Providing the best quality care and service for the patient, the client, and the referring veterinarian.

Diagnosis and Management of Hypotension

McGee Leonard, DVM
Critical Care Resident

"Hypotension, or low arterial blood pressure, is not a disease. It is a clinical manifestation of many different disease states. It results from failure of common regulatory mechanisms."

Introduction

- Physiology of blood pressure regulation
- Blood pressure measurement
- Causes of hypotension
- Clinical significance of hypotension
- Management of hypotension

Blood Pressure Physiology

- Arterial blood pressure is exerted on the blood vessels by the pumping heart
  - \[ BP = CO \times SVR \]
  - \( BP \): blood pressure
  - \( CO \): cardiac output
    - Determined by heart rate and stroke volume
  - \( SVR \): systemic vascular resistance
Regulation of Blood Pressure

- Vascular smooth muscle has sympathetic innervation
  - Norepinephrine is released continuously or in a pulsatile fashion
  - Increased norepinephrine leads to vasoconstriction
  - Decreased norepinephrine allows vasodilation

Regulation of Blood Pressure

- Cardiac myocytes receive sympathetic and parasympathetic innervation
  - Sympathetic stimulation has positive chronotropic and inotropic effects
  - Parasympathetic stimulation blocks chronotropic effects
  - Both nerves have pulsatile activity in the heart, but parasympathetic stimulation dominates at rest

Regulation of Blood Pressure

- Sympathetic discharge is controlled by the vasomotor center of the medulla
  - Receive input from baroreceptors in the left atrium, aortic arch, and carotid sinus
    - Decreased blood volume increases sympathetic tone
    - Increased blood volume decreases sympathetic tone

Regulation of Blood Pressure

- Sympathetic discharge is controlled by the vasomotor center of the medulla
  - Receives chemoreceptor input in response to local hypoxia or hypercapnia
  - Chemoreceptor feedback system is less important than the baroreceptor feedback system

Medulla
Regulation of Blood Pressure

- Hormones and cytokines that are pro-inflammatory generally cause vasodilation
  - Largely due to up-regulation of iNOS
- Norepinephrine, epinephrine, vasopressin, and angiotensin II have vasoconstrictive effects

Blood Pressure Physiology

- Basic measurements
  - Systolic: maximum pressure as the heart contracts
    - Primarily determined by stroke volume and arterial compliance
  - Diastolic: minimum pressure as the heart fills
    - Primarily determined by SVR and heart rate
  - Mean: an average measurement of pressure throughout the cardiac cycle

Normal Blood Pressure Values

- Dogs
  - Systolic 90-140 mmHg
  - Diastolic 50-80 mmHg
  - Mean 60-100 mmHg
- Cats
  - Systolic 80-140 mmHg
  - Diastolic 55-75 mmHg
  - Mean 60-100 mmHg

Measuring Blood Pressure

- Mean arterial pressure (MAP) is most closely related to overall perfusion pressure
  - Hypotension defined as MAP < 60 mmHg
  - Below MAP 60, glomerular filtration and cerebral perfusion may be compromised
There is no direct correlation between systolic or diastolic pressure and MAP:

\[ \text{MAP} = \text{DAP} + \frac{1}{3} (\text{SAP} - \text{DAP}) \]

Values should be used with caution in small animals.

Measurements may be inconsistent in peripheral vessels.

**Patient positioning**
- Lateral recumbency is best
- Measurement should be taken approximately level with the heart

**Cuff size**
- 40% limb circumference in dogs
- 30% limb circumference in cats

**Techniques for measurement**
- Direct
  - Gold standard
- Indirect
  - Doppler ultrasonography
  - Oscillometric methods
Measuring Blood Pressure

- **Direct measurement**
  - Requires an arterial catheter connected to a pressure transducer and monitor

- **Advantages of direct measurement**
  - Accurate, repetitive monitoring
  - Arterial line can be used for sampling

- **Disadvantages of direct measurement**
  - More technically demanding to achieve and maintain arterial access
  - Cost of equipment

Measuring Blood Pressure

- **Direct measurement**
  - The arterial catheter should be as large as possible
  - The transducer should be placed close to the patient
  - The measuring system should be free of blood clots and air bubbles and the tubing should not be longer than necessary

- **Arterial catheters**
  - Most commonly placed in the dorsal pedal artery
  - Alternative locations include the auricular, femoral, coccygeal, radial, or brachial arteries
  - 20-24 gauge over-the-needle catheter
  - Should be flushed every 1-4 hours
  - Never infuse anything into an artery
**Measuring Blood Pressure**

- Arterial catheters

  **Guide to Selecting an Arterial Catheter**
  - Large dogs: 22- or 20-gauge catheter
  - Medium and small dogs: 24- or 22-gauge catheter
  - Very small dogs and cats: 24-gauge catheter (usually difficult to place because the arteries are so small)

- Risks of arterial catheters
  - Hemorrhage
  - Infection
  - Clotting

**Measuring Blood Pressure**

- Indirect measurement
  - Non-invasive measurement of return of blood flow after temporary occlusion of an artery

**Measuring Blood Pressure**

- Arterial catheters in cats
  - Cats have poor collateral blood flow and are more prone to vascular spasm compared to dogs
  - Arterial catheters should only be maintained for 6-8 hours in a cat
Measuring Blood Pressure

- Advantage of indirect measurement
  - Less expensive
  - Less technically demanding/time consuming
- Disadvantages of indirect measurement
  - Inaccurate in small or obese animals
  - Inaccurate in patients with hypotension, peripheral edema, vasoconstriction, or arrhythmias
  - Also inaccurate for hypertension if SAP > 60

Measuring Blood Pressure

- Doppler ultrasonography

  - Uses a piezoelectric crystal to detect blood flow
  - Blood pressure cuff connected to a sphygmomanometer is used to occlude the artery and gradually release pressure until flow resumes

- When sound returns, the pressure is the cuff approximates systolic pressure
- Theoretically the pressure at which sound no longer changes approximates diastolic pressure
  - Very subjective measurement
Measuring Blood Pressure

- **Doppler ultrasonography**
  - Best indirect technique for patients <10 kg
  - Best indirect technique for hypotensive patients
  - Advantages: cheap and portable
  - Disadvantages: inability to measure DAP and thus MAP, still somewhat inaccurate in small patients (compared to direct)

Measuring Blood Pressure

- **Doppler ultrasonography in cats**
  - Measured values in cats may be 10-15 mmHg lower than systolic
  - Probably a more accurate measurement of MAP in this species

Measuring Blood Pressure

- **Oscillometric methods**
  - Device detects oscillations in blood vessel walls produced by changes in wall diameter during the cardiac cycle
  - Typically measures MAP and then calculates systolic and diastolic values

Measuring Blood Pressure

- **Oscillometric sphygmomanometry**
  - Advantages: automated ability to take repeated measurements, measurement of MAP
  - Disadvantages: cost of the machine, inaccurate compared to direct methods
Causes of Hypotension

- Common contributors to hypotension
  - Decreased cardiac output
  - Decreased cardiac preload
  - Decreased vascular resistance
  - Some or all of the above

Causes of Hypotension

- Cardiogenic
  - Primary: cardiomyopathy, valvular disease, arrhythmias
  - Secondary: SIRS/sepsis, electrolyte derangement, hypoxia, severe acidosis/alkalosis
  - Anesthetic drugs

Causes of Hypotension

- Decreased preload
  - Hypovolemia
  - Decreased venous return
  - Positive pressure ventilation

Causes of Hypotension

- Decreased vascular resistance
  - SIRS/sepsis
  - Electrolyte derangement
  - Severe hypoxia or acidosis/alkalosis
  - Anaphylaxis
  - Drugs/toxins
Clinical Signs of Hypotension

- Symptoms depend mainly on the cause of the hypotension
  - Severity, duration
- Low blood pressure leads to low tissue perfusion pressure
  - Non-linear relationship

Clinical Signs of Hypotension

- Most severe signs of hypotension are secondary to tissue hypoxia
  - Acute kidney injury
  - Vomiting, melena
  - Arrhythmias
  - Changes in mentation
  - Tachypnea
  - Coagulopathies
  - Etc……

Clinical Signs of Hypotension

- Clinical signs common in hypotensive patients
  - Abnormal pulse quality
  - Pallor
  - Prolonged CRT
  - Mental dullness, stupor, weakness
  - Hypothermia
  - Decreased urine output

Treatment of Hypotension

- Address the underlying cause if possible
- Differentiate cardiogenic from non-cardiogenic causes
  - Thoracic radiographs
  - ECG
  - Echocardiogram
Treatment of Hypotension

- Cardiogenic hypotension is usually managed with positive inotropes, diuretics, and vasodilators

- Non-cardiogenic hypotension
  - FLUID RESUSCITATE
  - The goal of aggressive fluid therapy is to increase cardiac output and vascular volume
  - Therapy also restores any deficiencies present
    - Electrolyte derangement
    - Anemia

Treatment of Hypotension

- Fluid therapy
  - Crystalloids
  - Colloids

- Pressor medications
  - Catecholamines
  - Vasopressin

- Crystalloids
  - 90 ml/kg for dogs 60 ml/kg for cats
  - Divide shock dose into 3-4 aliquots and assess perfusion parameters after each dose

- Colloids
  - Total dose of 20-30 ml/kg/day
  - Bolus dose of 3-5 ml/kg for cats, 5-10 ml/kg for dogs
Treatment of Hypotension

- If fluid resuscitation goals are met and hypotension persists consider
  - Secondary cardiogenic causes
    - Consider β-agonists
  - Vasodilation
    - Consider α-agonists or vasopressin

Cardiovascular effects of catecholamines

- α₁-agonists cause vasodilation or vasoconstriction in a dose-dependent fashion
- α₂-agonists are pure vasoconstrictors
- β₁-agonists increase heart rate and cardiac contractility
- β₂-agonists are vasodilators

Vasoactive catecholamines

- Dopamine
  - 5-10 µg/kg/min- primarily β with fewer α effects
  - 10-20 µg/kg/min- primarily α effects
- Dobutamine
  - Primarily a β1 agonist- increases cardiac contractility with little effect on SVR
- Norepinephrine
  - Primarily an α agonist

Side effects of catecholamines

- Beta agonists
  - Arrhythmias, tachycardia, vasodilation
  - High doses of dobutamine may cause CNS signs in cats
- Alpha agonists
  - Arrhythmias, tachycardia, increased SVR with subsequent ischemia
Treatment of Hypotension

- **Vasopressin**
  - aka antidiuretic hormone (ADH)
  - Synthesized in the hypothalamus and stored in the posterior pituitary
  - V1 receptors are found in vascular smooth muscle cells

- **Vasopressin**
  - Is not involved in regulation of blood pressure in a healthy state
  - Vasopressin deficiency, as well as enhanced responses to V1 receptor stimulation are both associated with states of shock
  - Can be used to decrease the required dose of catecholamines
  - Given as a CRI
    - 0.5-2 μU/kg/min

Treatment of Hypotension

- Side effects of vasopressin
  - Coronary and splanchnic vasoconstriction, decreased cardiac output, hypercoagulability

Questions?