Cardiovascular Consequences of General Anesthesia

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Objectives

- Review
- Side effects v. complications – setting expectations
- Reported incidence of anesthetic-associated CV complications
- Review of basics of CV system
- Anesthetic monitoring using the ECG
- Arrythmias; classification, treatment criteria, interventions

Setting Perspectives

Unconsciousness	• Depth assessment • Knowledge of how drugs/circuits work
Amnesia (loss of memory)	• Protocol selection • Unclear ramifications in our species
Analgesia (loss of pain *perception*)	• Protocol selection, adequate dosing intervals • Knowledge of pain medications
Akinesia (loss of movement)	• Depth assessment • Knowledge of how drugs/circuits work
Cardiopulmonary, thermoregulatory, and autonomic stability	• Clinical observation/monitors • Nursing practices/standards • Balanced protocols • Interventions (e.g., BP, rhythms, temperature etc.)

Setting Perspectives

And even though our goal is:

Cardiopulmonary, thermoregulatory, and autonomic stability

General anesthesia often produces:

Cardiopulmonary depression

Thermoregulatory dysregulation

Autonomic dysregulation

Setting Perspectives

‘Cardiopulmonary, thermoregulatory, and autonomic stability’

What is really meant:

Adequate oxygen delivery to tissues/organs during anesthetic event

Dependent on:

Cardiac output (CO; L/min)

Vascular resistance (VR)

Blood pressure (BP)

Oxygen carrying capacity (CaO2)

Delivery of oxygen to tissues (DO2)
= Cardiac output (L/min) x CaO2

Cardiac output (= HR x stroke volume)

$$CaO_2 = \underbrace{(Hb \times 1.39 \times SaO_2)}_{\text{Oxygen bound to Hb}} + \underbrace{0.003_{(mmHg)} \times PaO_2}_{\text{Oxygen Dissolved}}$$

Side Note About Side Effects v. Complications

Side Note About Side Effects v. Complications

- **Side effect** – effects other than those specifically desired during the use of a medication.

Often known for drugs used

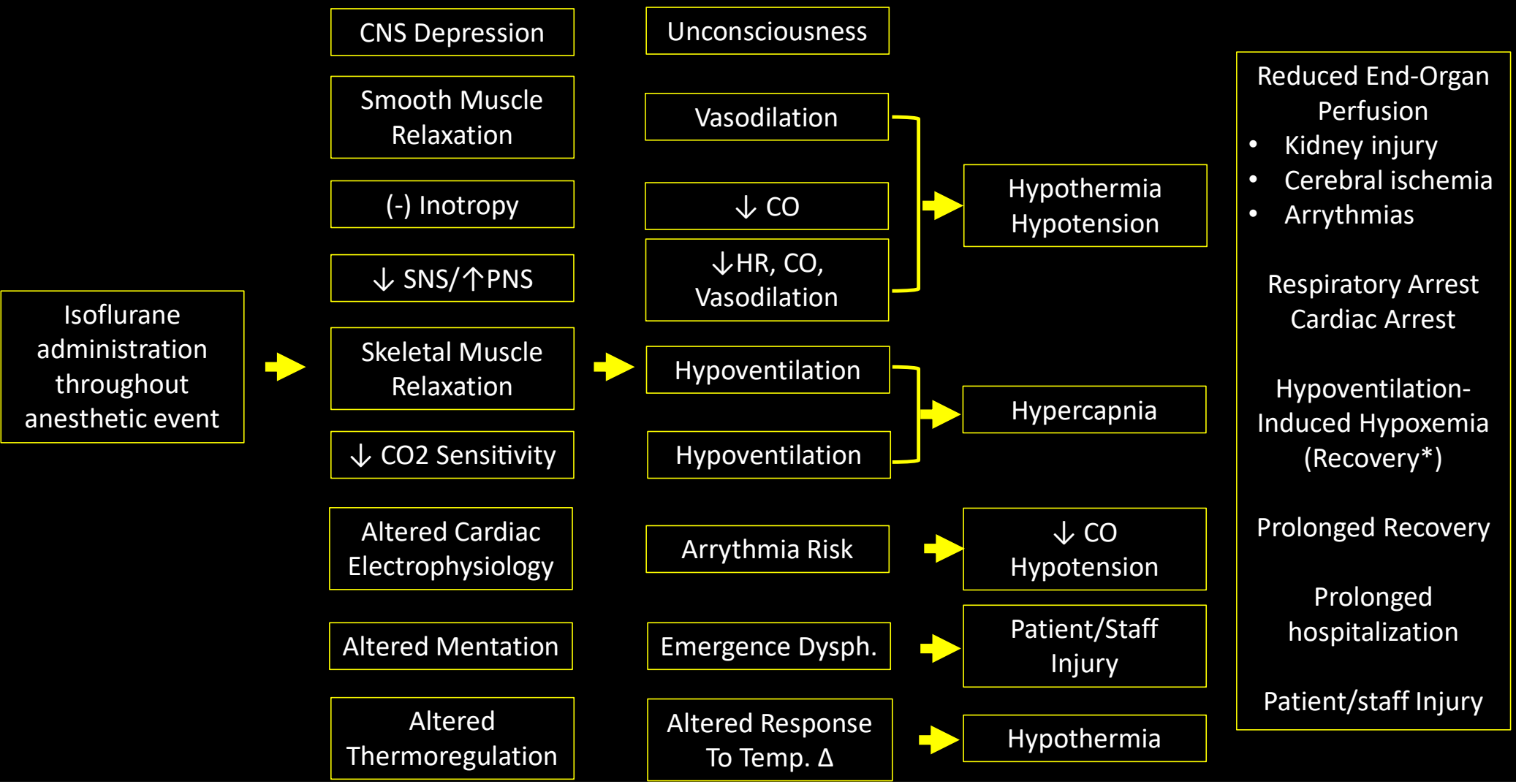
- **Adverse event –** unintended and/or undesired effects secondary to the use of a medication or completion of a medical/surgical procedure *producing a new or worsened morbidity, increased hospital stay, or mortality*.

Unmanaged side effects may progress to adverse events

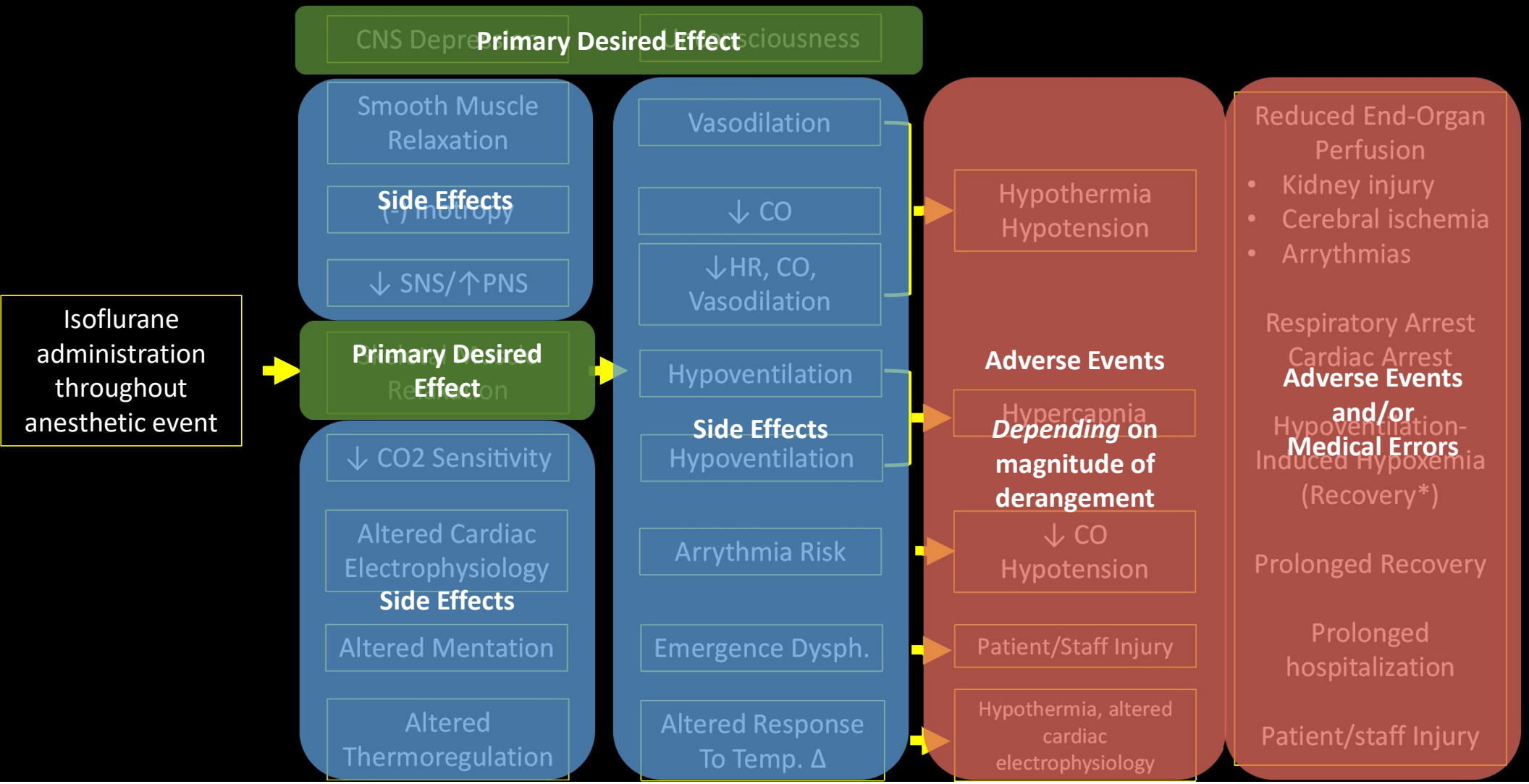
- **Medical error (complication)** – *preventable, undesirable effect of medical care, whether or not,* it is evident or harmful to the patient.

Unmanaged/mismanaged side effects or adverse events may progress to medical error (negligence) during patient management

Setting Perspectives



Setting Perspectives



Reported incidence of anesthetic-associated CV complications

Reported Incidence of *Cardiovascular* Side Effects/Adverse Events

- Hypotension – most common adverse effect reported
  (More next lecture)
  - Dogs – 20-30%
  - Cats – 25-35%
  - Mixed population – up to 60%

- Arrythmias – 6-10%
- Hemorrhage – < 2%

- Hypothermia – up to 40%+

Factors associated with anesthetic-related death in dogs and cats in primary care veterinary hospitals

Complications and Mortality Associated With Anesthesia in Dogs and Cats

Mazzaferro and Wagner 2001; Gaynor et al 2001; Gordan and Wagner 2013)

Basic CV System Review

Understanding where the blood is

Arterial system

10+%

Capillary beds

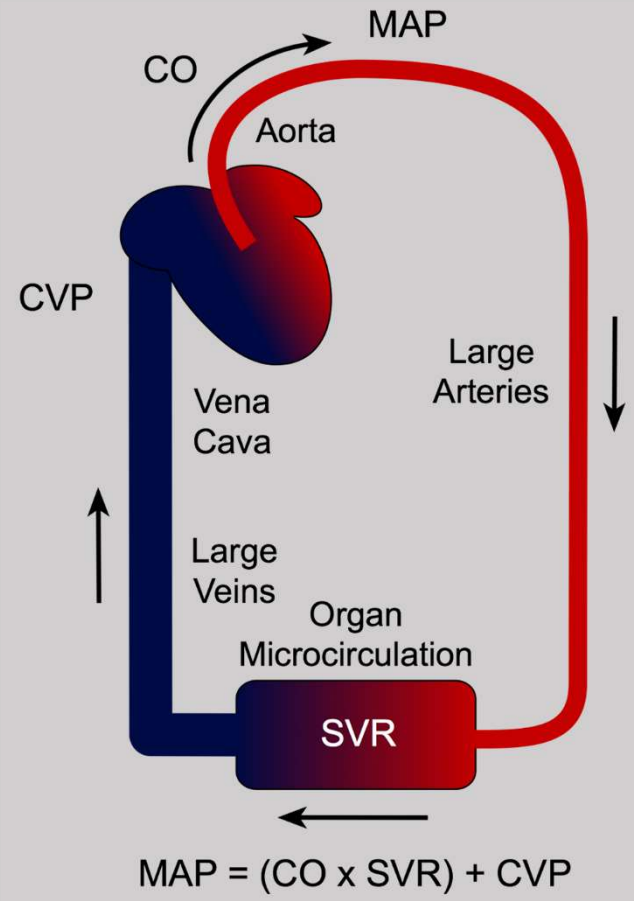
5%

Heart and Lungs

15+/-%

Venous system

70+/-%

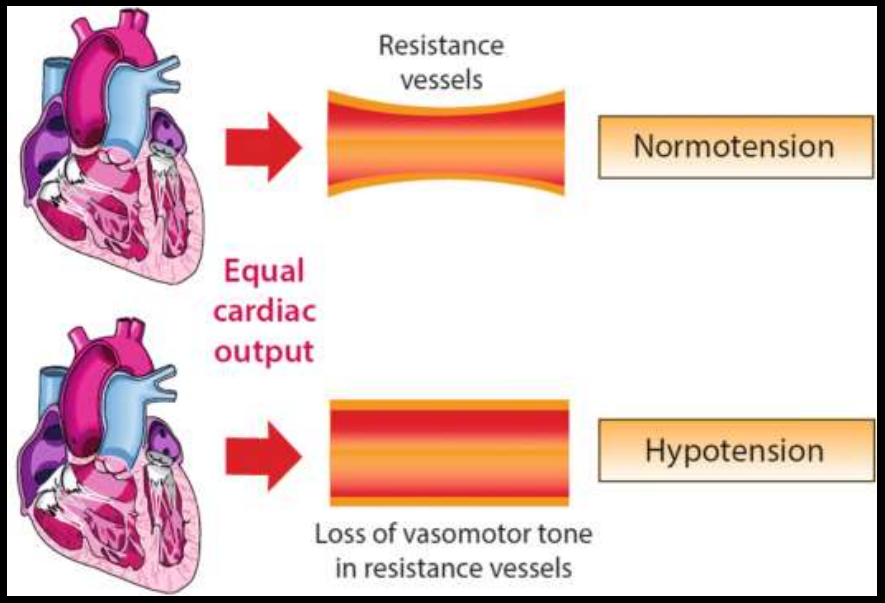


Why Hypotension? – Low Blood Pressure

When under general anesthesia (influence of isoflurane)

↓ muscle contractility

↓smooth muscle contractility
= vasodilation



Why Hypotension? – Low Blood Pressure

When under general anesthesia (influence of isoflurane)

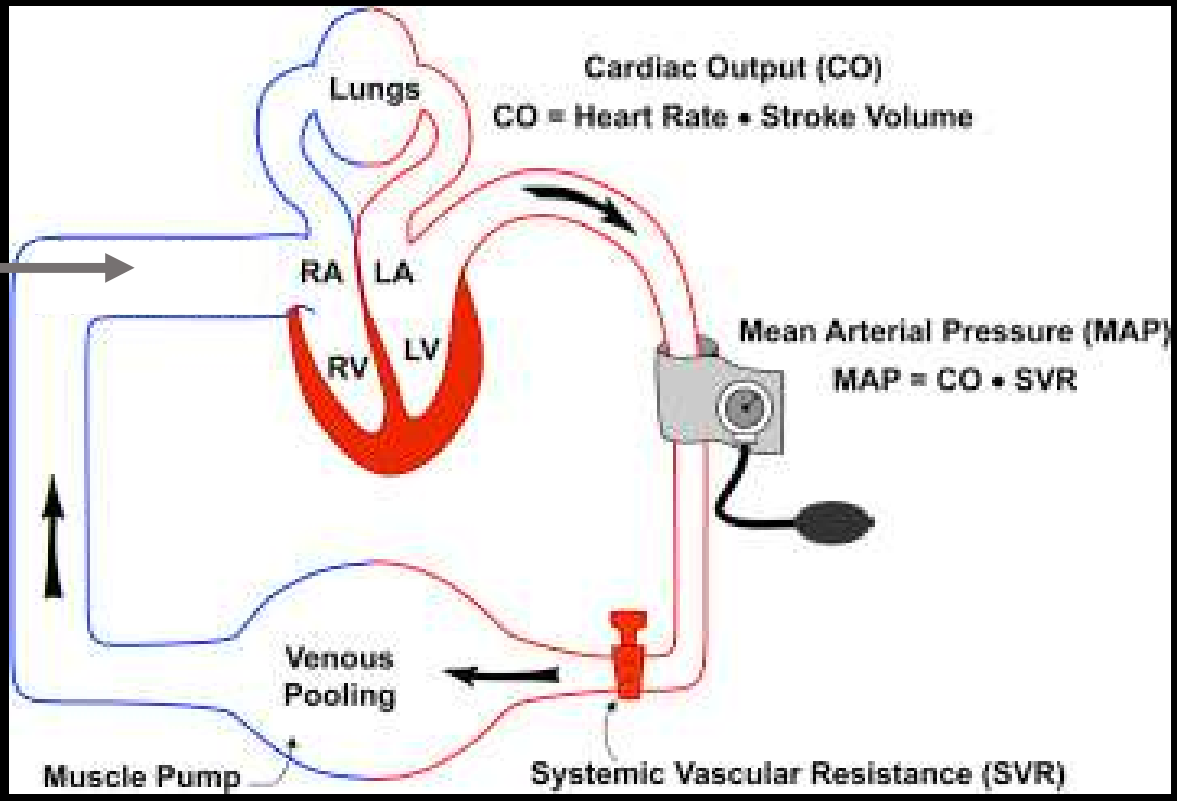
↓ muscle contractility

↓smooth muscle contractility

= vasodilation & reduced preload

Preload – blood returning to the heart

- Venous vessel 'tone'
- Blood volume
- Heart rate/rhythm



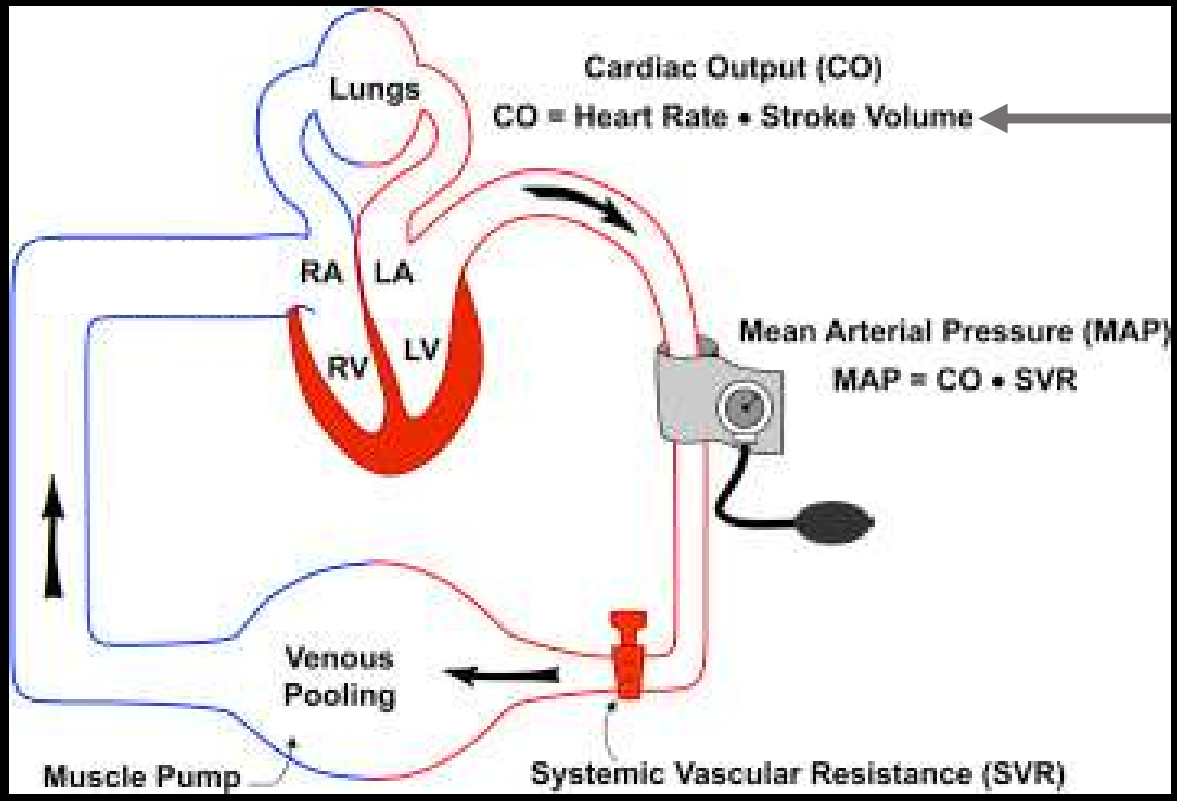
Wieling et al. 2016

Why Hypotension? – Low Blood Pressure

When under general anesthesia (influence of isoflurane)

↓ muscle contractility

↓Cardiac muscle contractility
= ↓ blood ejected / beat (↓ stroke volume)



At 1.5% isoflurane
Compared to awake

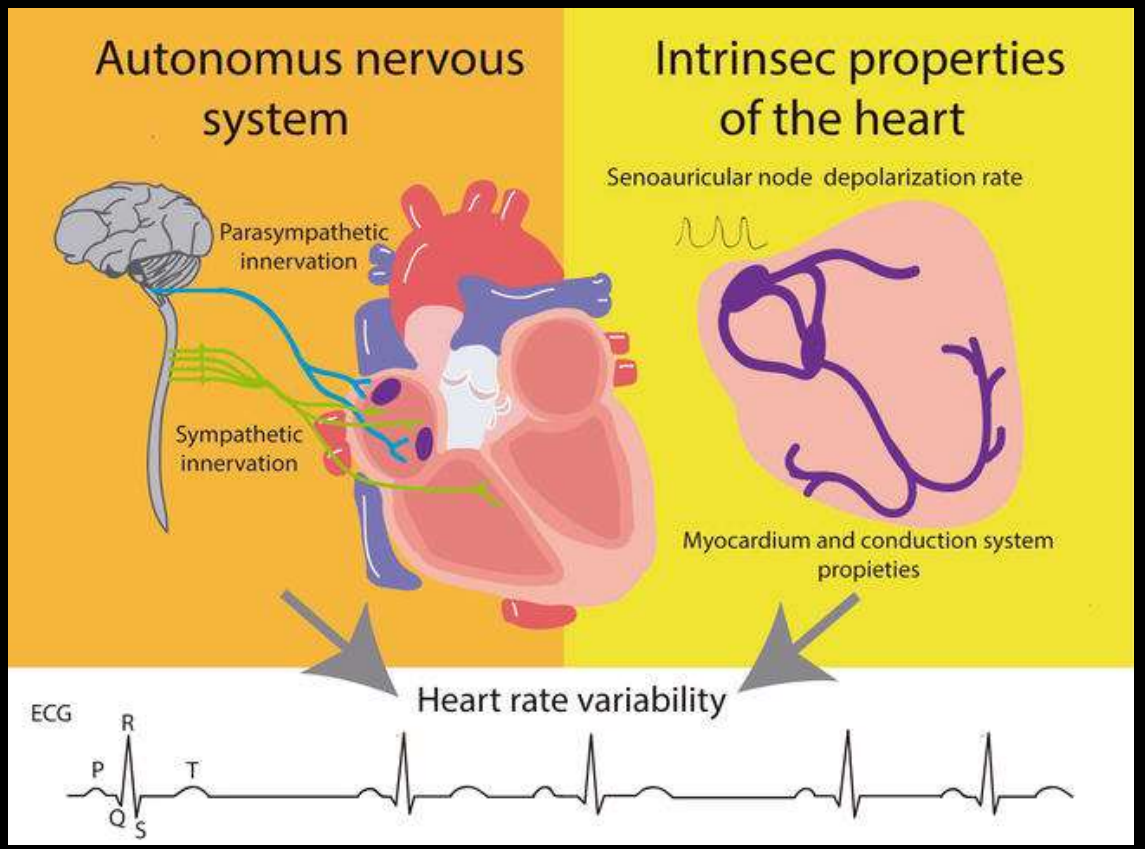
Variable	Change
Heart rate	↑24%
Stroke volume	↓35%
Vascular resistance	↓18%

Wieling et al. 2016; Bernard et al. 1990

Rhythm & Rate …influence cardiac output at any given time

- Intrinsic cardiac automaticity
  - Sinoatrial node
  - Atrioventricular node
- Autonomic nervous system
  - parasympathetic
  - sympathetic

Produces some rate/rhythm



Pre-operative ECG in Practice

- ECG leads should be placed *before induction* of general anesthesia
  - Recommended to observe ECG before induction of general anesthesia, on all patients, *when possible*
  - Know patient was normal before
    - Rhythms can easily change from awake (sedated) to anesthetized
    - Did you anesthetize a dog that had clear abnormalities before induction?
  - Almost every drug we give alters:
    - Electrophysiology of the heart
    - Conduction of electrical signals through the heart
    - Influencing systems (e.g., PNS, ANS)
    - *ECG is only clear way to monitor this aspect of CV system

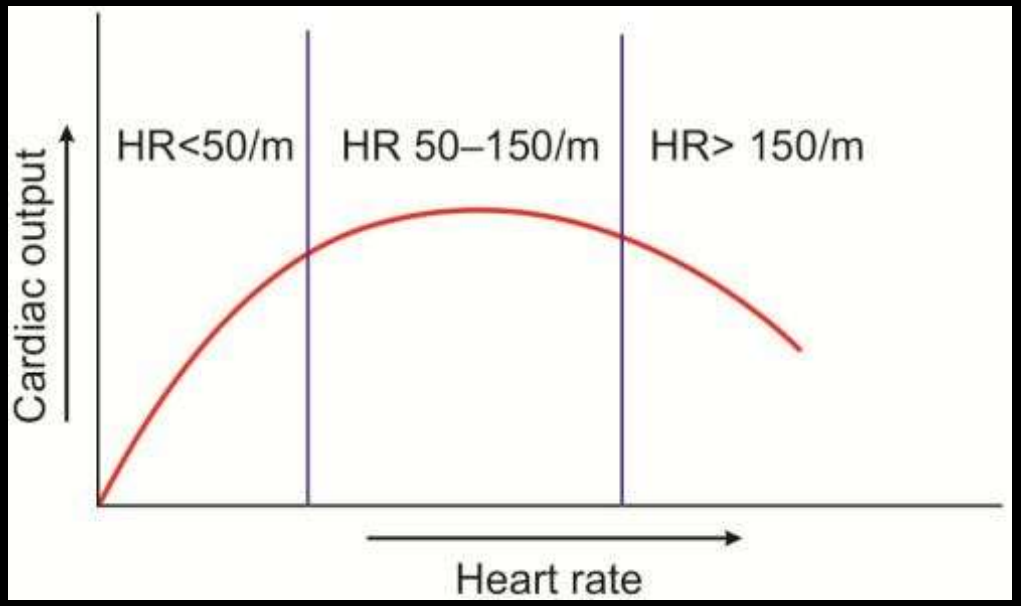
Relative Rate

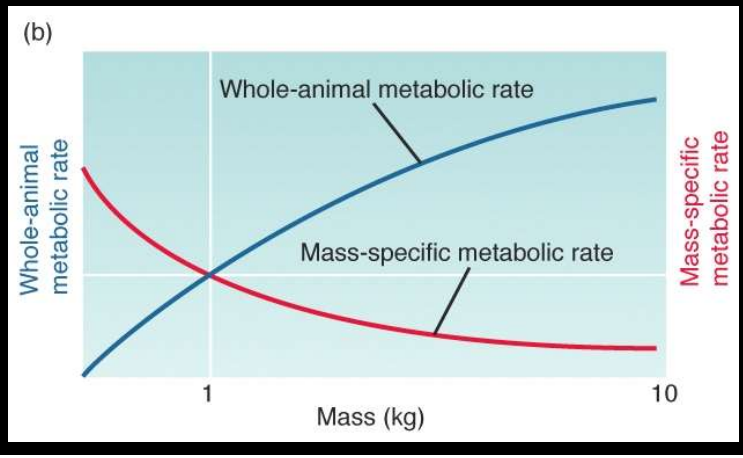
Allometric scaling

- A normal HR for one dog, not the same for another
- Larger dogs have a lower baseline functional HR
- Smaller dogs have a higher baseline functional HR

Pediatric = SNS still developing

- Unable to increase contractility or vascular resistance; *reliant on HR being normal/elevated*
- Not analog (e.g., development of 2 mo. > 1 mo. > 2 wk)
- Maintain HR in normal-to-tachycardic
- Consider premedicating with anticholinergic if < 1 mo. in age





Relative Rate

Bradycardia definition:

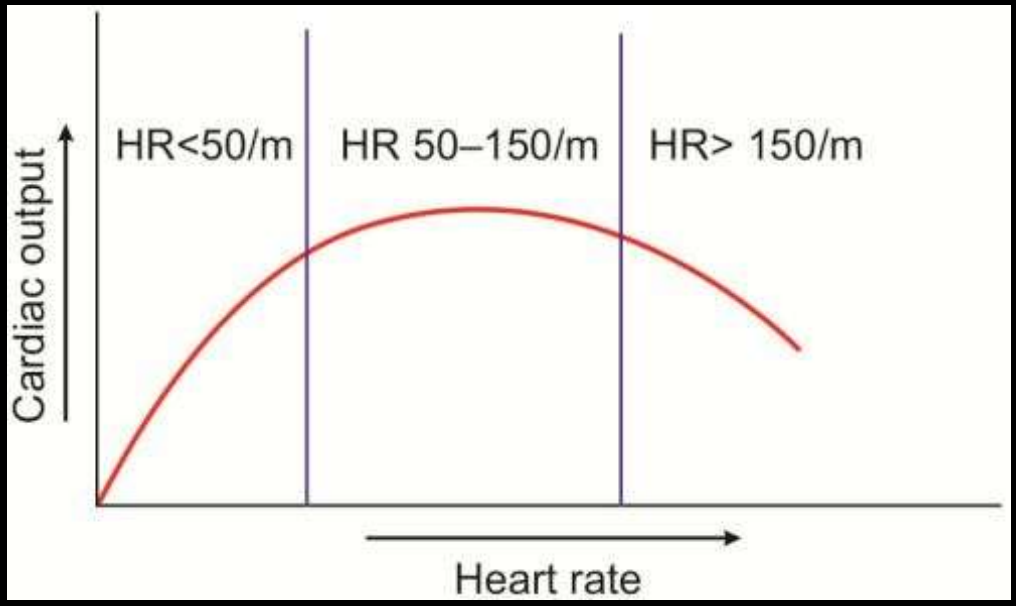
- HR < 50-80 in the dog
  - Larger breed dogs: HR < 50-60
  - Smaller breed dogs: HR < 70-80
- HR < 110-120 in the cat

Bradycardia with 2nd degree AV-block common

Tachycardia definition:

- HR > 140-180 in the dog
  - Larger breed dogs: HR > 140
  - Smaller breed dogs: HR > 180
- HR > 200-220 in the cat

*smaller breeds tolerate higher HRs than larger breeds



Criteria for treatment of heart rate and/or dysrhythmias

Is the rhythm affecting cardiac output?

IF patient hypotensive; than likely yes
Intervention is warranted

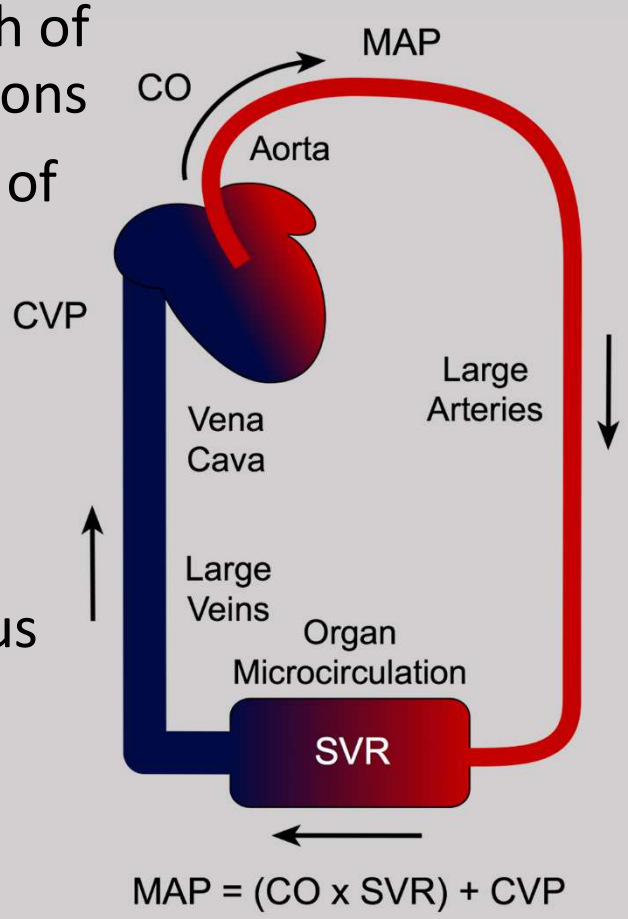
General anesthesia predisposes to bradycardias:

↓ autonomic nervous system output
Often drugs used which reduce rate (e.g., opioids, alpha-2 agonists)

Putting Things Together – Shifts Occur

Reduced strength of cardiac contractions

Altered control of rate/rhythm



Increased venous capacitance / reduced blood returning

Reduced arterial vasomotor tone (dilation)

Thermoregulatory Considerations

If no intervention occurred → patients would settle at a little above room temperature

- Definition: < 97 F body temperature
  - Recently suggested , 96.7 F should be considered adverse event

- Peri anesthetic hypothermia (PAH) is common
  - Dogs – 32-40%
  - Cats – up to 71%

Remember…
Unmanaged side effects may progress to adverse events

Thermoregulatory Considerations

- Why the high incidence?
    - High surface area-to-mass ratio → predisposing to radiant heat loss
    - Lack of effective standardized care for mitigating for hypothermia
- Side-effects from uncontrolled hypothermia related to:
    - Duration of PAH
    - Magnitude of PAH derangement
    - Context of the patient; procedure, comorbidities

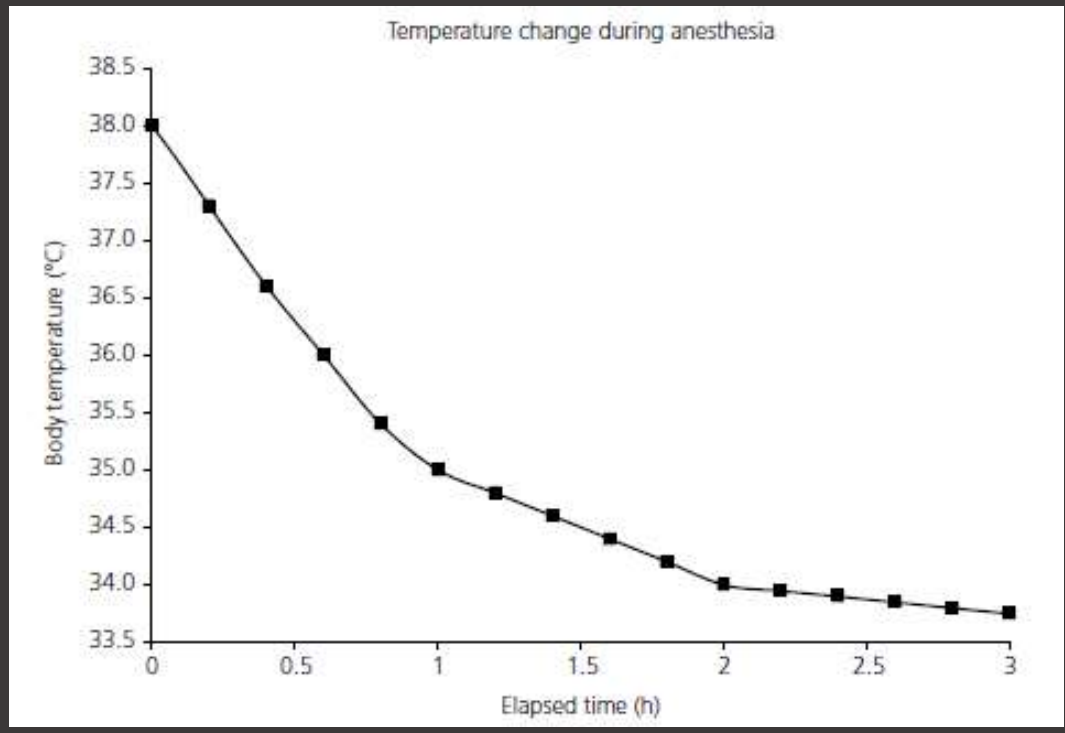
Thermoregulatory Considerations

- Implications of PAH well documented:
  - Relative anesthetic overdose
    - Every 1*C reduction is associated with approximately 5% reduction in anesthetic requirement
    - Increased solubility of anesthetic gases
    - Reduced metabolism of other, systemically, administered drugs
  - Prolonged recovery from anesthesia
  - Weak evidence for wound healing effects
  - Increased arrythmia risk
  - Impaired coagulation
    - Well documented (humans, in-vitro)
    - To-date, no effective investigation

Oesophageal temperature at end surgery (°C)	Number of cases	Mean ± SD time to righting (min)
35.0–35.4	4	23.4 ± 22.1
35.5–35.9	5	17.6 ± 14.8
36.0–36.4	12	14.9 ± 18.5
36.5–36.9	17	10.7 ± 3.9
37.0–37.4	15	9.9 ± 3.3
37.5–37.9	9	8.8 ± 5.5
> 38.0	5	7.7 ± 3.8

Timeline of Heat Loss

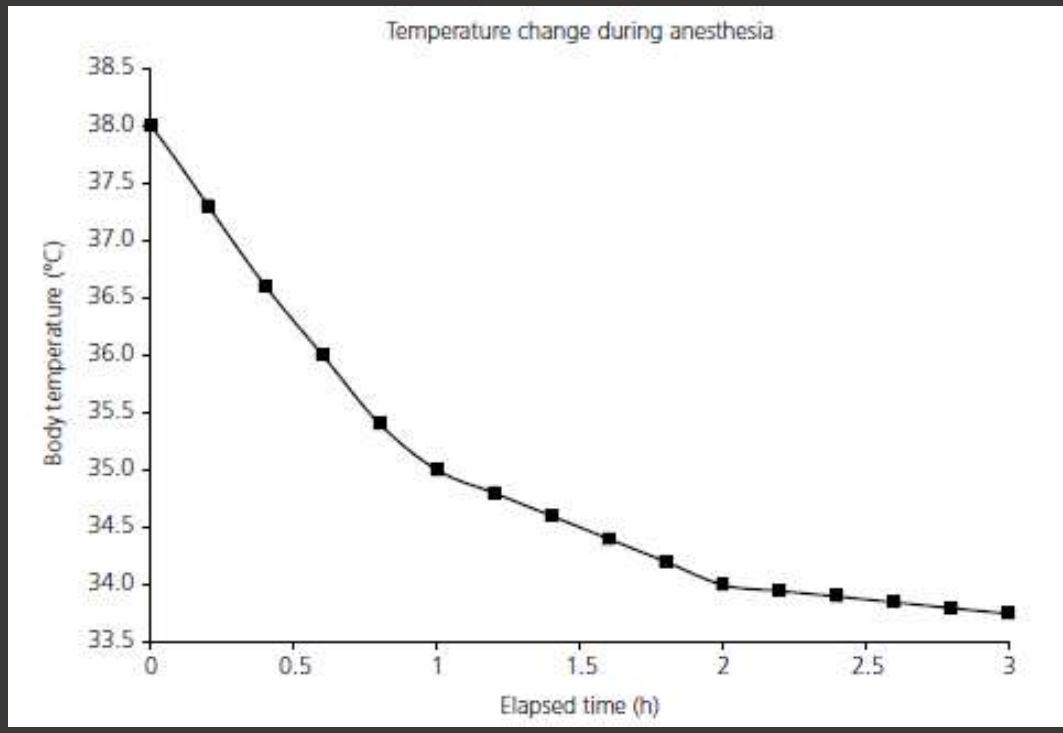
- Phase I (redistribution)
  - Core drops by 1.5+ °C in 1st hour
    - MUCH shorter in small patients
    - Greater loss in small patients
  - Core-to-periphery gradient
    - Normally 2-4 °C
    - Gradient lost → heat transferred via convection (blood flow)
    - Heat from core lost to peripheral tissue
    - Vasodilation*
  - Responsible for majority of all heat loss, if unmitigated against



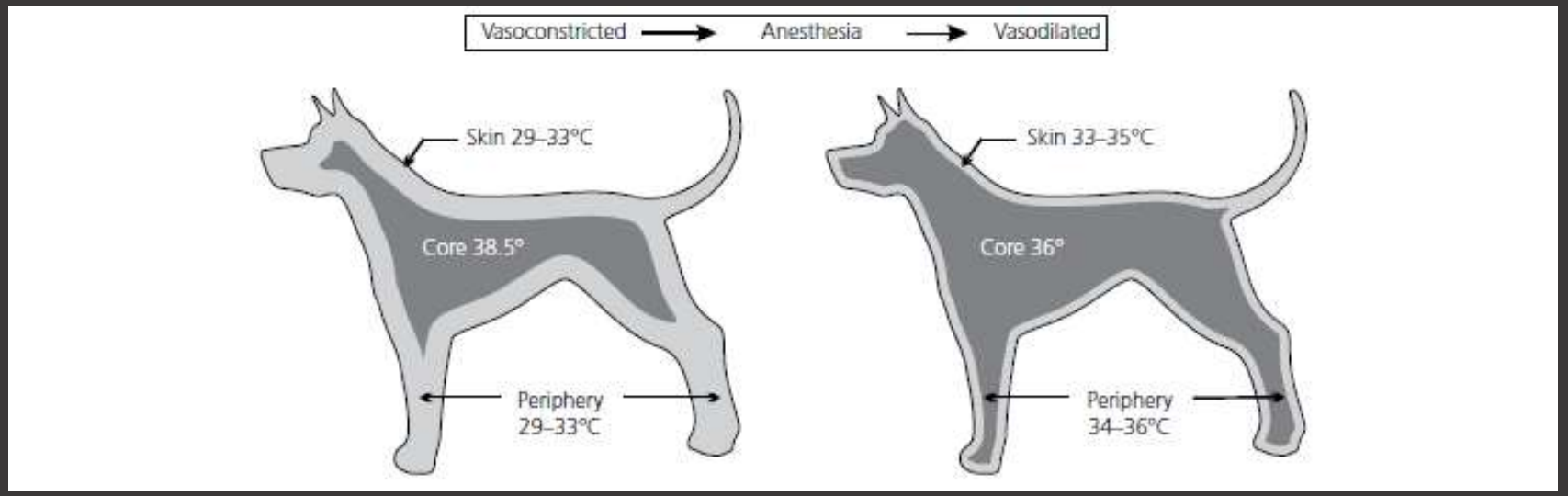
Timeline of Heat Loss

- Phase II (Linear)
  - Following 2-3+ hours
  - Environmental heat loss exceeding heat production (basal metabolism)
  - Conduction important in this phase

    Patients on cold surfaces/in cold rooms
- Phase III (Plateau)
  - Pseudo equilibrium with environment
  - Due to:
    - insulation/heat supplementation
    - severe hypothermia inducing vasoconstriction



Heat Loss


Vasoconstricted
Anesthesia
Vasodilated
Skin 29–33°C
Core 38.5°
Periphery
29–33°C
Skin 33–35°C
Core 36°
Periphery
34–36°C

Thermal Support

- Always available from pre-sedation-to-recovery

- Forced air warmers, warm water blankets – best

  (any patient < 10kg should have Bear Hugger/forced air warmer)

  - Warming packs – appropriate but little efficacy
  - Microwaved fluid bags, rice packs – *avoid if possible (heat concentrators)*

Heated rice bag during dental (Spring 2023)

wound management costing >$12,000; 20 days

Thermal Support cont.

- Have *warmed scrub, IVF, saline irrigation*, etc. – may mitigate severity of PAH acheived
- IV line warmers – useless

- When not interacting with sedate/anesthetized patient
  - Towel over to reduce radiative heat loss
  - *Never* have patient directly on cold mat or metal table
- Consider
  - Warming ambient ward temperature
  - *Pre-warming* patient prior to general anesthesia

Questions?

Thermal Support

Pre-warming before general anesthesia with isoflurane delays the onset of hypothermia in rats

Maxime Rufiange[1,2], Vivian S. Y. Leung[1,2], Keith Simpson[3], Daniel S. J. Pang[1,2]*