-41°C)
Severe Heat Stroke - >106°F (>41°C)

These Classic 'Degrees of Hyperthermia' alone cannot be used to define or predict how much heat injury is present. Individual dogs, varied conditions, and health status are all part of the picture.

SIGNS OF HYPERTHERMIA: these indicate that heat stress *has already occurred*

Early Stages

Tachypnea, hyperventilation, panting
Hyperdynamic femoral pulse
Hyperemia
Tachycardia
Hypersalivation
Dry mucous membranes
Cap refill <1 sec
Hematochezia (bloody stool)
Altered mentation: depression, stupor
Dark red mucous membranes
Seizure (late stage)
Hypotension
Weak, collapse
Vomiting
Diarrhea
Hemorrhage
Coma

Severe or Protracted Heatstroke

Weak femoral pulses
Pale, gray mucous membranes
Shallow respirations, progression to apnea
Vomiting, diarrhea – often bloody
Seizure, coma

Delayed Signs – as late as 3-5 days after apparent recovery

Oliguria (no urine) – renal failure
Icterus (yellow mucous membranes) – liver failure
Cardiac arrhythmias
Acute Respiratory Distress Syndrome (ARDS)
Disseminated Intravascular Coagulation (DIC)
Seizures

PHYSIOLOGIC EFFECTS of Hyperthermia

Causes of cell destruction and organ system dysfunction are multifactorial, and include thermal destruction of cell membrane lipids and chemical bonds, denaturation and inactivation of enzymes, and development of tissue hypoxia leading to acidosis.

1. Cardiovascular
   a) Increased metabolic rate and oxygen consumption
   b) Decreased cardiac output/organ tissue perfusion, acidosis, muscle degeneration
   c) Myocardial necrosis, pulmonary hypertension
   d) Sinus tachycardia, ventricular arrhythmias from to all of the above
   e) Hypovolemic shock, distributive shock secondary to vasodilation
2. Respiratory
   a) Parenchymal disease (harsh, crackles) from DIC or aspiration pneumonia
   b) Laryngeal edema
   c) Acute Respiratory Distress Syndrome associated with DIC – systemic inflammatory response, sepsis secondary to bacterial translocation for the GIT, and primary parenchymal injury
3. Neurologic
   a) Cerebral edema
   b) Neuronal degeneration, necrosis, petechial hemorrhage
   c) Seizures
4. Gastrointestinal – direct thermal injury to GI mucosa and hypoperfusion
   a) Mucosal barrier breakdown
   b) Bacteria translocation and bacterial endotoxemia
   c) GI hemorrhage
5. Renal
   a) Acute tubular necrosis from thermal injury, intravascular thrombosis, hypoperfusion, hypoxia, and myoglobinuria
   b) Obstructive uropathy secondary to crystallization of myoglobin and uric acid
6. Hepatic
   a) Hepatocellular necrosis
   b) Cholestasis
   c) Immune compromise as the reticuloendothelial system fails
7. Musculoskeletal
   a) Rhabdomyolysis from direct thermal injury
   b) Hypoperfusion
8. Biochemical
   a) Coagulopathy – vascular endothelial damage, capillary permeability, platelet destruction, impaired clot factor synthesis, fibrinolysis
   b) Acid Base - Early respiratory alkalosis from excess panting, later metabolic acidosis with dehydration leading to hypotension, poor tissue perfusion, causing lactic acidosis
   c) Electrolytes - hypokalemia from vomiting and panting/respiratory alkalosis, hyperkalemia later from acidosis, tissue destruction, renal compromise, hypernatremia and hyperchloridemia from dehydration, hypophosphatemia and hypomagnesemia (unknown mechanism)

DIAGNOSIS

History – activity, conditions, signs, symptoms
Physical exam findings – respiration, heart, pulses, color, hydration, mentation
Laboratory – hemogram, biochemistry, urine, coagulation
Hemogram – high PCV, anemia, thrombocytopenia, leukocytosis
Biochemistry - ↑ BUN, creatinine, liver/muscle enzymes, Na^+, Cl^-, K^+ (late)
↓ Decreases: glucose, Ca^+, K^+ (early), PO_4^-, Mg^{++}
Urinalysis – proteinuria, hematuria, myoglobinuria, tubular casts
Coagulogram - Prolonged PT, PTT, ACT; elevated FDPs; decreased fibrin, platelets

TREATMENTS

Initial stabilization should focus on ***decreasing body temperature to prevent further heat induced injury***, maximizing oxygen delivery to tissue by restoring tissue perfusion and arterial oxygen concentration, and minimizing further neurologic injury.

STOP WORK * REMOVE FROM HEAT * RAPID COOL DOWN * TRANSPORT

Normalizing Body Temperature - Surface Cooling

- Wet down with ice/cold water
- Place on cool surface
- Fan or place before air conditioner
- Ice packs may be placed to neck, axillary, and groin areas (large vessel areas: jugular, brachial, and femoral)
- Isopropyl alcohol applied **in small amounts** to hairless areas (axillae, inner ear pinnae, abdomen, inguinum) for evaporative and vasodilation properties
- Stop cooling methods once body reaches 103-104^{o}F (39.4-40^{o}C) as temperature will continue to fall. If hypothermia occurs, patient warming may be necessary

Normalizing Body Temperature - Internal Cooling Techniques

- Cold intravenous isotonic fluid administration
- Cold water enema –will lose accurate rectal temperature monitoring

♬ ***NOTE*:**
Ice water baths have historically been discouraged due to concerns that (1) vasoconstriction will reduce heat transfer out of the body and actually raise internal temperature and (2) the shivering would generate more heat. To date, there are no scientific studies to prove or disprove these assumptions. Actively rapidly cooled dogs do better when worked again - last longer and perform better, than those who were not. In the field use what you have to promote rapid body cooling, and monitor response.

Another concern is the use of large quantities of alcohol, which is generally discouraged, because significant vasodilation may promote/worsen shock and in some cases lead to uncontrollable decreases in temperature. Again, use what you have but limit alcohol use to the less haired areas for best effect with the least amount.

VETERINARY CARE

If dog is bad enough to require treatment in the field, stop work even if recovery seems apparent and transport to a veterinary clinic.

- Temperature variations may rebound, be unstable for hours to days
- Complications may arise as far as 4 days after a heat stress incident

Hospital Treatment

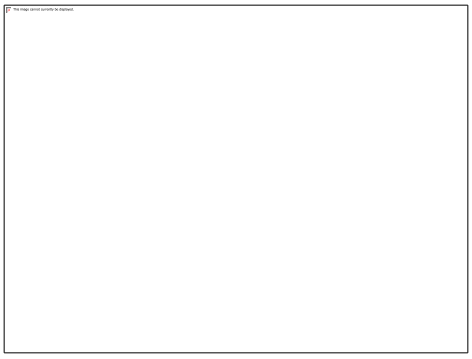
Restoring and Maintaining Tissue Perfusion – treating hypovolemic shock

- IV catheter placement
- Blood collection for baseline values ideal
- Isotonic electrolyte solution @ 20-40 ml/kg bolus; reassess and repeat until cardiovascular parameters normalize. Another fluid guideline alternative is 90 ml/kg/hr, reassess every 15 minutes during administration to adjust rate based on patient response
- If blood pressure does not improve with adequate fluid resuscitation, drug therapy options: dobutamine 5-10 μg/kg/min, dopamine 5-20 μg/kg/min, norepinephrine 0.1-20 μg/kg/min

  ♬ NOTE: adequate fluid therapy is important, as vasopressors may redistribute blood away from the gut, leading to more severe GIT compromise
  - Monitor HR (80-120), ECG, CRT (<2 sec), BP (120/80)
  - Maintenance fluids (40-60 ml/kg/day) plus fluid losses once stabilized

Airway and Breathing

- Oxygen therapy until respiration and oxygen delivery efficiency evaluated
- Short term oxygen safe: minimize breathing effort, corrects hypoxemia
- Respiratory distress and inability to pant properly contributes to continuing hyperthermia despite cooling measures
- If airway patency is compromised, intubation may be needed



Central Nervous System

- Blood glucose (normal 60-110) check immediately in the presence of neurologic abnormalities. If hypoglycemic:
    - 50% dextrose bolus @ 0.25-0.5 g/kg
    - Add dextrose to maintenance fluids @ 2.5-5% concentration
- Altered mentation after restored tissue perfusion or other signs indicative of cerebral edema (seizures, cranial nerve deficits, paresis, miosis/mydriasis, inappropriate bradycardia, apnea):
    - Mannitol 0.5-1.0 g/kg over 20 minutes
    - Hypertonic saline 7% 3-5 ml/kg
    - Elevate head ~30 degrees
    - Seizures: Diazepam 0.5 mg/kg IV; phenobarbital 2-10 mg/hr

Additional assessment and treatment, after initial stabilization, focuses on the renal, gastrointestinal, hepatic, and coagulation systems while continuing to monitor cardiovascular, respiratory, and neurologic systems.

Renal System

- BUN, creatinine, and potassium evaluations are paramount
- Desired urine output once tissue perfusion is restored and fluid replacements achieved is 2 ml/kg/hr

Gastrointestinal System

- Control vomiting: Ondansetron 0.2 mg/kg IV; Dolasetron 0.5 mg/kg IV
  NOTE: Cerenia not used if hepatic dysfunction suspected
- Treat gastric ulceration: Famotidine 0.5-1.0 mg/kg; Ranitidine 0.5-2.0 mg/kg
- Treat bacterial translocation, +/- sepsis, with broad spectrum antibiotic
  Penicillin and fluoroquinolone; Cephalosporin and fluoroquinolone

Coagulation System

- DIC common sequelae: PT, PTT, platelets, FDPs, D-dimers monitored
- Fresh frozen plasma may be administered to control hemorrhage

Hepatic System - Biochemical evaluation of liver enzymes

PROGNOSIS

Heat stroke patients are given a guarded prognosis due to the systemic complications that may occur. One study found factors associated with increased risk for death included DIC, hypoglycemia, and acute renal failure. The mortality rate was 50%; however all of the dogs that survived had been treated by their owners and transported to a hospital within 90 minutes. Other risk factors identified include delayed admission to the hospital (>90 minutes), seizures, ventricular arrhythmias, and some abnormal blood values.

FUTURE RISK

Having suffered heat stress does not mean a dog is more prone to this in the future. It has never been studied in dogs, never been scientifically validated. One theory suggested heat injury resets the hypothalamus, but this as well has never been shown to be true.

What is true? If a handler fears their dog is now more susceptible, they don't train as long or as hard, leading to a less fit dog which is a risk factor for heat stress.

What can we do: Prevention, minimize risk, monitor your dog, and use common sense!

Ask yourself:	Is dog overweight?	Less fit?
	Is work period too long?	Is there a medical problem?
	Muzzle work in the heat?	Dehydration?

PREVENTION TECHNIQUES

Recognize signs of early thermal stress BEFORE they become a medical issue

- Uncontrolled panting that distraction (ball, toy, food) cannot stop (the 'smile')
- Seeking shade or lying down without command. Remember, you may be a source of shade so K9 may move with you to stay in your shadow.
- Reluctance to work or delayed return – working search, patrol, chase of a toy, or return from retrieving a toy; they seem like they are not listening to command but are actually trying to lie down or seek shade during work or play that is causing their rise in body temperature
- Voluntarily releases reward – cannot pant with something in their mouth

Body condition – proper weight and fitness level

Annual veterinary examination

Work-Rest cycles appropriate for environmental and search conditions
Search periods should be as short as possible

- 15 minutes has been shown to be the upper limit in outside temperatures in excess of 86^{o}F / 30^{o}C. Variations may exist depending on other conditions – dog fitness, hydration, humidity, search terrain
- Search at midday and in direct sunlight should be kept especially short; if possible, avoid midday search and concentrate on early morning, early evening, or at night

Sufficient rest period between individual search operations is required

- Fatigue and lack of sleep lead to a clear decline in mental and physical capabilities of these canines, risking that they miss a victim
- Rest period between should be at least 40 minutes, as body temperatures fall slowly
- Rest time must be adapted to ambient temperature: the hotter it is, the longer the rest time
- Shade and wind are the best places to rest, improving heat dissipation

Hydration

- Maintaining adequate hydration cannot be overemphasized
- Water intake maintenance guideline: 2-4 ml/kg/hr, or 1.5-3 liters/day for a 75# canine; *work & heat stress add 1.25-2 times this amount, maybe more*
- 40-60 ml/kg/day is another formula
- Free access to sufficient drinking water or frequent offer of water
- Encourage to drink with training, flavored additives (no/low electrolytes)
- Oral electrolyte solutions of questionable value, though dogs that drool a lot may benefit

Monitor body temperature

Body temperature continues to rise for some time after physical exertion is over
Canines have been known to continue to search even when their temperature had risen into their critical range. They literally would work until they dropped; handler recognition and monitoring are critical to determine when to stop a search
Encourage some acclimatization rather than relying on air conditioning for the main down time. Although 20 days is needed for full acclimatization, even 4 days will lower the strain on rescue canines in a hot climate.

Body temperature and degree of exhaustion are not the same in all dogs

- Greyhounds, considered sprinters, had temperatures ranging from 104-106^{o}F
- Labrador Retrievers, considered intermediate athletic performers, had temperatures between 102-107^{o}F while hunting.
- During a long race, sled dogs, the endurance athletes of the dog world, often had temperatures between 104-108^{o}F

More Prevention Methods

- Wet down hair coat before, during, and after search
- Walk in the shade when at all possible, as ground temperatures may be higher than the air temperature especially when walking or working on asphalt or sand
- Check paws frequently, as these bear the brunt of physical abuse on hot surfaces (inflammation, cuts and abrasions)
- Hot, unfamiliar climes expose canines to unfamiliar bacteria which may increase risk of gastrointestinal stress. Maintain their normal feed and if possible use bottled water for drinking
- Cooling vest? Little evidence of effectiveness, thaw out quickly, need way to keep cool until use (hard in the field), interfere with tactical gear and equipment; may help recovery after work

Subcutaneous Fluids BEFORE Working in a Hot Environment?

Currently there is no published scientific data regarding potential benefits and/or contraindications for giving working dogs subcutaneous fluids in an effort to prevent and/or delay the onset of dehydration and other heat-related conditions.

Factors to consider against:

- Austere and unsanitary conditions increasing potential for infection or abscess introduced by the needle
- Volume needed to 'pre-load' a 30 kg (70 lb) canine against 5% dehydration is 1500 ml, a large amount at one time
- A normovolemic canine would not absorb the fluids very quickly as they are not needed by the body
- Large humps of fluids may interfere with harness or safety vests worn by some working canines
- Canine heat dissipation is mainly via respiratory tract (panting), a pure water loss. Most commonly 0.9% NaCl is the available subcutaneous fluid; this may exacerbate hypernatremia if the canine becomes dehydrated.
- Proper acclimation, enforced work-rest cycles, opportunity to orally hydrate, resting in shade or air-conditioning, healthy weight, and monitoring temperature are the best ways to maintain hydration or catch a problem early

Factors to consider for:

- Giving 500 ml may increase the amount of time a canine can work in a hot environment before becoming dehydrated
- No known infection/abscess occurrence in >500 military working dogs (MWDs) - Dr. Janice Baker, anecdotal
- Political situation: in Haiti, Urban Search and Rescue groups were concerned about giving the canines water in view of a populace that did not have enough potable water. Handlers were directed not to give their dogs oral water, so the medics were giving them subcutaneous fluids.
- Handlers report better endurance, scenting, and recovery from hard work when they received prophylactic SC fluids compared to when they did not

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