CARDIOVASCULAR MANAGEMENT OF THE ANESTHETIZED PATIENT
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AGENDA

- Physiology
- Protocol selection
  - Cardiovascular effects of individual drugs
- Monitoring
- Managing hypotension
- Common cardiac diseases
**Physiology**

- **Oxygen delivery**
  - \( \text{DO}_2 = \text{CaO}_2 \times \text{CO} \)

- **Arterial oxygen content**
  - \( \text{CaO}_2 = (1.34 \times \text{Hb} \times \text{SaO}_2) + \text{PaO}_2 \times 0.0031 \)

- **Cardiac output**
  - \( \text{CO} = \text{SV} \times \text{HR} \)

- **Stroke Volume**
  - Preload
  - Contractility
  - Afterload

- **Arterial blood pressure**
  - \( \text{CO} \times \text{SVR} \)
Patient Assessment

- History
- Complete physical exam
- Cardiovascular and pulmonary
  - Auscult heart
    - Prolonged periods of time
    - Right, left, sternum
  - Feel pulse
    - Quality
    - Synchrony
- Radiographs
- Bloodwork
Choosing a Protocol

- All drugs affect cardiovascular system
  - Patient dependent
  - Condition dependent

- Understanding drug side effects
  - Know what to expect
    - HR
    - CO
    - SVR
    - ABP
  - Step ahead in treating anesthesia complications
SELECTING YOUR PROTOCOL

- Sedation Protocol

  - Importance of sedation
    - Lowers dose needed of induction agent
    - Lowers MAC of inhalant
    - Smoother plane of anesthesia

  - Drugs available
    - Phenothiazine
    - Alpha-2 Agonist
    - Benzodiazepine
    - Opioid
Sedation Drugs
Phenothiazine

- Acepromazine
  - No change in heart rate
  - Decreases systemic vascular resistance
    - Cardiac output
  - Decreases blood pressure

- Patient selection
  - Healthy patient
  - Anxious patient
  - Avoid in very young and very old patient
  - Long lasting and non reversible
Sedation Drugs
Alpha-2 Agonists

- Dexmedetomidine
  - Decrease in heart rate
  - Increase followed by decrease in systemic vascular resistance
  - Increase in blood pressure followed by decrease in blood pressure
  - Decrease in cardiac output

- Patient selection
  - Healthy patient
  - Aggressive patient

  - DO NOT use in neonates (under 16 weeks)
Sedation Drugs
Benzodiazepines

- Diazepam and Midazolam
  - No changes in heart rate
  - No changes in systemic vascular resistance
  - No changes in blood pressure
  - No changes in cardiac output

- Patient selection
  - Sick patients
    - Not a great sedative in the healthy patient
      - Still lowers MAC and induction dose
  - Variable absorption if given IM or SQ
  - Long lasting but reversible
Sedation Drugs
Opioids

- Morphine, Hydromorphone, Fentanyl, Oxymorphone
- Buprenorphine
- Butorphanol

- Decrease in heart rate (receptor dependent)
- No changes in blood pressure
  - Decrease in blood pressure if histamine release
- No change in cardiac output

Patient selection
- Safe for most patients
- Very young – careful with bradycardia
- Appropriate opioid for each patient/problem
Induction Protocols

- Propofol
  - Decrease in systemic vascular resistance
  - Decrease in cardiac output
  - Decrease in blood pressure
    - Dose and rate of injection dependent
    - Caution in very sick patients
    - Caution in patients with cardiovascular disease

- Ketamine
  - Increase in HR - sympathetic
  - Increase in contractility - sympathetic
  - Increase in cardiac output – sympathetic
    - Caution in patients with arrhythmias
    - Caution in patients with LVOT obstruction
INDUCTION PROTOCOLS

- Etomidate
  - No changes in any cardiovascular parameter
  - Great drug for patients with cardiovascular disease
    - Induction quality - myoclonus
    - Expensive
    - Hemolysis
    - Adrenal suppression

- Inhalant Anesthetic – mask induction
  - Decrease in contractility
  - Decrease in systemic vascular resistance
  - Faster induction with low cardiac output
  - Slower induction with high cardiac output
MAINTENANCE

- **Inhalant anesthetic**
  - Isoflurane
  - Sevoflurane
  - Desflurane

- **Dose dependent**
  - Decrease in contractility
  - Decrease in systemic vascular resistance

*CAUTION*
Monitoring Anesthesia Cardiovascular

- Heart Rate
- Heart Rhythm
- Pulse oximetry
- Capnography
- Blood Pressure
MONITORING ANESTHESIA
CARDIOVASCULAR

- Circulation
  - Feeling for a pulse
    - As soon as animal is induced
    - Pulse is not an indication of blood pressure
      - Pulse pressure = systolic-diastolic pressure
    - Indication of presence of circulation
    - Palpate peripheral pulse
  - Lack of pulse for > 4 min
    - Irreversible brain damage
MONITORING ANESTHESIA
CARDIOVASCULAR

- ECG
  - Rhythm of the heart
  - Presence of arrhythmias
  - No information about circulation
    - No information about blood pressure
    - No information about cardiac output
  - Recommend to place ECG leads prior to induction
  - Recommend ECG on high risk patients
    - Episodes of tachycardia during PE
    - GDV
    - Splenectomy
    - Trauma patients (i.e. hit by car)
ECG
MOST COMMON ARRHYTHMIAS

- Second degree AV block
  - Increase in vagal tone
    - Drug induced
      - Opioids
      - Alpha-2 agonists
      - Inhalant
    - Pathological
  - May or may not require treatment
  - HR and blood pressure dependent
  - Atropine
ECG
MOST COMMON ARRHYTHMIAS

- Ventricular premature contractions
  - Heart disease
    - Cardiomyopathy
      - Dogs and cats
  - Other conditions
    - Hemangiosarcoma
    - GDV
    - Trauma
      - Cardiac contusions
  - May or may not require treatment
  - Characteristics, number of VPCs/minute
  - Lidocaine
    - IV bolus followed by CRI
ECG
OTHER POSSIBLE ARRHYTHMIAS

- Atrial tachycardia
  - Associated with cardiac disease
  - Rule out
    - Pain
    - Hypovolemia
    - Hypoxemia

- Ventricular tachycardia
  - Associated with cardiac disease
  - Should be treated
  - Reconsider anesthesia
Pulse oximetry
- Measurement of oxygen hemoglobin saturation
- Assess oxygenation
- No information about circulation or ventilation
- Results may be inaccurate
  - Poor circulation
    - Inaccurate pulse measurement
    - Severe vasoconstriction

Recovery
- Animal is breathing 21% oxygen
  - Helpful to assess hypoventilation
  - Asses need for supplemental oxygen
MONITORING ANESTHESIA
CARDIOVASCULAR

- Capnography
  - Used to assess ventilation
  - ETCO₂: 35-45 mmHg

- Provides information about
  - CO₂ production
  - Pulmonary perfusion
  - Alveolar ventilation
  - Respiratory patterns
  - Elimination of CO₂ from the anesthesia circuit
  - Anesthesia machine malfunction
MONITORING ANESTHESIA
CARDIOVASCULAR

- Production of CO$_2$ by tissues
- Circulatory transport of CO$_2$ to the lungs
- Elimination of CO$_2$ by the lungs to the anesthesia machine

- Facilitates early detection of life threatening conditions
  - Sudden decrease in ETCO$_2$
    - Decrease in cardiac output
      - Cardiac arrest
MONITORING ANESTHESIA
CARDIOVASCULAR

- Blood Pressure measurement
  - Most important parameter to measure
  - Organ perfusion
  - Anesthesia will change blood flow to all organs
    - Brain
    - Heart
    - Kidneys
    - GI

- Maintain minimal pressure to optimize perfusion to vital organs
Monitoring Anesthesia
Cardiovascular

- Systolic > 90 mmHg
- Mean > 60 mmHg
- Diastolic > 35 mmHg

- Systolic – contractility

- Diastolic – vasculature tone
  - Period during which heart is perfused

- Mean – 1/3 systolic + 2/3 diastolic
  - Most important pressure to measure
MONITORING ANESTHESIA
CARDIOVASCULAR

- Techniques
  - Non Invasive
    - Oscillometric
    - Doppler
  - Invasive blood pressure
    - Arterial line
I’m monitoring... now what?

- Monitoring is essential!
- Knowing how to react is equally important!

- Have a plan ahead of time
  - Condition of the animal
  - Positioning
  - Protocol chosen
  - Procedure being performed
    - Common complications
      - Allows planning
TREATING HYPOTENSION

- Step by step approach
- Evaluate your patient
  - Depth of anesthesia
  - Fluids
  - Drugs
DEPTH OF ANESTHESIA

- Inhalant anesthetics
  - Vasodilation
  - Decrease in contractility

- Check depth of anesthesia
  - Jaw tone
  - Eye signs and position
  - Vital signs
    - Respiratory rate and character
    - Heart rate

- Lower dose of inhalant
DECREASING MAC

- Balanced anesthesia
- Addition of intravenous drugs

- Improve analgesia
  - Redose analgesic
    - Morphine, hydromorphone
  - Add a CRI
    - opioid, ketamine, or alpha-2 agonist

- Improve muscle relaxation
  - Administer a benzodiazepine
    - Midazolam
    - Diazepam
FLUIDS

- Crystalloids healthy patient
  - Delivery of 3-5 ml/kg/hr
    - Patient and surgical procedure dependent

- Heart Disease
  - Avoid any fluid bolus!!
  - Fluid rate for surgical procedure
    - 2-3 ml/kg/hr
      - Patient dependent

- Fluid overload – pulmonary edema
  - Cats more likely to develop than dogs
TREATMENT DRUGS

- Drugs available for treating hypotension
  - Ephedrine
  - Dobutamine
  - Dopamine
  - Phenylephrine

- Characteristics
  - Different mechanisms of action
  - Choice of drug is case dependent
**EPHEDRINE**

- **Mechanism of action**
  - Direct: $\alpha$ and $\beta$ receptors
  - Indirect: norepinephrine
  - Heart rate: tachycardia or severe bradycardia

- **Case selection**
  - Temporary increase in ABP and cardiac output
    - Before starting a CRI
    - Before surgical stimulation
    - As an emergency drug

- **Administration through a bolus injection**
  - Dose – 0.1-0.2 mg/kg – repeat if needed
  - 10-15 minutes
DOBUTAMINE

- **Mechanism of action**
  - Acts primarily on $\beta_1$ receptors with some $\beta_2$
  - Variable changes in heart rate

- **Case selection**
  - Low systolic pressure – increase in contractility
  - Elective cases
  - Emergency cases
  - Not good choice for septic cases

- **Administration through CRI**
  - Short acting
  - Dose – 1.0 mcg/kg/min – 10.0 mcg/kg/min
  - Dilute drug in saline
DOPAMINE

- **Mechanism of action**
  - Acts primarily on $\alpha$ and $\beta$ receptors
  - Dose dependent
  - Variable changes in heart rate

- **Case selection**
  - Low dose – increase in contractility ($< 4 \text{ mcg/kg/min}$)
  - Elective cases
  - High dose – vasoconstriction ($> 5 \text{ mcg/kg/min}$)
  - Emergency cases

- **Administration through CRI**
  - Short acting
  - Dose – 2.0 mcg/kg/min – 15 mcg/kg/min
  - Dilute drug in saline
PHENYLEPHRINE

- **Mechanism of action**
  - Acts primarily on $\alpha$-1 receptors
    - Vasoconstriction
      - Reflex bradycardia

- **Case selection**
  - Low diastolic pressure
    - Vasodilation
      - Inhalant, sepsis
      - Spinal anesthesia

- **Administration through CRI**
  - Short acting
  - Dose – 0.1 mcg/kg/min – 1.0 mcg/kg/min – to effect
  - Dilute drug in saline
Mitral Valve Degeneration

- Clinical presentation
  - Middle aged - senior dog
  - Small – medium breeds
  - Left apical systolic murmur

- Echocardiogram
- Radiographs
ANESTHESIA CONCERNS

- Regurgitation of blood from ventricle into atrium/lungs
  - Reduction in stroke volume
  - Pulmonary edema

- Minimize increases in SVR – increase amount of regurgitation
  - NO alpha-2 agonist

- Maintain blood pressure – proper myocardial oxygenation

- Maintain HR (80-120 bpm)
ANESTHESIA PROTOCOL

- Premedication
  - Opioid (full or partial mu agonist) and benzodiazepine
  - Oxygen 5 minutes + ECG

- Induction
  - Etomidate
  - Low dose propofol
  - Low dose ketamine
  - Rely on pre-medication to heavily decrease induction doses

- Maintenance
  - Inhalant (conservative – low SVR)
  - Regional anesthesia (dental block)
  - Opioid

- Fluid therapy 3-4 ml/kg/hr – no bolus!
**Special Attention**

- **Stop enalapril 12 hrs before anesthesia**
  - Refractory to treatment under anesthesia

- **Blood pressure**
  - \(< 140 \text{ mmHg systolic } > 90 \text{ mmHg}\)
    - Avoid increase in SVR (pain)
    - Low blood pressure – dobutamine (2-10 mcg/kg/min)
    - High blood pressure – analgesia

- **HR**
  - Low dose of atropine (0.01-0.02 mg/kg) IV
Dilated Cardiomyopathy

- Clinical presentation
- Large breed dogs
  - Doberman
  - Boxer (special case)
  - Labrador
  - Golden Retriever
- Murmur
- Tachycardia
- Arrhythmia
- Cardio consult highly recommended
ANESTHESIA CONCERNS

- Impaired systolic function – decreased contractility

- Stroke volume decreased due to decreased contractility
  - Flow unable to move forward
  - Decrease in cardiac output
  - Increased risk of fluid overload resulting in pulmonary edema

- Avoid increase in SVR (afterload)

- Avoid excessive decrease in afterload
  - Contractility will not increase sufficiently to compensate
  - Cannot use fluids to compensate for increase in intravascular space

- Avoid excessive increase and decrease in HR
  - Low HR – end diastolic volume may be too high
  - High HR – increased oxygen consumption + arrhythmia
ANESTHESIA PROTOCOL

- Premedication
  - Opioid (full mu agonist) +/- benzodiazepine (older patient + breed)
    - Calm until induction – risk of laryngeal collapse
  - Oxygen for 5 minutes + ECG

- Induction
  - Etomidate
  - Ketamine +/- low dose benzodiazepine
  - Benzodiazepine + Fentanyl induction

- Maintenance
  - Inhalant + balanced anesthesia

- Fluid therapy 3-5 ml/kg/hr
**Special Attention**

- Avoid increase in SVR
  - Do not use alpha-2 agonists

- Hypotension
  - No fluid bolus!
  - Dobutamine CRI – increase contractility with mild decrease in SVR

- Monitoring – full monitoring equipment
  - ECG – before induction

- Recovery
  - Oxygen mask until very awake
  - Quiet recovery
  - Continue to monitor blood pressure, HR, and oxygenation
Hypertrophic cardiomyopathy

- Clinical presentation
  - Young/old cats
  - Murmur present (not always)
  - Some breeds are predisposed
    - Maine Coon
    - Ragdolls
  - Medical condition
    - Hyperthyroidism

- Cardio consult highly recommended – echocardiogram
  - Stabilize condition if at all possible
ANESTHESIA CONCERNS

- Impaired diastolic dysfunction
  - Inability to change stroke volume
  - CO heavily depended on HR

- Avoid big changes in HR
  - High HR
    - less filling time - decrease stroke volume
    - Increase in myocardial oxygen demand
  - Low HR
    - decrease in CO

- Avoid decrease in SVR

- AVOID STRESS - ALWAYS
PROTOCOL

- Premedication
  - Opioid (full mu agonist) and benzodiazepine
  - Alfaxalone + opioid if fractious
  - Oxygen 5 minutes + ECG

- Induction
  - Propofol with low dose ketamine (1 mg/kg)
  - Etomidate

- Maintenance
  - Inhalant + proper analgesia for balanced anesthesia
  - Low dose Dexmedetomidine if needed – 1-2 mcg/kg IM

- Fluid therapy 3-5 ml/kg/hr – no bolus!
Special Attention

- Full monitoring

- Maintain systolic arterial blood pressure > 90 mmHg, but lower than 150 mmHg
  - Ephedrine or dopamine
  - NO fluid bolus

- Arrhythmias very common
  - VPC’s

- Post-op
  - Maintain on oxygen (mask)
  - Monitor ABP and SPO2
  - Proper analgesia
SAFE ANESTHETIC MANAGEMENT

- Knowledge of anesthetic drug pharmacology and their effects
- Knowledge of cardiac and respiratory physiology
- Proper monitoring
- Prior planning and preparation

High anesthetic risk? Evaluate the risk....

- Refer to a practice with an anesthesiologist
- Consult with an anesthesiologist
QUESTIONS?

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