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ADVANCE2025

They're Heating Up: Pathophysiology and Treatment Options for Heat Stroke

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They're Heating Up: Pathophysiology and Treatment Options for Heat Stroke

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What is Heat Stroke?

- Nonpyrogenic increase in body temperature above 104°F

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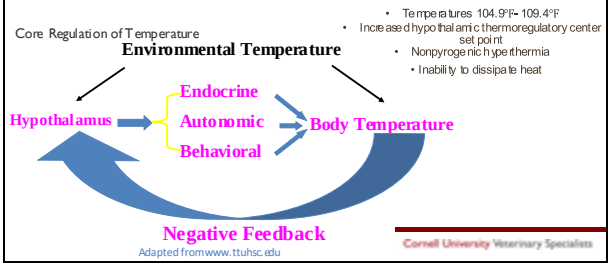
Hyperthermia



- Temperatures 104.9°F- 109.4°F
- Increased hypothalamic thermoregulatory center set point
- Nonpyrogenic hyperthermia
- Inability to dissipate heat

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Thermoregulatory Control

Heat Gain	Heat Loss
Exercise	Behavioral Changes
Oxidative Metabolism	Peripheral Vasodilation
Increased Metabolic Rate	Panting

Hypothalamic Regulation

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Thermoregulatory Center

- Hypothalamus
  - Regulates body temperature
  - Effects on body temperature:
    - endocrine
    - autonomic
    - behavioral
- Cooling
  - Peripheral vasodilation
  - Panting
- Warming
  - Peripheral vasoconstriction
  - Shivering

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Methods of thermoregulations…

- Evaporation
- Conduction
- Convention
- Radiation

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Pyrogenic hyperthermia - "Fever"

- Treatments:
  - active cooling - causes metabolic stress and physical discomfort.

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Nonpyrogenic hyperthermia - "heat stroke"

- change in hypothalamic thermoregulatory set point
  - allows for active cooling without discomfort and metabolic distress

Who is susceptible?

- overweight animals
- brachycephalic breeds
  - BAOS
- thick coated animals
- geriatric & pediatric animals
- Comorbidities
  - airway/ lung diseases
    - laryngeal paralysis
    - tracheal collapse
  - heart disease

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What causes heat stroke?

- Excessive exercise in warm weather
  - acclimation to the environment can take up to 60 days, partial acclimation within 10-20 days.
- Poor ventilated areas
  - cars
  - left in yards without shade and water

Clinical Signs

→ Respiratory
- Tachypnea/Panting
- Cyanosis
- Stridor
- Swollen Tongue

→ Cardiovascular
- Tachycardia
- Epistaxis

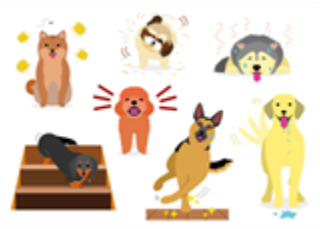
→ Gastrointestinal
- Vomiting
- Diarrhea
- Hypersalivation

→ Neurologic
- Ataxia
- Seizures
- Listlessness
- Muscle Tremors
- Dilated Pupils
- Loss of Consciousness
- Head Tremors
- Vocalizing

Early signs of heat stroke…

- Nonpyrogenic hyperthermia
  - Panting
    - progressing to distressed panting
    - noisy breathing (as heat stroke worsens)
  - Drooling
- Injected mucous membranes
  - Red tongue
  - Tachycardia
  - Vomiting
  - Diarrhea

Advanced signs of heat stroke….



- Lethargy
- Confusion
- Collapse/ weakness
- Seizures

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Pathophysiology of heat dissipation

- Increase in hypothalamic temperature
- Increased neuronal signals to panting center
- Panting and increased evaporative cooling

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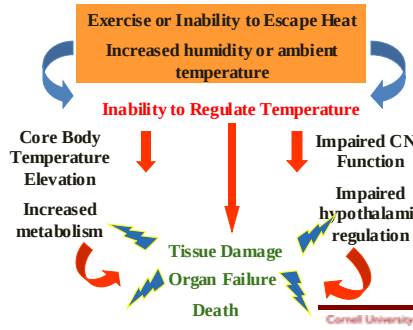

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Pathophysiology of Hyperthermia

- Increased dead space ventilation
- Metabolic alkalosis
- Continued panting
- Peripheral vasodilation
- Decreased splanchnic circulation

Tissue Effects of Hyperthermia

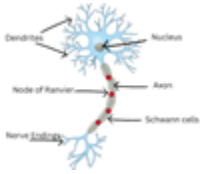
- Widespread cellular injury
- Uncoupling of oxidative phosphorylation
- Decreased enzymatic function
- Tissue oxygen debt
- Anaerobic glycolysis
- Lactic acidosis

Pathophysiology of Hyperthermia

- Increased dead space ventilation
- Metabolic alkalosis
- Continued panting
- Peripheral vasodilation
- Decreased s circulation

- Increased cardiac output
- Later, vasomotor collapse
- Hypovolemia
- Multiple organ dysfunction

Effects by Body system…



- CNS -
  - susceptibility to cytotoxicity is increased
    - resulting in injury
    - death of neurons
    - cerebral edema, hemorrhage and necrosis
  - Coagulation
    - Endothelial damage
      - cytotoxicity - releases thromboplastin and factor XII
        - Activating coagulation cascade
    - Disseminated intravascular coagulation (DIC)
      - Petechial hemorrhage
      - Bloody urine

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Effects on the cardiovascular & GI system

- Cardiovascular
  - Cardiac output increased
  - peripheral vasodilation increased
  - Central vasoconstriction increased
    - Compensatory measures fail venous blood pools, vasodilation
      - Leading to decreased circulating blood volume
      - Hypotension
      - Shock
  - Inadequate blood circulation
    - Electrolyte derangements
    - Acidosis
    - Production of microthrombi
  - Ventricular arrhythmias
    - Due to ischemia of myocardium and exacerbated perfusion abnormalities
- Pulmonary
  - Direct injury to pulmonary vascular endothelial cells
    - Leading to pulmonary edema
    - Increased pulmonary vascular resistance
    - Acute respiratory distress syndrome (ARDS)
- GI
  - cytotoxicity
  - Prolonged hypotension
  - Hypovolemia
  - Production of microthrombi
    - Due to decreased perfusion and ischemia
      - Compromising GI tract
  - Cellular hypoxia
    - Produces reactive oxygen and nitrogen species
    - Stimulates inflammatory cells
      - Further damaging GI tract
  - Increased permeability of GI mucosa
    - Translation of bacteria and bacterial production
      - Endotoxins
  - Bacteremia & endotoxemia
  - Sepsis
    - Causing further ischemia
    - Cardiac dysfunction
    - Shock
    - Eventually death

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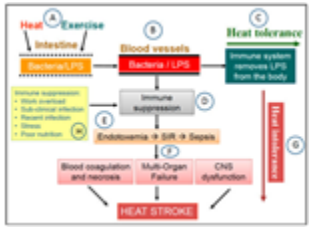
Neuronal Injury

- Direct neuronal injury
- Dysoxia
- Cellular death
- Cerebral edema
- Seizures
- Progression and potential for reversal directly related to degree and duration of injury



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Criteria for SIRS in Veterinary Patients

Parameter	Value
Temperature	<100 °F or > 103.5°
Heart Rate	>160 bpm (dogs) >250 bpm (cats)
Respiratory Rate/CO_2	20 breaths/min P_aCO_2 < 32 mm Hg
White Blood Count	< 4000 or >12,000 > 10% bands

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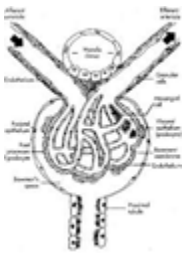
Renal Effects of Hyperthermia



- tubular cells
- Decreased renal perfusion
  - Hypovolemia
  - Hypotension
- Rhabdomyolysis
  Pigment injury to tubular epithelium
- Urinalysis
  Renal tubular casts and glucosuria

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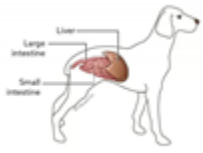
Hepatocellular effects of Hyperthermia

- Thermal injury to hepatocytes
  - Elevations in ALT, AST, T Bili
  - Persistent hypoglycemia
- Portal vein hypotension
- Congestion and thrombosis
  - Direct thermal injury/ protein denaturation
    - leading to tubular necrosis
  - indirect injury - secondary to vasoconstriction, dehydration, myoglobinuria, secondary to rhabdomyolysis



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Identifying Heat Stroke

Prince - temp 104.1 F

Fluffy - temp 104.1 F

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NURSING CARE

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Checklist:
The Rule of 20

Rebecca Kirby, DVM, DACVIM, DACVECC

www.dvm360.com/view/checklist-rule-20-pdf

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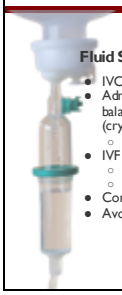
Fluid balance, COP



Fluid Support

- IVC access
- Administer room temperature balanced electrolyte solution (crystalloids)
  - Plasmalyte-A, Normosol-R, LRS
- IVF bolus
  - Hypovolemia
  - Hemoconcentrated
- Continued support
- Avoid overhydration

Oncotic Support

- Reduce third-spacing
  - Fluid loss to interstitial space - edema
- Synthetic Colloids
  - Hydroxyethyl starch*
  - 5 mL/kg IV bolus
  - Increased intravascular volume

*contraindicated in patients at risk for coagulopathies

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Oxygenation and Ventilation

Oxygenation

- Monitor SPO2
  - Increase FiO2
    - Increased metabolism (increased O2 demand)
    - Upper airway obstruction = may need to intubate
- Aerobic metabolism = CO2 production
- Anaerobic metabolism = lactate production

Ventilation

- Monitor blood gas (pvCO2) vs ETCO2 (if intubated)
- Tachypnea may lead to dead-space ventilation
- Increased metabolism = increased CO2 production
- CNS depression may lead to hypoventilation

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Blood Pressure

Hypotension

- Target MAP >60 mmHg
- Target DAP >40 mmHg

Targeted treatments

- Hypotension
  - Vasopressors
  - Positive inotropes
- Perfusion
  - Volume support

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Heart rate, contractility, rhythm

Targeted treatments

- Tachycardia
  - Volume
  - Stress
- Contractility
  - Positive inotropes
- Rhythm
  - Accelerated idioventricular rhythm
    - Lidocaine

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Glucose

Hypoglycemia

- Glucose <60 mg/dL
- Why?
  - Increased metabolic rate (increased glucose consumption)
  - Sepsis (bacteria consumption)
  - Hepatic damage (reduced glucose production)
- Supplement with dextrose CRI (2.5%-5%)
- Monitor BG's

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Body Temperature

Hyperthermia interventions

- Provide cool environment
- Fans and/or air conditioning
- Apply cool (not cold) water to coat
  - NOT ice or cold water
- Ice/cool packs to inguinal and axilla regions
- Cool to 103 F
- Avoid overcooling

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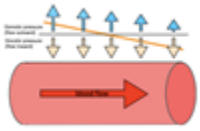
Albumin

Hypoalbuminemia

- Poor prognosis if <2.0 g/dL
- Albumin loss in feces or urine
- Decreases COP
  - Increased risk for edema



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Electrolytes

Monitor

- Sodium
- Potassium
- Magnesium
- Phosphate
- Lactate

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Mentation

Monitor

- Progression of decreased mentation
- Coma and/or seizure = poor prognosis
- Intubation supplies on hand

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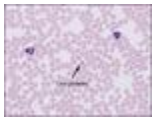
RBCs and Hemoglobin



Monitor

- Anemia vs hemoconcentration
- Thrombocytopenia
- Peripheral nucleated RBC (nRBC) presence increases with severity and poorer outcomes

GI Motility and Integrity

Diarrhea

- Hematochezia/melena
  - RBC and protein losses
- Intestinal lining ulcers/sloughing
- Bacterial translocation
  - Sepsis
- Nutrition malabsorption
- *Perianal irritation/rash

Interventions

- GI ulcerations
  - IV famotidine (H2 antagonist)
  - Oral sucralfate
- Calmoseptine/ointment as perineal skin protectant

Nutrition

Feeding

- Enteral feeding preferred
  - liquid diets vs critical care canned
- Support albumin, electrolytes, rehydration, and glucose
- NG tube???

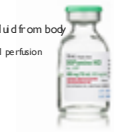
Renal Function

Monitor

- Creatinine <1.5 mg/dL
- Urine output
  - Urinary collection system to monitor ins and outs
  - Normal range: 1-2 mL/kg/hr
  - Renal tubular casts (renal damage)
  - Glucosuria (d/t glucose dysregulation)
  - Myoglobinuria (bloody urine)
- Novel urine biomarkers - significantly higher levels in dogs with heatstroke
  - neutrophil gelatinase-associated lipocalin (NGAL)
  - retinol-binding protein
  - C-reactive protein (CRP)

Support

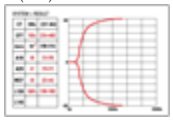
- Dopamine
  - Maintain urine output
  - 3-5 mcg/kg/min
- Furosemide
  - Diuretic
  - Remove excess fluid from body
    - Edema
    - Increase renal perfusion



Coagulation

Hemostatic derangement

- Thrombocytopenia
- Prolonged PT and PTT
- Altered thromboelastography (TEG)



Considerations

- Increased bleeding risk
  - Look for petechiae, bruises
- Synthetic starches contraindicated

Immune Status, Antibiotics

Supportive therapy

- Focus on non-nephrotoxic, broad spectrum antibiotics
- Assume immune compromised - wear gloves for all interaction

Drug Dosage and Metabolism

Drug clearance

- Increased metabolism = increased drug clearance
- Impaired hepatic function = decreased drug clearance
- Impaired renal function = decreased drug clearance
- Also consider effects on GI motility

Wound Care and Bandages

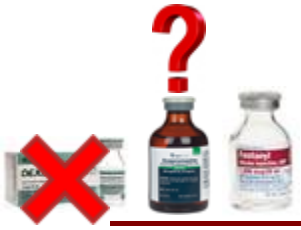
Monitoring

- Monitor for swelling distal to IVC sites
- Perianal rashes from contact with diarrhea
  - Sanitary shave
  - Calmoseptine
  - Prevention vs reaction
- Burns
  - Wear gloves
  - Analgesia
  - Keep covered
- Change soiled or strikethrough bandages

Pain Control

Anxiety/analgesia

- Avoid alpha-2 agonists - peripheral vasoconstriction
- Phenothiazines - alpha-1 agonist
  - Good - peripheral vasodilation to improve heat loss
  - Bad - may contribute to refractory hypotension (i.e., sepsis)
- Short acting analgesia
  - Fentanyl CRI
  - May contribute to GI stasis



Nursing Care

Non-ambulatory patients

- Lubricate eyes
- Passive range of motion (PROM)
- Soft bedding
- Turn hips/reposition q2-4hrs
- Fan/cool towels as needed
- Communicate with team any concerns

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TLC

"Until one has loved an animal, a part of one's soul remains unawakened."

~Anatole France

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THANK YOU!!

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