Anesthesia for Commonly Presented Dental Patients

Craig Mosley DVM, MSc, DACVAA
VCA Canada 404 Veterinary Emergency & Referral Hospital

1

Thank you

Dechra

2

”Typical” Dental Patient

- Geriatrics (42-52% of dog population >7yrs)
  - Decline in organ function or reserve, “elderly normal”
- Patients with comorbid conditions
  - Cardiovascular, renal, respiratory
- Longer procedures

3

Goals

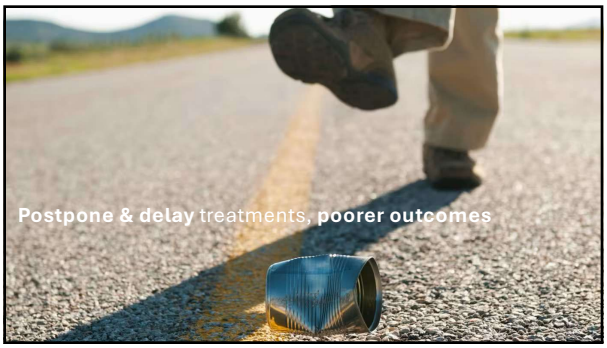
- Postponing dental care is detrimental
- Clinical decision making is hard but…
  - Common things are common
- Simple, yet informed approaches are safe & effective
- Build confidence & ability managing complex cases

4

Geriatrics & Anesthesia

- **Greater risk of anesthetic** morbidity & mortality
  - Decline in organ function or reserve
  - Less able to respond to stress of surgery/anesthesia
- **Age-related concurrent disease**
  - **Main cause of increased mortality in geriatric humans**

6



7

8

Geriatrics & Anesthesia

- **Greater risk of anesthetic** morbidity & mortality
- **Predictable physiologic changes**
- **Early intervention might help stabilize & mitigate concurrent disease**

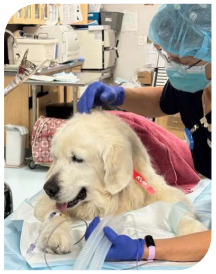
10

Physiological Changes

May not be directly correlated with chronological age

- Cardiovascular – arrhythmias, hypotension
- Respiratory – hypoxia, hypercarbia, apnea
- Renal – less reserve, less tolerant of hypovolemia & dehydration
- Hepatic – qualitatively normal, body composition alters distribution of drugs
- CNS – more sensitive to sedatives & anesthetics
- General considerations - hypothermia, patient positioning, pain

11



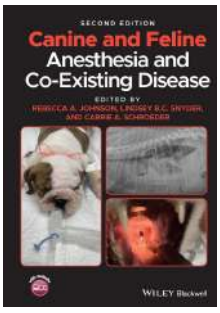
12

Geriatric Anesthesia

- More susceptible to anesthetic induced cardiopulmonary depression
  - More support required (blood pressure, arrhythmia, respiratory depression, thermoregulation etc)
- Greater & more prolonged effects, lower doses
  - Proper planning & knowledge, more important than specific drug
- Co-existing conditions
  - Greater attention to detail
  - Prepared to manage & optimize based on specific co-existing condition

13

Anesthesia and Coexisting Conditions



14

"Heart Disease"

- Incidental heart murmur, most common presenting feature
- Arrhythmias, dyspnea, syncope – far less common
- Refer to cardiologist for complete cardiac work up

15

16

Clinical Decision Making

- Every clinical decision has implications
- Maximize benefit & minimize cost
  - Forget "gold standard" thinking, embrace spectrum of care options
  - Think holistically, think value-based
- Too often decisions in veterinary medicine are made with an emphasis on minimizing risk (based on "belief")
  - Impossible to minimize risk to zero & every decision has its own inherent risks
- **Should be guided by evidence & be patient/client centered**

17

Risk based decision making

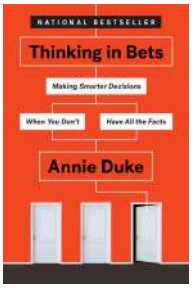
- Routine bloodwork on all patients prior to anesthesia
  - No evidence, costs, 95% CI
- Bloodwork on all patients prior to NSAID administration
  - No evidence, costs, risk withholding care
- CT on all patients prior to exploratory laparotomy
  - Costs, risk of V.O.M.I.T., probability (will it change diagnosis)
- Echocardiogram on all patients with a heart murmur
  - Costs, limited resource, probability (will it change diagnosis)

18

Thinking in Bets

Probabilistic & Strategic Thinking

- Most small dogs with new murmurs
  - **MVD**
- Most large dogs with new murmurs
  - Unknown, breed, arrhythmias, clinical signs, echo
- Most cats
  - **HCM or DRVOTO**
  - Anesthetic management unlikely to change



19

Management of incidentally detected heart murmurs in dogs and cats

Etienne Côté, DVM; N. Joel Edwards, DVM; Stephen J. Ettinger, DVM; Virginia Luis Fuentes, VetMB, PhD; Kristin A. MacDonald, DVM, PhD; Brian A. Scansen, DVM, MS; D. David Sisson, DVM; Jonathan A. Abbott, DVM

JAVMA, Vol 246, No. 10, May 15, 2015

- Value of additional testing/workup
  - 10 yr, min poodle, 3/6 murmur, no other clinical signs
  - 7 yr, GSD, 3/6 murmur, "lazy"
  - 14 yr, DSH, 2/6 murmur, no other clinical signs
  - 14 yr, DSH, 3/6 murmur, gallop rhythm, thyroid nodule, weight loss

20

Summary/Suggestions (Dogs)

- Diastolic, continuous, accompanied other abnormal heart sound or arrhythmia – **recommend echo**
- Puppies soft murmur (1-2), likely innocent/functional, insignificant
- Small breed <20 kg, normal heart size & absence of clinical signs, insignificant MVD, **consider serial thoracic rads**
- Large breed >20 kg, specific diagnosis difficult with auscultation & rads alone – **recommend echo**

22

Summary/Suggestions (Cats)

- If greater than 4/6, diastolic, continuous, arrhythmia or gallop – **recommend echo**
- Grade 1/3 – 3/6 systolic, underlying cause & clinical significance not easily predicted from auscultation alone (most either HCM or DRVOTO)
  - Consider ABP
  - Thyroid assessment
  - Measure NT-BNP (low value clinically significant cardiomyopathy unlikely)
  - Radiographs limited sensitivity
- **Consider echo**

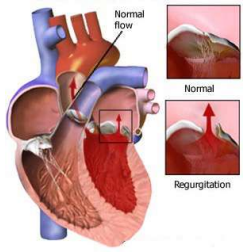
23

Mitral Valve Disease

- Small breed <20 kg with incidental heart murmur
- Thoracic rads - normal heart size & no clinical signs
  - Insignificant MVD
- Monitor with serial thoracic radiographs
- Consider referral to cardiologist
  - Owner preference

24

Mitral Valve Disease



25

Hemodynamic Goals

- Minimize regurgitation of blood & maintain forward flow (SV & CO)
  - Normal to slightly ↑ heart rate
  - Avoid drugs that will ↑ SVR (afterload)
    - Increase regurgitant fraction
    - Directly decreases cardiac output
  - Maintain preload
    - Optimal ventricular filling during diastole
  - Optimize contractility

26

Premedication Options

- None
- Opioid alone
- Benzodiazepine (midazolam) + opioid
- Acepromazine + opioid
- Dexmedetomidine + opioid

27

Acepromazine + opioid

- Predictable sedation, anti-arrhythmic, anesthetic sparing, reduces SVR (hypotension)
  - Afterload reduction desirable for managing MMVD (ACE inhibitors)
- Use **cautiously in hypovolemic/dehydrated patients**
  - Those relying on vasoconstriction for maintaining blood pressure
- Prepared to manage & support hypotension with **dopamine**
- Low dose can improve recovery

29

Dexmedetomidine + opioid

- Very predictable sedation, arrhythmogenic, anesthetic sparing
- Increases SVR, bradycardia & reduces CO
  - Exactly what you don't want to do!!
- Very poor choice "contra-indicated"

30

Premedication Options

- None
- Opioid alone
- Benzodiazepine (midazolam) + opioid
- Acepromazine + opioid
  - 0.01-0.02 mg/kg IM
- Dexmedetomidine + opioid

31

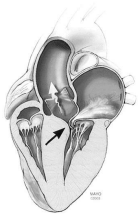
Hypertrophic Cardiomyopathy (HCM)

- Middle age cat +- spicy
- New or pre-existing systolic murmur, no rhythm disturbance, no gallop
- Presumptive diagnosis HCM or DRVOTO (physiologic)
  - R/O hyperthyroidism, anemia, hypertension
  - Restrictive uncommon – unlikely to impact anesthetic selection/management
- Referral to cardiologist
  - Owner preference

32

Hypertrophic Cardiomyopathy

- Diastolic dysfunction, reduced SV & CO
  - Hypertrophic ventricles, small chamber volume
  - Impaired ventricular relaxation (lusiotropy)
- Dynamic LVOT obstruction during systole
  - Exaggerated with increased pressure gradient across outflow tract
  - ↑ contractility, ↓ SVR
- Hypertrophy may predispose to ischemia
  - Sufficient time for myocardial perfusion



33

Hemodynamic Goals

- Optimize diastolic ventricular volume
  - Adequate preload
  - Minimize tachycardia
    - More time for ventricular filling & myocardial perfusion
- Avoid exacerbating LVOT obstruction
  - Avoid drugs increasing contractility
  - Avoid excessive vasodilation

34

Options

- Opioid alone
- Midazolam + opioid
- Acepromazine + opioid
- Ketamine + midazolam/acepromazine + opioid
- Dexmedetomidine + opioid
- Alfaxalone IM

35

Options

- Ace IM ±
  - Minimal sedation, reduces afterload, **may increase LVOT obstruction**

36

Options

- Ace IM ±
  - Minimal sedation, reduces afterload, may increase LVOT obstruction
- Ketamine IM ±
  - Effective, increases heart rate & contractility, **may increase LVOT obstruction**

37

Options

- Ace IM ±
  - Minimal sedation, reduces afterload, may increase LVOT obstruction
- Ketamine IM ±
  - Effective, increases heart rate & contractility, may increase LVOT obstruction
- Dexmedetomidine IM ±
  - Effective, increases afterload, **may decrease LVOT obstruction**
  - Improve myocardial perfusion? (lower HR longer diastolic time)
  - May not be ideal for cardiac examinations

38

Doppler echocardiographic effects of medetomidine on dynamic left ventricular outflow tract obstruction in cats

Leigh A. Lamont, DVM, MS; Barret J. Bulmer, DVM; David D. Sisson, DVM, DACVIM; Kurt A. Grimm, DVM, MS, DACVA, DACVCP; William J. Tranquilli, DVM, MS, DACVA

JAVMA, Vol 221, No. 9, November 1, 2002

39

Alfaxalone IM

- Can be used as a premed/restraining drug (sedative)
- Cardiopulmonary effects well tolerated
- Better when combined with opioid and/or benzodiazepine
- Large volume of injectate
- Short duration of action
- Twitchiness can be seen
- Higher doses associated with general anesthesia

42

Options

- Opioid alone
- Midazolam + opioid
- Acepromazine + opioid
- Ketamine + midazolam/acepromazine + opioid
- Dexmedetomidine + opioid
- Alfaxalone IM

43

Optimizing Catheterization Conditions

- Chill protocols
  - Trazodone
  - Gabapentin
- EMLA cream prior to IVC
  - Eutectic mixture of local anesthetic (EMLA)
  - Transdermal lidocaine & prilocaine
  - Ideal for facilitating catheter placement
    - Lightly sedated patients
    - Novice/new nurses

44

Current Cardiovascular Meds

- General suggestions
  - ACE-I withhold day of surgery, may increase intraoperative hypotension
  - Clopidogrel – D/C 5-7 days prior to surgery, cost benefit
  - Pimobenden, beta-blockers, diuretics & others – continue
- Always be prepared to manage & address hypotension

45

Induction

- Alfaxalone or propofol
  - Very similar induction characteristics
  - Minimal hypotension/apnea when titrated to effect
- Ketamine/diazepam
  - Less potential for hypotension/apnea
  - Higher heart rates??
  - **Less ideal in patients with suspected HCM**
  - **Fine in patients with MVD**

46

Fluid Rates

- ~~Reduce rates, half regular maintenance rate~~
  - Largely based on opinion (risk avoidance) rather than evidence
- General trend towards using lower fluid rates
  - Less reliance on fluids for maintenance of blood pressure
  - AAHA guidelines 3-5 mL/kg/hr (surgical maintenance)
    - Supporting data largely extrapolated from human medicine

47

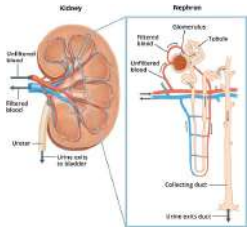
Fluid Rates (my approach)

- Standard 5-10 mL/kg/hr with decreasing rate over time
- If evidence of failure (imaging, clinical evidence) and/or currently on diuretic may reduce by 50% but….
  - Preoperative assessment of patient
  - PCV/TP
  - Urine production & USG
- Cats seem more prone to fluid overload (my experience)

48

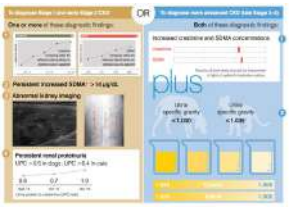
Chronic Kidney Disease

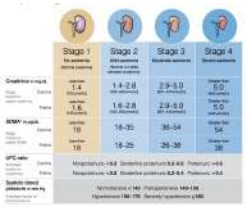
- Elevated creatinine & SDMA & low USG
  - **Idiopathic, associated with aging**
  - R/O - chronic infections, immune-mediated, urolithiasis, toxin, hypertension, genetic, cancer etc…



51

Staging CKD





52

Staging CKD & Anesthesia Risk

- Severity of disease (prognosis), direct therapy
  - Stage 1, >3 yrs
  - Stage 2, 2-3 yrs
  - Stage 3, 1.5-2 yrs
  - Stage 4, < 6 mos

Cats

- Reasonable to manage any patient with evidence of "pre-clinical" CKD (IRIS 1) to minimize further kidney insult
- If present manage proteinuria, hypertension

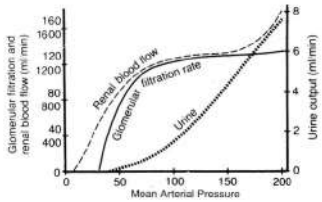
53

Anesthetic Plan/Goals

- Avoid drugs that can potentiate nephropathy
  - Aminoglycosides, NSAID's – PG dependent kidney only
    - PG dependent – hypotension, hypovolemia
- Avoid drugs requiring renal excretion or metabolism for clearance
  - Ketamine?
- Optimize renal blood flow (RBF) & GFR
  - Adequate blood pressure
  - Minimize renal vasoconstriction
- Minimize renal metabolic demands
  - Diuresis

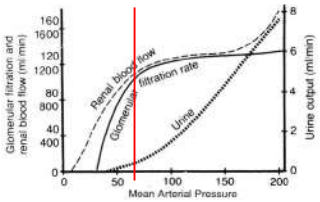
55

Regulation of Renal Blood Flow



56

Regulation of Renal Blood Flow



57

Alterations to Renal Blood Flow

- Anesthetic induced hypotension
- Catecholamine induced α_1 adrenoreceptor activation
  - Renal vasoconstriction
- Impaired autoregulatory mechanisms
  - Renal disease and/or concurrent drugs (i.e. NSAID's)

59

Premedication Options

- Opioid alone
- Midazolam + opioid
- Acepromazine + opioid
- Dexmedetomidine + opioid
- Alfaxalone (select cases, small patients)

60

Acepromazine + opioid

- Hypotension decrease renal blood flow?
  - Mild in normovolemic patients, low doses
- MAC sparing – less inhalant hypotension
  - Maintains renal blood flow & GFR despite hypotension
- Reno-protective (α1 adrenergic blocking)?
  - Anesthetic induced hypotension
  - Maintains renal blood flow & GFR despite hypotension
  - Minimize catecholamine induced vasoconstriction

64

Dexmedetomidine + opioid

- Decrease CO --> RBF
  - RBF better than saline control & vasopressin significantly reduced in isoflurane anesthetized dogs given medetomidine (20 & 40 mcg/kg IV)
- Inhibits vasopressin, promotes diuresis
  - May protect kidneys during ischemia (dog), ischemia-reperfusion injury (rodents)

65

Lower Stress Levels

Minimize catecholamine induced vasoconstriction

- Preoperatively - prearrival sedation
  - Trazadone
  - Gabapentin
- IV placement & IM drug administration
  - Gentle handling, attentive to patient cues
  - Topical local anesthetics (EMLA cream)
- Intraoperatively
  - Appropriate depth of anesthesia
- Postoperatively
  - Sufficient analgesia

66

Concurrent Kidney Medications

- May contribute to refractory hypotension
  - Angiotensin converting enzyme (ACE) – Inhibitors
    - Benazapril, enalapril
  - Calcium channel blockers
    - Amlodipine
  - Angiotensin II receptor antagonists/blockers (ARB)
    - Telmisartan
- No literature - on kidney specific effects

67

Intraoperative Support/Goals

- **Optimize oxygen delivery**
  - Fluids
  - Dopamine
  - RBC
- **Minimize oxygen demand**
  - Fluids
  - Diuresis
- Prevent renal vasoconstriction
  - Adequate anesthetic depth, avoid stress
- Assess urine output
  - Urinary catheter
  - Estimate, assess bladder size changes
  - **USG**

69

Fluid Rates (my approach)

- **Hydration (always access to water)**
  - Often place on fluids for several hours prior to procedure
  - 1.5-2x maintenance for 3-4 hrs
- Standard 5-10 mL/kg/hr with decreasing rate over time based on perioperative evidence
  - Preoperative hydration assessment of patient
  - PCV/TP
  - Urine production & USG

70

NSAID & CKD

- NSAID associated AKI predominantly **hemodynamically mediated** in PG dependent kidney
  - **Hypotensive, hypovolemic, dehydrated**
- **Non-PG dependent, limited risk NSAID induced kidney injury**
- Cost vs benefit
  - Short prescriptions in well hydrated CKD patients
  - Chronic pain & CKD benefits may far outweigh risks
  - Owner compliance & informed consent

71

Thank you!

73

Tips for Managing Common "Challenges" During Anesthesia

Craig Mosley DVM, MSc, DACVAA

VCA Canada 404 Veterinary Emergency & Referral Hospital

Thank you

Dechra

Overview

- Challenges – both expected & unexpected issues/complications
  - Perianesthetic agitation, poor recoveries
  - Worrisome monitoring values
  - Not breathing
  - Gastroesophageal reflux (GER)
  - Unanticipated awakening

Improving **Patient's** Quality of Anesthesia

- Consider entire perianesthetic period (emphasis comfort & stress)
  - Pre & post
- Sedation/calming, gentle handling
  - Chill protocols
    - Trazodone, gabapentin
  - **EMLA cream prior to catheterization**
  - **Sedation prior to catheterization?**
- Vomiting & nausea
  - Maropitant
- Smooth stress-free recovery

Poor Recovery

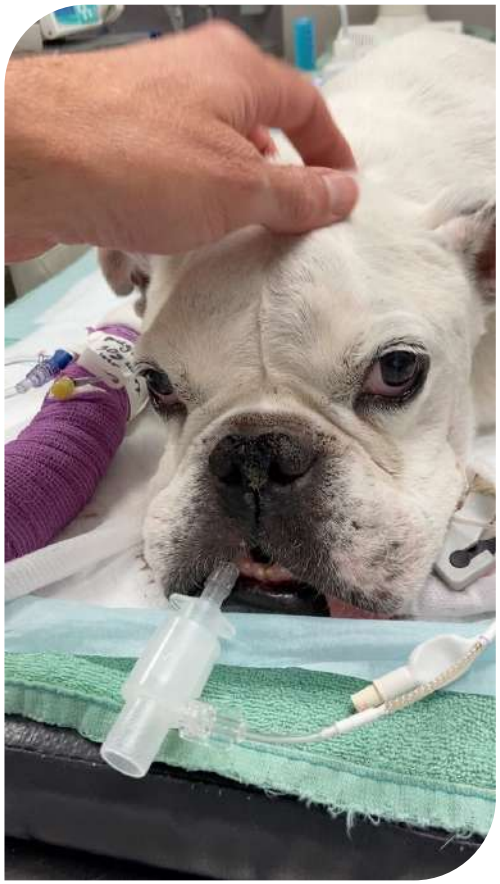
- Disruptive & unsettling
- Risk of injury
- Negative experience
- Suggestive of poor perioperative analgesic/sedation management

Preventing Poor Recovery

- Ensure sufficient sedation/analgesia
- Recover when you & patient are ready, sternal in kennel, do not vigorously restrain
- Comfort care – bladder, positioning, warmth, quiet
- If experiencing stormy recovery, determine cause
- Manage

Causes Poor Recovery

- Pain
  - Surgical site, full distended bladder
- Dysphoria
  - Can be normal when recovering from inhalant anesthesia
  - Consider time of premedication given
- Hypothermia
  - Extreme discomfort
- Airway irritation/compromise
  - Leads to patient distress



Dysphoria vs Pain

- Emergence dysphoria
  - Acepromazine (0.01-0.02 mg/kg)
  - Propofol (1-2 mg/kg)
  - Dexmedetomidine (1-2 µg/kg)
- Opioid dysphoria
  - Acepromazine (0.01-0.02 mg/kg)
  - Dexmedetomidine (1-2 µg/kg)
  - Naloxone (dilute & titrate IV to effect)
- Pain
  - Opioid (other analgesics)
  - Dexmedetomidine (1-2 µg/kg)

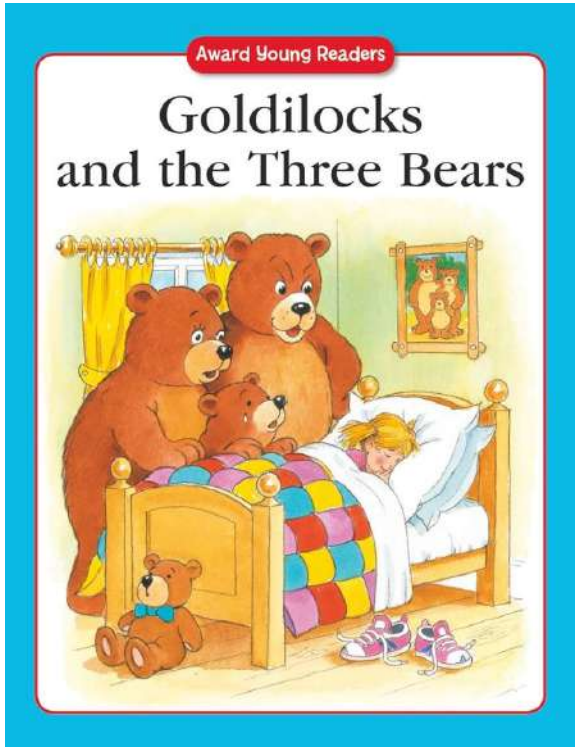
Dysphoria vs Pain

Dysphoria vs Pain

- Emergence dysphoria
  - Acepromazine (0.01-0.02 mg/kg)
  - Propofol (1-2 mg/kg)
  - **Dexmedetomidine (1-2 µg/kg)**
- Opioid dysphoria
  - Acepromazine (0.01-0.02 mg/kg)
  - **Dexmedetomidine (1-2 µg/kg)**
  - Naloxone (dilute & titrate IV to effect)
- Pain
  - Opioid (other analgesics)
  - **Dexmedetomidine (1-2 µg/kg)**

“Goldilocks” Approach to Monitoring

- Automated patient monitoring
  - Prone to over & under interpretation
  - Accuracy
  - “Arrhythmia’s”
  - Spurious readings etc
- Drugs – known side-effects
  - Apnea, twitchiness, tachycardia etc



Interpretation – MAP (54 mmHg)

- 12 wk puppy
  - Early castration
- 2 yr healthy dog
  - Uncomplicated FB
- 10 yr old dog with CKD
  - FME, 3+ hr surgery

Anesthesiology. 2020 March ; 132(3): 461–475. doi:10.1097/ALN.0000000000003063.

Preoperative Risk and the Association between Hypotension and Postoperative Acute Kidney Injury

Michael R. Mathis, M.D., Bhiken I. Naik, M.B.B.Ch., Robert E. Freundlich, M.D., M.S., M.S.C.I., Amy M. Shanks, Ph.D., Michael Heung, M.D., Minjae Kim, M.D., Michael L. Burns, M.D., Ph.D., Douglas A. Colquhoun, M.B. Ch.B., M.Sc., M.P.H., Govind Rangrass, M.D., Allison Janda, M.D., Milo C. Engoren, M.D., Leif Saager, M.D., M.M.M., Kevin K. Tremper, M.D., Ph.D., Sachin Kheterpal, M.D., M.B.A.* on behalf of Multicenter Perioperative Outcomes Group Investigators

- Risk factors
  - Anemia, estimated GFR (Stage 1-4 kidney disease), surgery type, ASA status, duration of anesthesia
  - Low risk patients - no association with hypotension (mild & severe)
  - Med risk patients - association with severe hypotension
  - High risk patients - association with mild hypotension

Oscillometric Blood Pressure

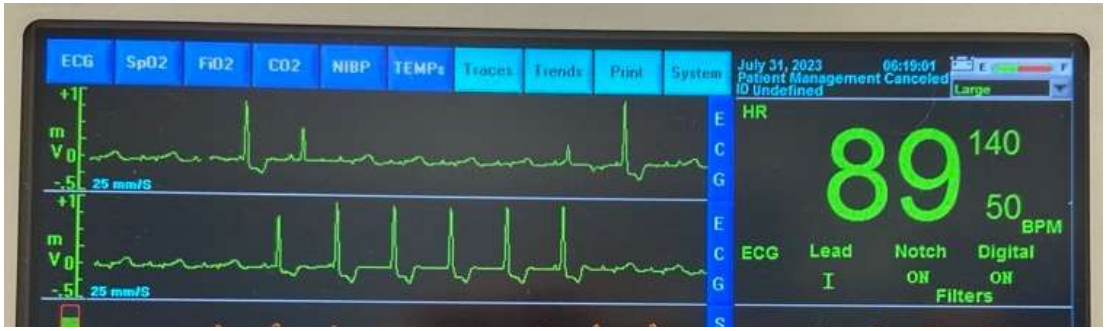
- Requires normal heart rhythm
  - May be inaccurate in arrhythmic patients
- Low pulse amplitude may lead to high incidence of monitor failure
- Accuracy/efficacy varies markedly
- Invest in technology optimized for veterinary patients
  - Suntech, Cardell

Doppler Blood pressure

- Doppler measures systolic blood pressure
  - > 90 mmHg (systolic)

- Cat & “toy” dog breeds
  - Doppler correlates best with mean arterial pressure (anesthetized)
  - > 60-70 mmHg using doppler is often considered acceptable

”Arrhythmias”



Arrhythmias

”Arrhythmias”

Arrhythmias

Arrhythmias

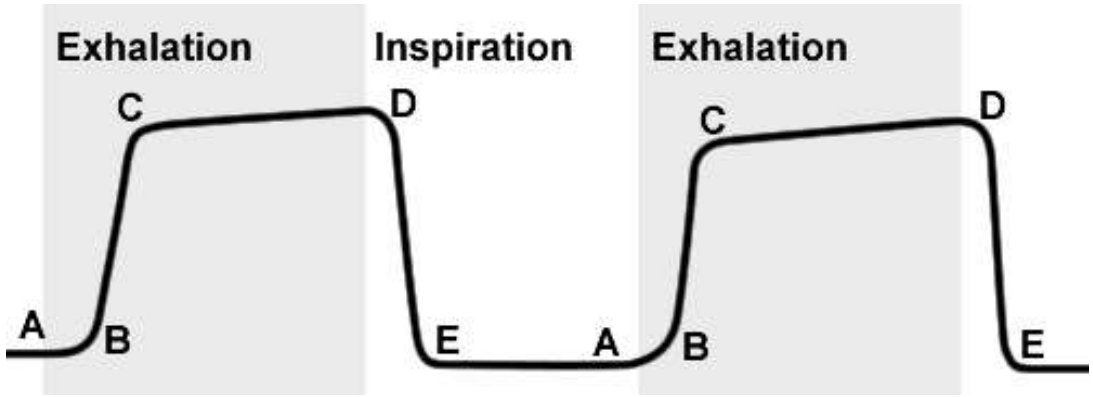
Isorhythmic Atrioventricular Dissociation

Isorhythmic Atrioventricular Dissociation

“Seizures, anesthetic adverse reactions etc”

High or low capnograph readings

- Respiratory monitor (**ventilation**)
- Indirect indicator of anesthetic depth
- Provides information regarding cardiovascular function
- Evaluates proper equipment function



High or low capnograph readings

- 30-35 mmHg - normal **awake ETCO2**
- < 50-60 mmHg - normal anesthetized animal
  - Compromised patients less tolerant of elevated CO_2
  - **$PaCO_2$ > 60 mmHg may be associated with CV changes**
  - **$PaCO_2$ > 80 mmHg can contribute to narcosis**

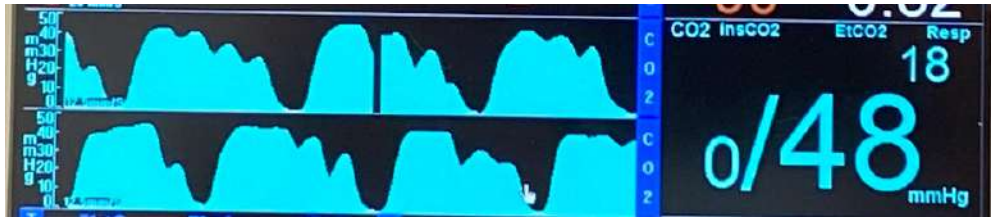
Low $ETCO_2$ (< 35 mmHg)

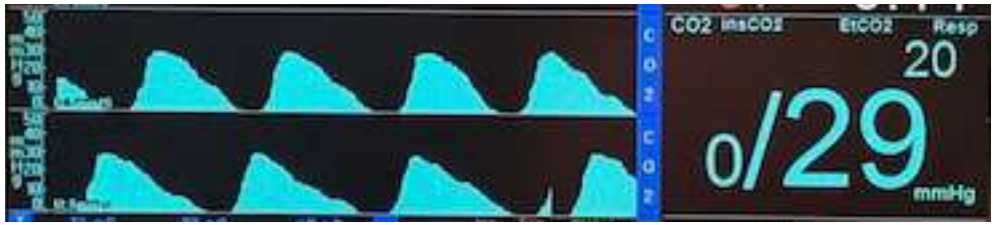
- Hyperventilating
  - Too light

- Inaccurate value (under estimation)
  - **High fresh gas flows, non-rebreathing systems**
  - Leak/break in line

High Fresh Gas Flow (FGF)

- Dilution of exhaled gases (CO_2) by incoming fresh gas
  - Non-rebreathing systems
  - Small patients, small tidal volumes
  - More dilution sidestream than mainstream





Capnography Limitations (small patients)

Adult port, Bain system

Pediatric port, Bain system

Capnography Limitations (small patients)

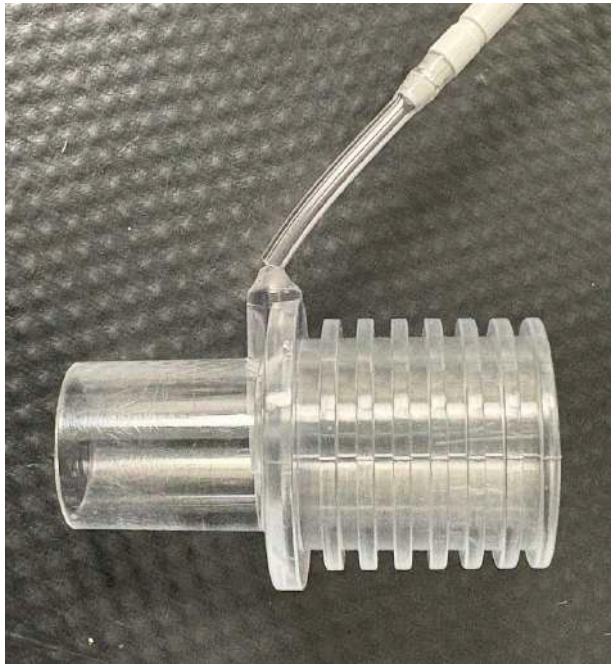
Adult port, Bain system

Pediatric port, Circle system

- **True ETCO2 can be significantly underestimated**

Leak in sampling line

Leak in sampling line



Stuck Expiratory Valve

Apnea (hypoventilation) during anesthesia

- Assess patient
  - SpO2, BP, HR, **ETCO2**
- Identify cause

Why do patients stop, or fail to breathe during anesthesia?

- Lack of “drive” to ventilate
  - CO_2
  - ~~Hypoxia~~
  - ~~Voluntary control~~
- Blunted response to “drive” – CNS depression
  - Excessive anesthetic depth, intravenous top ups
  - Bolus opioid administration – transient
  - Head/brainstem trauma

Why do patients stop, or fail to breathe during anesthesia?

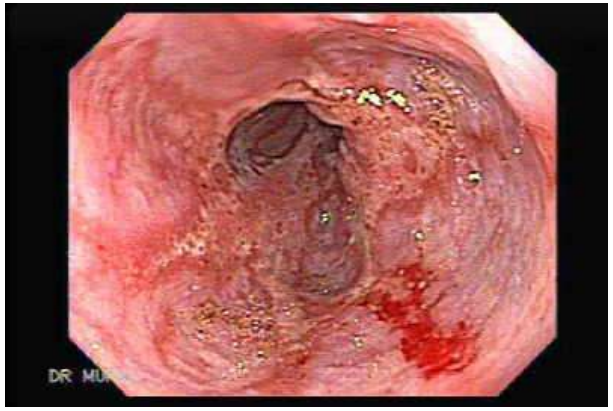
- Altered breathing pattern **– apneustic-like breathing pattern**
- Several breaths in quick succession follow by variable period of apnea
  - Ketamine
  - Dexmedetomidine
- Normally self limiting & minimal clinical impact

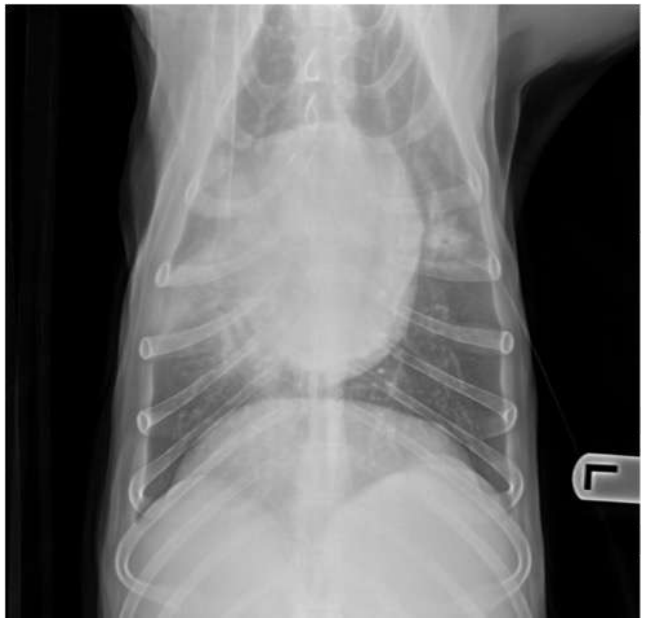
Pseudo “hypoventilation/apnea”

- Commonly occurs following induction
- Excessive “bagging” of patient
  - Checking ETT cuff, ensuring transfer to inhalant anesthetic
- Manual breaths larger than patient would take spontaneously
- Reducing CO_2 – diminishes patients intrinsic drive to breathe

Gastroesophageal reflux (GER)

- GER common in anesthetized dogs 12.5-60%
- Brachycephalic's higher risk
- Chemical esophagitis
- Aspiration pneumonia





GER - Causes

- Light plane of anesthesia
- Intraoperative administration of drugs
  - opioids, intravenous anesthetics etc…
- Decreased lower esophageal sphincter tone (pregnancy)
- High pressure from stomach (intestinal obstruction)
- Esophageal probes
- Prolonged fasting

GER - Management

- PREVENTION
- Suction & flush with water or 1-2% Na bicarbonate
- Extubate in sternal
- Extubate with cuff slightly inflated (caution cats)
- Protective medication?
  - H_2 blockers – famotidine
  - Proton pump inhibitors - omeprazole
  - Sucralfate

“Preventing” GER

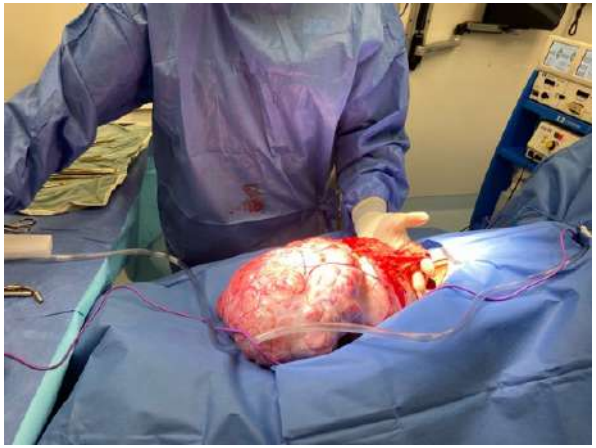
- Omeprazole - raises gastric pH, may decrease GER
- Famotidine - raises gastric pH
- Metoclopramide – prokinetic
- Cisapride – prokinetic
- Maropitant - **does NOT reduce GER**, will reduce vomiting & improved food consumption post-anesthesia

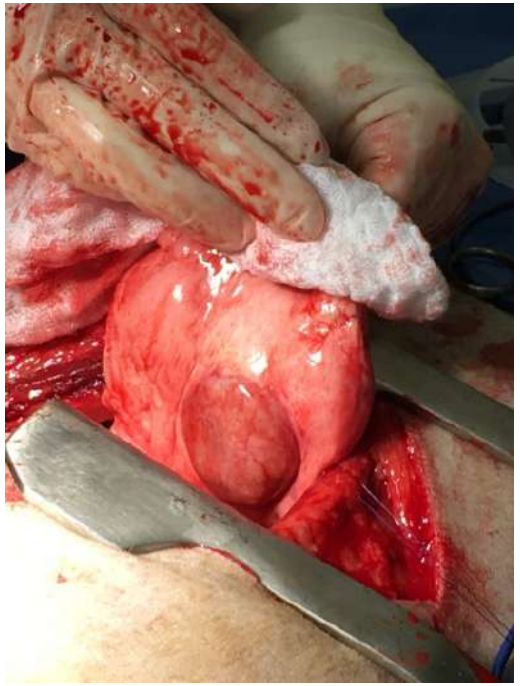
Reacting during anesthesia (inhaled anesthetic)

- Insufficient delivery of anesthetic, relative to stimulation
  - Vaporizer (dose) too low
  - Vaporizer empty
  - Fresh gas flow rate too low (relative to patient size)… rebreathing system only
  - Moved to new anesthetic machine
  - Patient not breathing/ventilating
  - Improper intubation
- Mis-interpretation of clinical signs (i.e. struggling to breath rather than too light)

Best treatment is PREVENTION

- **Failure to anticipate**
- Level of surgical stimulation varies





Efficacy of analgesic techniques vary

- Opioids, alpha-2 agonists
  - Doses and/or infusions
- Local anesthetics
  - Excellent local anesthesia does not confer suitable CNS depth
  - Vestibular stimulation
  - Stimulation of area outside locoregional

Too light - treatment

- Fastest
  - Additional intravenous anesthetic, ¼ of induction dose
- Fast
  - Additional opioid, sedative (dexmedetomidine), ketamine, lidocaine
  - Consider consequences
- Slow
  - Increase vaporizer
  - Ventilate
  - Increase fresh gas flow
    - Rebreathing system only!!!

Thank you!

1

Thank you

Dechra

2

Overview

- Challenges – both expected & unexpected issues/complications
  - Perianesthetic agitation, poor recoveries
  - Worrisome monitoring values
  - Not breathing
  - Gastroesophageal reflux (GER)
  - Unanticipated awakening

3

Improving **Patient's** Quality of Anesthesia

- Consider entire perianesthetic period (emphasis comfort & stress)
  - Pre & post
- Sedation/calming, gentle handling
  - Chill protocols
    - Trazodone, gabapentin
  - **EMLA cream prior to catheterization**
  - **Sedation prior to catheterization?**
- Vomiting & nausea
  - Maropitant
- Smooth stress-free recovery

5

Poor Recovery

- Disruptive & unsettling
- Risk of injury
- Negative experience
- Suggestive of poor perioperative analgesic/sedation management

6

Preventing Poor Recovery

- Ensure sufficient sedation/analgesia
- Recover when you & patient are ready, sternal in kennel, do not vigorously restrain
- Comfort care – bladder, positioning, warmth, quiet
- If experiencing stormy recovery, determine cause
- Manage

7

Causes Poor Recovery

- Pain
  - Surgical site, full distended bladder
- Dysphoria
  - Can be normal when recovering from inhalant anesthesia
  - Consider time of premedication given
- Hypothermia
  - Extreme discomfort
- Airway irritation/compromise
  - Leads to patient distress

8

Dysphoria vs Pain

- Emergence dysphoria
  - Acepromazine (0.01-0.02 mg/kg)
  - Propofol (1-2 mg/kg)
  - Dexmedetomidine (1-2 µg/kg)
- Opioid dysphoria
  - Acepromazine (0.01-0.02 mg/kg)
  - Dexmedetomidine (1-2 µg/kg)
  - Naloxone (dilute & titrate IV to effect)
- Pain
  - Opioid (other analgesics)
  - Dexmedetomidine (1-2 µg/kg)

9

Dysphoria vs Pain

10

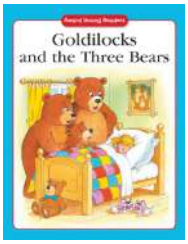
Dysphoria vs Pain

- Emergence dysphoria
  - Acepromazine (0.01-0.02 mg/kg)
  - Propofol (1-2 mg/kg)
  - **Dexmedetomidine (1-2 µg/kg)**
- Opioid dysphoria
  - Acepromazine (0.01-0.02 mg/kg)
  - **Dexmedetomidine (1-2 µg/kg)**
  - Naloxone (dilute & titrate IV to effect)
- Pain
  - Opioid (other analgesics)
  - **Dexmedetomidine (1-2 µg/kg)**

11

"Goldilocks" Approach to Monitoring

- Automated patient monitoring
  - Prone to over & under interpretation
  - Accuracy
  - "Arrhythmia's"
  - Spurious readings etc
- Drugs – known side-effects
  - Apnea, twitchiness, tachycardia etc



12

Interpretation – MAP (54 mmHg)

- 12 wk puppy
  - Early castration
- 2 yr healthy dog
  - Uncomplicated FB
- 10 yr old dog with CKD
  - FME, 3+ hr surgery

14

Anesthesiology. 2020 March ; 132(3): 461–475. doi:10.1097/ALN.0000000000003063.

Preoperative Risk and the Association between Hypotension and Postoperative Acute Kidney Injury

Michael R. Mathis, M.D., Bhiken I. Naik, M.B.B.Ch., Robert E. Freundlich, M.D., M.S., M.S.C.I., Amy M. Shanks, Ph.D., Michael Heung, M.D., Minjae Kim, M.D., Michael L. Burns, M.D., Ph.D., Douglas A. Colquhoun, M.B. Ch.B., M.Sc., M.P.H., Govind Rangrass, M.D., Allison Janda, M.D., Milo C. Engoren, M.D., Leif Saager, M.D., M.M.M., Kevin K. Tremper, M.D., Ph.D., Sachin Kheterpal, M.D., M.B.A.* on behalf of Multicenter Perioperative Outcomes Group Investigators

- Risk factors
  - Anemia, estimated GFR (Stage 1-4 kidney disease), surgery type, ASA status, duration of anesthesia
  - Low risk patients - no association with hypotension (mild & severe)
  - Med risk patients - association with severe hypotension
  - High risk patients - association with mild hypotension

15

Oscillometric Blood Pressure

- Requires normal heart rhythm
  - May be inaccurate in arrhythmic patients
- Low pulse amplitude may lead to high incidence of monitor failure
- Accuracy/efficacy varies markedly
- Invest in technology optimized for veterinary patients
  - Suntech, Cardell





16

Doppler Blood pressure

- Doppler measures systolic blood pressure
  - > 90 mmHg (systolic)
- Cat & "toy" dog breeds
  - Doppler correlates best with mean arterial pressure (anesthetized)
  - > 60-70 mmHg using doppler is often considered acceptable

17

"Arrhythmias"

18

Arrhythmias

19

"Arrhythmias"

20

Arrhythmias

21

Arrhythmias

22

Isorhythmic Atrioventricular Dissociation

23

Isorhythmic Atrioventricular Dissociation

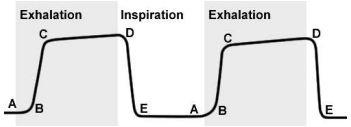
24

"Seizures, anesthetic adverse reactions etc"

26

High or low capnograph readings

- Respiratory monitor (**ventilation**)
- Indirect indicator of anesthetic depth
- Provides information regarding cardiovascular function
- Evaluates proper equipment function



27

High or low capnograph readings

- 30-35 mmHg - normal **awake ETCO2**
- < 50-60 mmHg - normal anesthetized animal
  - Compromised patients less tolerant of elevated CO_2
  - **$PaCO_2$ > 60 mmHg may be associated with CV changes**
  - **$PaCO_2$ > 80 mmHg can contribute to narcosis**

28

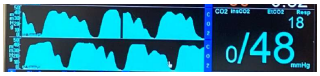
Low $ETCO_2$ (< 35 mmHg)

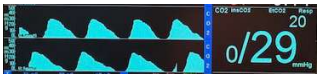
- Hyperventilating
  - Too light
- Inaccurate value (under estimation)
  - **High fresh gas flows, non-rebreathing systems**
  - Leak/break in line

31

High Fresh Gas Flow (FGF)

- Dilution of exhaled gases (CO2) by incoming fresh gas
  - Non-rebreathing systems
  - Small patients, small tidal volumes
  - More dilution sidestream than mainstream



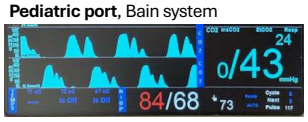


32

Capnography Limitations (small patients)

Adult port, Bain system

Pediatric port, Bain system



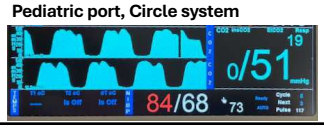
33

Capnography Limitations (small patients)

Adult port, Bain system

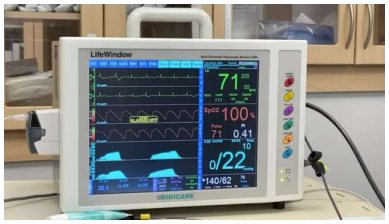
- **True ETCO2 can be significantly underestimated**

Pediatric port, Circle system



34

Leak in sampling line



37

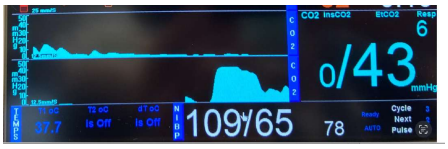
Leak in sampling line

38

Stuck Expiratory Valve

40

Apnea (hypoventilation) during anesthesia



- Assess patient
  - SpO2, BP, HR, **ETCO2**
- Identify cause

41

Why do patients stop, or fail to breathe during anesthesia?

- Lack of "drive" to ventilate
  - CO_2
  - ~~Hypoxia~~
  - ~~Voluntary control~~
- Blunted response to "drive" – CNS depression
  - Excessive anesthetic depth, intravenous top ups
  - Bolus opioid administration – transient
  - Head/brainstem trauma

42

Why do patients stop, or fail to breathe during anesthesia?

- Altered breathing pattern – **apneustic-like breathing pattern**
- Several breaths in quick succession follow by variable period of apnea
  - Ketamine
  - Dexmedetomidine
- Normally self limiting & minimal clinical impact

43

Pseudo "hypoventilation/apnea"

- Commonly occurs following induction
- Excessive "bagging" of patient
  - Checking ETT cuff, ensuring transfer to inhalant anesthetic
- Manual breaths larger than patient would take spontaneously
- Reducing CO_2 – diminishes patients intrinsic drive to breathe

44

Gastroesophageal reflux (GER)

- GER common in anesthetized dogs 12.5-60%
- Brachycephalic's higher risk
- Chemical esophagitis
- Aspiration pneumonia

50

GER - Causes

- Light plane of anesthesia
- Intraoperative administration of drugs
  - opioids, intravenous anesthetics etc…
- Decreased lower esophageal sphincter tone (pregnancy)
- High pressure from stomach (intestinal obstruction)
- Esophageal probes
- Prolonged fasting

51

GER - Management

- PREVENTION
- Suction & flush with water or 1-2% Na bicarbonate
- Extubate in sternal
- Extubate with cuff slightly inflated (caution cats)
- Protective medication?
  - H_2 blockers – famotidine
  - Proton pump inhibitors - omeprazole
  - Sucralfate

52

"Preventing" GER

- Omeprazole - raises gastric pH, may decrease GER
- Famotidine - raises gastric pH
- Metoclopramide – prokinetic
- Cisapride – prokinetic
- Maropitant - **does NOT reduce GER**, will reduce vomiting & improved food consumption post-anesthesia

53

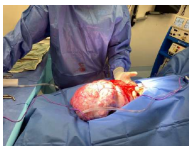
Reacting during anesthesia (inhaled anesthetic)

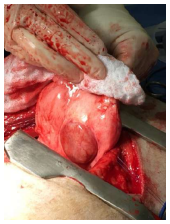
- Insufficient delivery of anesthetic, relative to stimulation
  - Vaporizer (dose) too low
  - Vaporizer empty
  - Fresh gas flow rate too low (relative to patient size)… rebreathing system only
  - Moved to new anesthetic machine
  - Patient not breathing/ventilating
  - Improper intubation
- Mis-interpretation of clinical signs (i.e. struggling to breath rather than too light)

54

Best treatment is PREVENTION

- **Failure to anticipate**
- Level of surgical stimulation varies





55

Efficacy of analgesic techniques vary

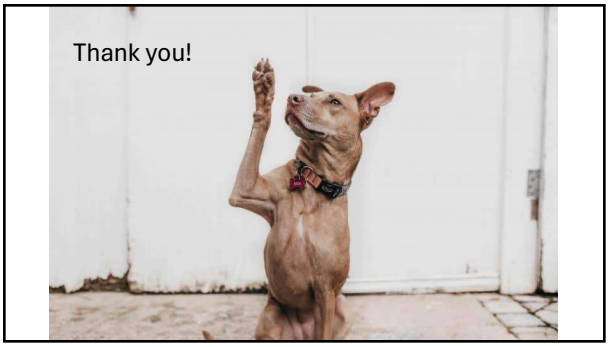
- Opioids, alpha-2 agonists
  - Doses and/or infusions
- Local anesthetics
  - Excellent local anesthesia does not confer suitable CNS depth
  - Vestibular stimulation
  - Stimulation of area outside locoregional

56

Too light - treatment

- Fastest
  - Additional intravenous anesthetic, ¼ of induction dose
- Fast
  - Additional opioid, sedative (dexmedetomidine), ketamine, lidocaine
  - Consider consequences
- Slow
  - Increase vaporizer
  - Ventilate
  - Increase fresh gas flow
    - Rebreathing system only!!!

57



58

1

Thank you

Dechra

2

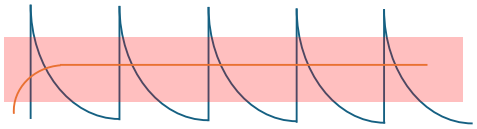
Overview

- Why consider continuous intravenous infusions
- What are they used for
- How are they used, common infusions
- Pitfall and considerations

3

Intravenous Infusion

- Controlled delivery, consistent clinical effects
  - Minimizes "peaks" & "valleys" associated with bolus administration
  - May help avoid side effects (toxicity) & sub-therapeutic doses



4

Intravenous Infusion

- Controlled delivery, consistent clinical effect
  - Minimizes "peaks" & "valleys" associated with bolus administration
  - May help avoid side effects (toxicity) & sub-therapeutic doses
- More easily "titrated to effect"
- Inhalant sparing effects possible
- Drugs with short half-lives (i.e. dopamine, dobutamine, norepinephrine)
- Simple & cost effective?
  - Human ICU, post surgical units etc...

5

Common infusions in veterinary medicine

- Analgesia & anesthesia sparing
  - Fentanyl, dexmedetomidine, ketamine, lidocaine
- Anesthesia
  - Alfaxalone, propofol, ketamine
- Cardiovascular support
  - Dopamine, norepinephrine, lidocaine

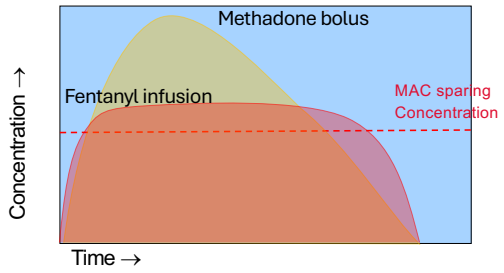
6

Infusion Alternative

- Intraoperative bolus of opioid immediately prior to incision or larger premedication doses
- "Practical person's CRI"
  - Divide total desired dose opioid - give ½ dose as premedication, give ½ dose prior to first incision
- For example
  - Desired total dose at time of incision 0.1 mg/kg
  - 0.05 mg/kg in premed, and 0.05 mg/kg prior to incision

7

Practical "CRI"



8

Fentanyl (Analgesia)

- **Useful for avoiding side effects & difficult to manage pain**
- Inhalant sparing ceiling, around 15-20 mcg/kg/hr
- Consider possibility of accumulation/prolonged effects after long duration infusions
- Cats - tendency for more behavioural side effects & variable response?

- Analgesia
  - 1-5 mcg/kg loading dose
  - 2-5 mcg/kg/hr, up to 20 mcg/kg/hr intraop for MAC sparing effect

10

Ketamine (Analgesia & anesthesia)

- **Analgesia & anesthetic adjunct (largely empirical doses)**
  - 0.2-0.5 mg/kg loading dose
  - 0.3-1.8 mg/kg/hr or **5-30 mcg/kg/min**
- Chronic pain*
  - 0.2-0.5 mg/kg loading dose
  - 8 mcg/kg/min over 4 hours, every two weeks, 2 treatments effects persisted for 8 weeks

* L Fry, J Rychel, C Tearney, A Guedes. Preliminary study of intravenous ketamine infusions for the management of chronic pain in dogs. VAA, 52(1);2025:124.e3-124.e4.

11

Ketamine

- Very little high quality veterinary specific evidence
  - Plenty of safety evidence & many individual studies point to benefit
    - May influence pain scores >12 hrs post-op
    - Does not influence rescue analgesia requirements post-op
  - Much extrapolated from human data

- No clear consensus or guideline in veterinary medicine
- **Maladaptive pain**
  - Chronic pain, pre-existing inflammation
  - Nerve pain
  - Major trauma

12

Ketamine (humans)

- 2018 ASA consensus statements in human medicine
- Acute & chronic pain
  - Wide variability in use
  - Pain prevention (severe perioperative pain)
  - Opioid sparing
  - Anti-hyperalgesic (decrease sensitization)
  - Decreases incidence of post-surgical neuropathic pain
  - Safe
  - Evidence does not strongly support a role in chronic pain management but…

13

Ketamine (humans)

CHRONIC PAIN MEDICINE

Ketamine Infusions for Chronic Pain: A Systematic Review and Meta-analysis of Randomized Controlled Trials

Orhurhu, Vwaire MD, MPH[1]; Orhurhu, Mariam Salisu MD, MPH[2]; Bhatia, Anuj MD, FRCPC[3]; Cohen, Steven P. MD[1,4]

Author Information

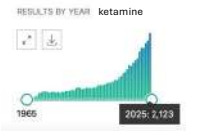
Anesthesia & Analgesia 129(1):pp 241-254, July 2019. | DOI: 10.1213/ANE.0000000000004185

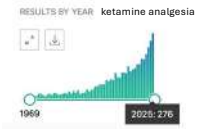
- **Evidence suggests IV ketamine provides significant short-term analgesic benefit in patients with refractory chronic pain**, with some evidence of a dose-response relationship. **Larger, multicenter studies with longer follow-ups are needed to better select patients and determine the optimal treatment protocol**

14

Future of ketamine

- General anesthetic
- Procedural sedative
- Analgesia (acute & chronic)
- Depression
- PTSD
- Anxiety
- Substance use disorders
- Status asthmaticus
- Neuroprotection





16

Ketamine (Analgesia & anesthesia)

- **Analgesia & anesthetic adjunct (largely empirical doses)**
  - 0.2-0.5 mg/kg loading dose
  - 0.3-1.8 mg/kg/hr or 5-30 mcg/kg/min
- Chronic pain*
  - 0.2-0.5 mg/kg loading dose
  - 8 mcg/kg/min over 4 hours, every two weeks, 2 treatments effects persisted for 8 weeks

* L Fry, J Rychel, C Tearney, A Guedes. Preliminary study of intravenous ketamine infusions for the management of chronic pain in dogs. VAA, 52(1);2025:124.e3-124.e4.

17

Dexmedetomidine (Sedation & analgesia)

- Anesthetic adjunct
  - Sedative, analgesic, muscle relaxant
  - May help offset isoflurane induced hypotension
  - Role in septic patients?
- **Sedation of hospitalized patients**
- Analgesia in awake patients?
- More widely evaluated in dogs, similar doses often used in cats

18

Dexmedetomidine (Sedation & analgesia)

- Sedation (walking)
  - 1-3 mcg/kg
  - 0.5-2 mcg/kg/hr
- Anesthesia (adjunct)
  - 1-5 mcg/kg loading dose (premedication)
  - 0.5-3 mcg/kg/hr

19

Lidocaine (Arrhythmias & analgesia)

- **Primarily used as antiarrhythmic (ventricular)**
- Popular as non-controlled, readily available intravenous analgesic
  - Equivalency/mixed studies (i.e. fentanyl-ketamine vs fentanyl-lidocaine)
  - Weak pain model (i.e. OVH)
- May enhance GI motility
  - Mixed evidence in literature
- Use not well described in cats
  - Significant cardiorespiratory depression in anesthetized cats (2005)
  - Recent study (2025) suggests intravenous lidocaine may be safe in cats

20

Lidocaine (Arrhythmias & analgesia)

- Dog (antiarrhythmic)
  - 1-2 mg/kg bolus
  - 25-200 mcg/kg/min
    - 150-200 first hour, 100 second hour, 50 third
- Dog & cats* (analgesia)
  - 1-2 mg/kg bolus
  - 20-50 mcg/kg/min
- Cats* (analgesia)?
  - 2mg/kg bolus, 50 mcg/kg/min for 1 hour

*Comassetto et al. Intravenous lidocaine may contribute to postoperative analgesia without detectable adverse effects in cats undergoing ovariohysterectomy: a randomized trial. JAVMA, Oct 22;2025:1-8.

21

Managing Hypotension

22

Preventing hypotension

- Proper patient preparation
  - Hydration
  - Fluid support (in-hospital)
  - Concurrent drugs (ACE inhibitors, ARB - telmisartan)
- Minimizing use of vasodilating drugs
  - Inhalants
  - Aceproamzine
- Appropriate depth of anesthesia for level of stimulation

23

Hypotension “First Response”

- 2x check measurement
  - Accuracy – cuff, placement, arrhythmia
- Assess patient & procedure
- Anesthetic depth
  - Add CV sparing drugs/techniques
  - Opioids, lidocaine, local anesthesia
- Check heart rate (bradycardia?)
  - Med-large dog < 60 bpm
  - Small dog < 80 bpm
  - Cat < 120 bpm

24

Hypotension

- Fluid bolus (5-20 ml/kg/15min)
  - Well tolerated in most patients
  - Minimal effects in normovolemic patients
  - Induces diuresis, decrease metabolic demand
- Drug for BP support
  - Dopamine
  - Norepinephrine
  - Dobutamine

27

Dopamine (blood pressure support)

- Historically sympathomimetic of choice to support blood pressure intraoperatively (regionally specific)
- Occasionally see unexpected cardiovascular side effects (tachycardia, bradycardia)
- **Dose dependent effects**
  - 3-5 mcg/kg/min
    - renal & splanchnic vasodilation
  - 5-10 mcg/kg/min
    - myocardial contractility
  - 10-20 mcg/kg/min
    - vasoconstriction

30

Norepinepherine (blood pressure support)

- **Pressor of choice septic patients, those refractory to dopamine**
- Increasingly used as first line blood pressure support, more specific pressor effects
- Dose - 0.1-1.0 mcg/kg/min (T½ - 2 min)
- Bottle concentration is often 1000 mcg/mL
  - Dilute to less than 100 mcg/mL
  - Long-term infusions (several hours – days), dilute to less than 25 mcg/mL

31

Dobutamine (blood pressure support)

- Occasionally used to treat blood pressure, strong regional/individual preferences
- Primarily increases contractility
  - DCM, weak heart muscle
- **Does not reliably increase blood pressure, despite marked increases in CO due to reductions in SVR**
  - Oxygen delivery & perfusion??
- Dose
  - 2-15 mcg/kg/min

32

Intravenous Infusion - cons

- Requires good understanding of PK & PD
  - Context sensitive half life
- Adds to complexity of anesthesia?
  - Is it necessary, ask why.. what are the alternatives?
    - Analgesia
    - Anesthesia
    - CV support
- Impact on recoveries (prolonged?)

36

Intravenous Infusion - cons

- Best delivered with programmable syringe driver
  - Cost
- Mixing/diluting into delivery fluids
  - **Do not recommend**, hinders ability to change fluid rate/deliver bolus, acting as compounding pharmacist (interactions, stability etc.)

37

Syringe Drivers

- https://www.syringepump.com
- https://www.psscientific.com/new-era-infusion-one-ne-300-iust-infusion-syringe-pump
- 550 CDN

- https://www.bbraun-vetcare.com/en/products/b11/perfusor-space.html
- 2500 CDN

38

Dopamine 1600 mcg/ml				Dopamine 800 mcg/ml		
Dose	5	7	10	5	7	10
(mcg/kg/min)						
Weight	ml/hr	ml/hr	ml/hr	ml/hr	ml/hr	ml/hr
1	0.19	0.26	0.38	0.38	0.53	0.75
2	0.38	0.53	0.75	0.75	1.05	1.50
3	0.56	0.79	1.13	1.13	1.58	2.25
4	0.75	1.05	1.50	1.50	2.10	3.00
5	0.94	1.31	1.88	1.88	2.63	3.75
6	1.13	1.58	2.25	2.25	3.15	4.50
7	1.31	1.84	2.63	2.63	3.68	5.25
8	1.50	2.10	3.00	3.00	4.20	6.00
9	1.69	2.36	3.38	3.38	4.73	6.75
10	1.88	2.63	3.75	3.75	5.25	7.50
11	2.06	2.89	4.13	4.13	5.78	8.25
12	2.25	3.15	4.50	4.50	6.30	9.00
13	2.44	3.41	4.88	4.88	6.83	9.75
14	2.63	3.68	5.25	5.25	7.35	10.50
15	2.81	3.94	5.63	5.63	7.88	11.25
16	3.00	4.20	6.00	6.00	8.40	12.00
17	3.19	4.46	6.38	6.38	8.93	12.75
18	3.38	4.73	6.75	6.75	9.45	13.50
19	3.56	4.99	7.13	7.13	9.98	14.25
20	3.75	5.25	7.50	7.50	10.50	15.00
21	3.94	5.51	7.88	7.88	11.03	15.75

39

Practical use issues

- Proper "piggybacking" into primary fluid line
  - T-ports, extension sets, secured (tape, Luer lock ports), labelled
- Inadvertent bolus administration with changing primary fluid rate
- Infusions should be as close to IV catheter as possible, with **vasoactive products in closest port**
- Proper dilution/mixing of drugs
  - Ketamine 10 mg/mL, dexmedetomidine 50 mcg/mL, NE 10-50 mcg/mL
  - Compatibility, interactions, stability etc
  - Errors

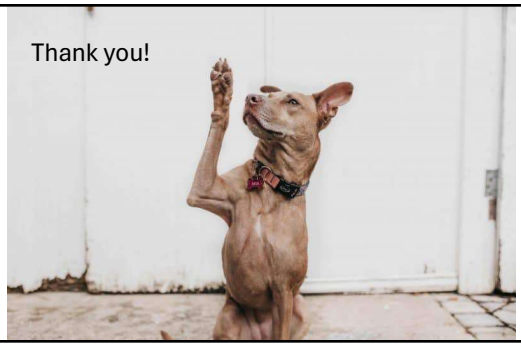
40

Summary

- Continuous intravenous infusion can provide clinical benefit perioperative period
  - Analgesia, inhalant sparing, cardiovascular support
- Patient outcome & appropriate use scenarios, research ongoing
- Pharmacological understanding required
- Dedicated delivery devices are best
- Practical use considerations should be explored

41

Thank you!



42

Continuous Intravenous Infusions...
the Good and the Bad

Craig Mosley DVM, MSc, DACVAA
VCA Canada 404 Veterinary Emergency & Referral Hospital

Thank you

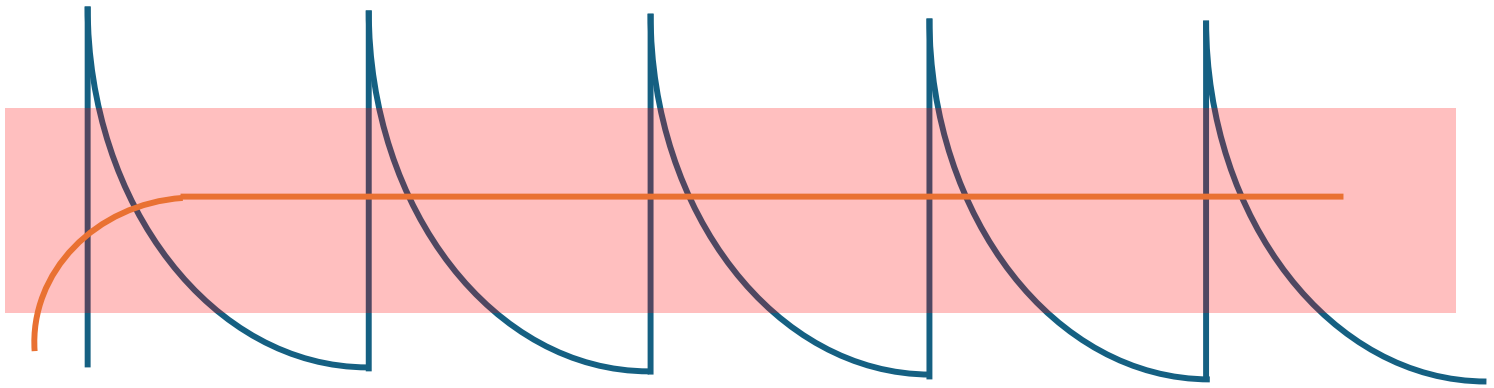
Dechra

Overview

- Why consider continuous intravenous infusions
- What are they used for
- How are they used, common infusions
- Pitfall and considerations

Intravenous Infusion

- Controlled delivery, consistent clinical effects
  - Minimizes “peaks” & “valleys” associated with bolus administration
  - May help avoid side effects (toxicity) & sub-therapeutic doses



Intravenous Infusion

- Controlled delivery, consistent clinical effect
  - Minimizes “peaks” & “valleys” associated with bolus administration
  - May help avoid side effects (toxicity) & sub-therapeutic doses
- More easily “titrated to effect”
- Inhalant sparing effects possible
- Drugs with short half-lives (i.e. dopamine, dobutamine, norepinephrine)
- Simple & cost effective?
  - Human ICU, post surgical units etc…

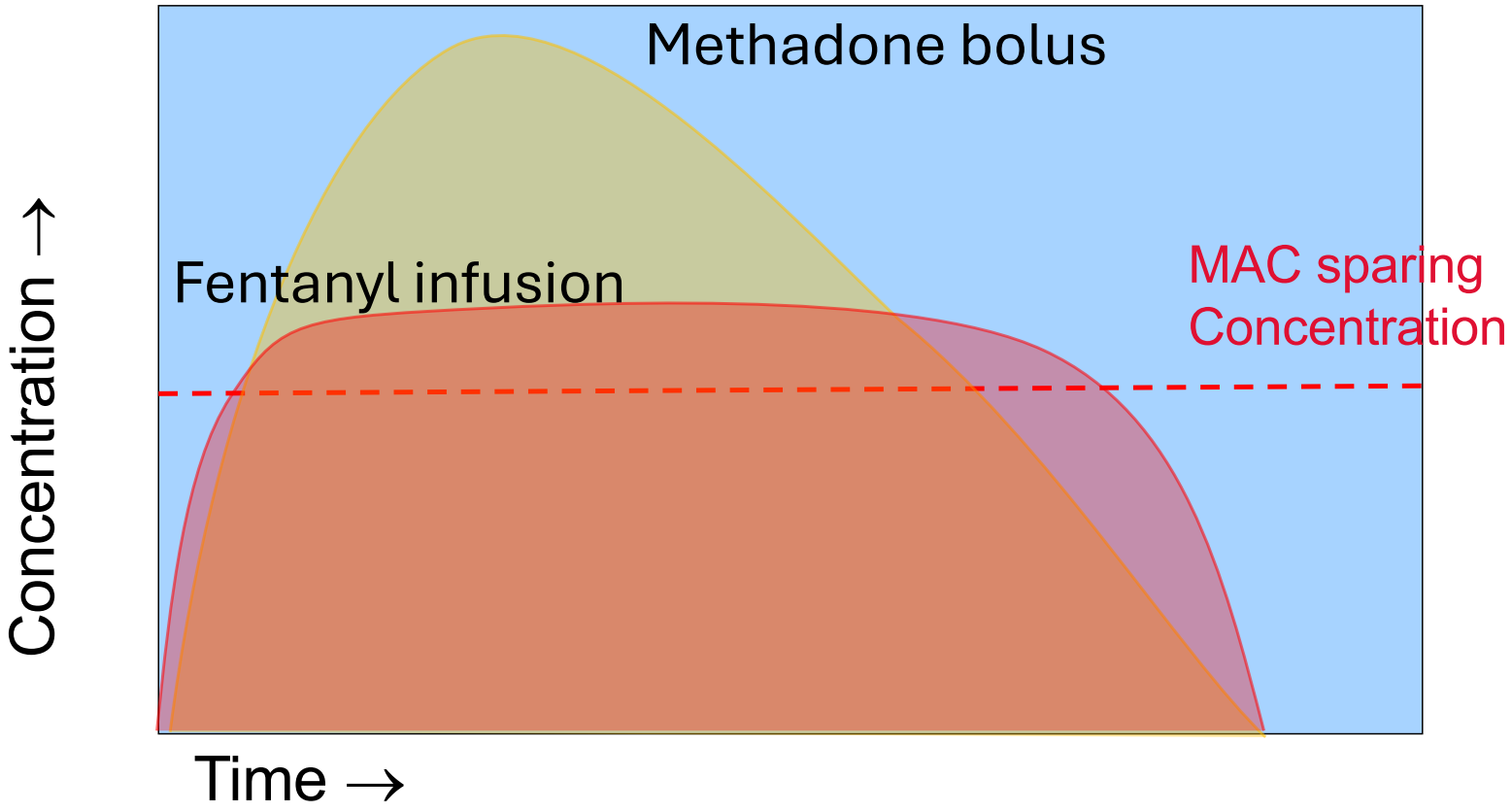
Common infusions in veterinary medicine

- Analgesia & anesthesia sparing
  - Fentanyl, dexmedetomidine, ketamine, lidocaine
- Anesthesia
  - Alfaxalone, propofol, ketamine
- Cardiovascular support
  - Dopamine, norepinephrine, lidocaine

Infusion Alternative

- Intraoperative bolus of opioid immediately prior to incision or larger premedication doses
- “Practical person’s CRI”
  - Divide total desired dose opioid - give ½ dose as premedication, give ½ dose prior to first incision
- For example
  - Desired total dose at time of incision 0.1 mg/kg
  - 0.05 mg/kg in premed, and 0.05 mg/kg prior to incision

Practical “CRI”



Fentanyl (Analgesia)

- **Useful for avoiding side effects & difficult to manage pain**
- Inhalant sparing ceiling, around 15-20 mcg/kg/hr
- Consider possibility of accumulation/prolonged effects after long duration infusions
- Cats - tendency for more behavioural side effects & variable response?

- Analgesia
  - 1-5 mcg/kg loading dose
  - 2-5 mcg/kg/hr, up to 20 mcg/kg/hr intraop for MAC sparing effect

Ketamine (Analgesia & anesthesia)

- **Analgesia & anesthetic adjunct (largely empirical doses)**
  - 0.2-0.5 mg/kg loading dose
  - 0.3-1.8 mg/kg/hr or **5-30 mcg/kg/min**
- Chronic pain*
  - 0.2-0.5 mg/kg loading dose
  - 8 mcg/kg/min over 4 hours, every two weeks, 2 treatments effects persisted for 8 weeks

* L Fry, J Rychel, C Tearney, A Guedes. Preliminary study of intravenous ketamine infusions for the management of chronic pain in dogs. VAA, 52(1);2025:124.e3-124.e4.

Ketamine

- Very little high quality veterinary specific evidence
  - Plenty of safety evidence & many individual studies point to benefit
    - May influence pain scores >12 hrs post-op
    - Does not influence rescue analgesia requirements post-op
  - Much extrapolated from human data

- No clear consensus or guideline in veterinary medicine
- **Maladaptive pain**
  - Chronic pain, pre-existing inflammation
  - Nerve pain
  - Major trauma

Ketamine (humans)

- 2018 ASA consensus statements in human medicine
- Acute & chronic pain
  - Wide variability in use
  - Pain prevention (severe perioperative pain)
  - Opioid sparing
  - Anti-hyperalgesic (decrease sensitization)
  - Decreases incidence of post-surgical neuropathic pain
  - Safe
  - Evidence does not strongly support a role in chronic pain management but…

Ketamine (humans)

CHRONIC PAIN MEDICINE

Ketamine Infusions for Chronic Pain: A Systematic Review and Meta-analysis of Randomized Controlled Trials

Orhurhu, Vwaire MD, MPH*; Orhurhu, Mariam Salisu MD, MPH†; Bhatia, Anuj MD, FRCPC‡; Cohen, Steven P. MD§,‖

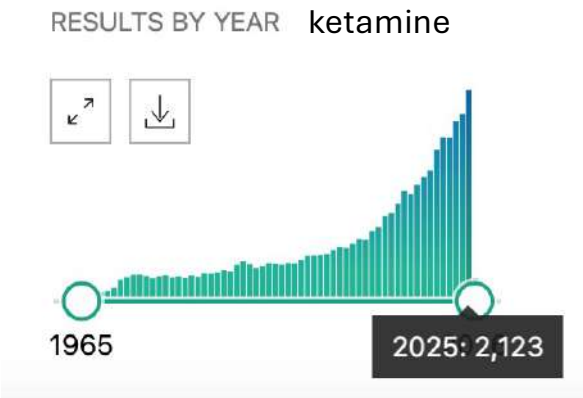
Author Information

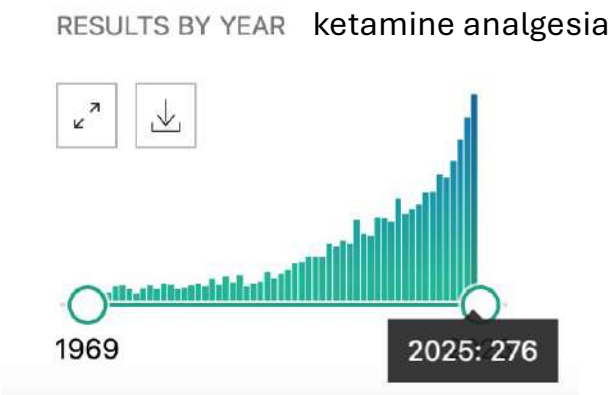
Anesthesia & Analgesia 129(1):p 241-254, July 2019. | *DOI:* 10.1213/ANE.0000000000004185

- **Evidence suggests IV ketamine provides significant short-term analgesic benefit in patients with refractory chronic pain**, with some evidence of a dose-response relationship. **Larger, multicenter studies with longer follow-ups are needed to better select patients and determine the optimal treatment protocol**

Future of ketamine

- General anesthetic
- Procedural sedative
- Analgesia (acute & chronic)
- Depression
- PTSD
- Anxiety
- Substance use disorders
- Status asthmaticus
- Neuroprotection





Ketamine (Analgesia & anesthesia)

- **Analgesia & anesthetic adjunct (largely empirical doses)**
  - 0.2-0.5 mg/kg loading dose
  - 0.3-1.8 mg/kg/hr or 5-30 mcg/kg/min
- Chronic pain*
  - 0.2-0.5 mg/kg loading dose
  - 8 mcg/kg/min over 4 hours, every two weeks, 2 treatments effects persisted for 8 weeks

* L Fry, J Rychel, C Tearney, A Guedes. Preliminary study of intravenous ketamine infusions for the management of chronic pain in dogs. VAA, 52(1);2025:124.e3-124.e4.

Dexmedetomidine (Sedation & analgesia)

- Anesthetic adjunct
  - Sedative, analgesic, muscle relaxant
  - May help offset isoflurane induced hypotension
  - Role in septic patients?
- **Sedation of hospitalized patients**
- Analgesia in awake patients?
- More widely evaluated in dogs, similar doses often used in cats

Dexmedetomidine (Sedation & analgesia)

- Sedation (walking)
  - 1-3 mcg/kg
  - 0.5-2 mcg/kg/hr

- Anesthesia (adjunct)
  - 1-5 mcg/kg loading dose (premedication)
  - 0.5-3 mcg/kg/hr

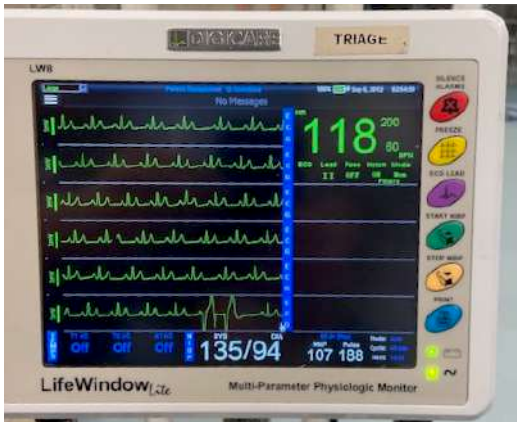
Lidocaine (Arrhythmias & analgesia)

- **Primarily used as antiarrhythmic (ventricular)**
- Popular as non-controlled, readily available intravenous analgesic
  - Equivalency/mixed studies (i.e. fentanyl-ketamine vs fentanyl-lidocaine)
  - Weak pain model (i.e. OVH)
- May enhance GI motility
  - Mixed evidence in literature
- Use not well described in cats
  - Significant cardiorespiratory depression in anesthetized cats (2005)
  - Recent study (2025) suggests intravenous lidocaine may be safe in cats

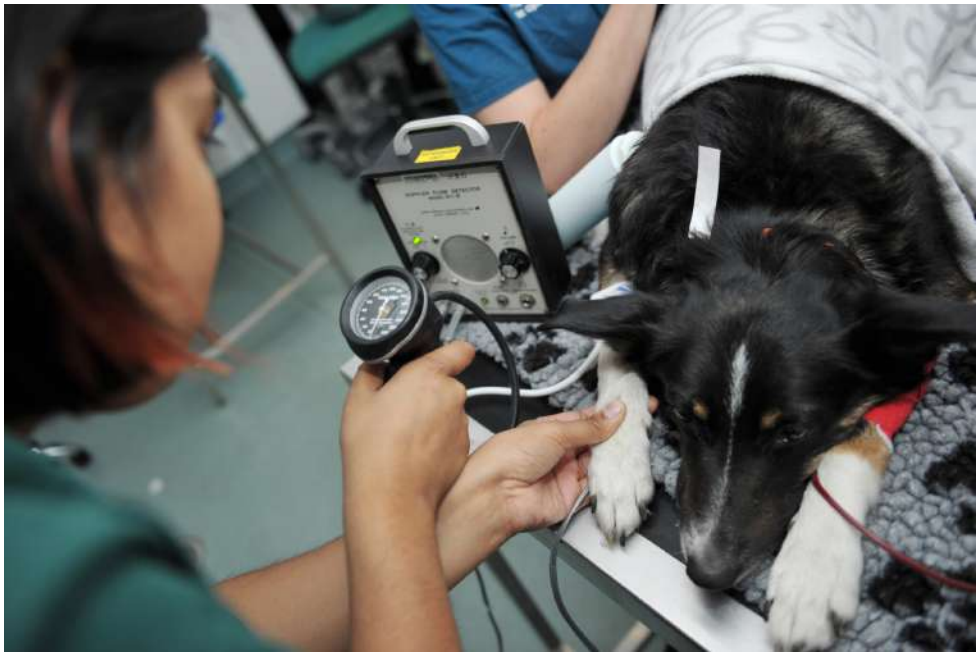
Lidocaine (Arrhythmias & analgesia)

- Dog (antiarrhythmic)
  - 1-2 mg/kg bolus
  - 25-200 mcg/kg/min
    - 150-200 first hour, 100 second hour, 50 third
- Dog & cats* (analgesia)
  - 1-2 mg/kg bolus
  - 20-50 mcg/kg/min
- Cats* (analgesia)?
  - 2mg/kg bolus, 50 mcg/kg/min for 1 hour

*Comassetto et al. Intravenous lidocaine may contribute to postoperative analgesia without detectable adverse effects in cats undergoing ovariohysterectomy: a randomized trial. JAVMA, Oct 22;2025:1-8.



Managing Hypotension



Preventing hypotension

- Proper patient preparation
  - Hydration
  - Fluid support (in-hospital)
  - Concurrent drugs (ACE inhibitors, ARB - telmisartan)
- Minimizing use of vasodilating drugs
  - Inhalants
  - Aceproamzine
- Appropriate depth of anesthesia for level of stimulation

Hypotension “First Response”

- 2x check measurement
  - Accuracy – cuff, placement, arrhythmia
- Assess patient & procedure
- Anesthetic depth
  - Add CV sparing drugs/techniques
  - Opioids, lidocaine, local anesthesia
- Check heart rate (bradycardia?)
  - Med-large dog < 60 bpm
  - Small dog < 80 bpm
  - Cat < 120 bpm

Hypotension

- Fluid bolus (5-20 ml/kg/15min)
  - Well tolerated in most patients
  - Minimal effects in normovolemic patients
  - Induces diuresis, decrease metabolic demand
- Drug for BP support
  - Dopamine
  - Norepinephrine
  - Dobutamine

Dopamine (blood pressure support)

- Historically sympathomimetic of choice to support blood pressure intraoperatively (regionally specific)
- Occasionally see unexpected cardiovascular side effects (tachycardia, bradycardia)
- **Dose dependent effects**
  - 3-5 mcg/kg/min
    - renal & splanchnic vasodilation
  - 5-10 mcg/kg/min
    - myocardial contractility
  - 10-20 mcg/kg/min
    - vasoconstriction

Norepinepherine (blood pressure support)

- **Pressor of choice septic patients, those refractory to dopamine**
- Increasingly used as first line blood pressure support, more specific pressor effects
- Dose - 0.1-1.0 mcg/kg/min (T½ - 2 min)
- Bottle concentration is often 1000 mcg/mL
  - Dilute to less than 100 mcg/mL
  - Long-term infusions (several hours – days), dilute to less than 25 mcg/mL

Dobutamine (blood pressure support)

- Occasionally used to treat blood pressure, strong regional/individual preferences
- Primarily increases contractility
  - DCM, weak heart muscle
- **Does not reliably increase blood pressure, despite marked increases in CO due to reductions in SVR**
  - Oxygen delivery & perfusion??
- Dose
  - 2-15 mcg/kg/min

Intravenous Infusion - cons

- Requires good understanding of PK & PD
  - Context sensitive half life
- Adds to complexity of anesthesia?
  - Is it necessary, ask why.. what are the alternatives?
    - Analgesia
    - Anesthesia
    - CV support
- Impact on recoveries (prolonged?)

Intravenous Infusion - cons

- Best delivered with programmable syringe driver
  - Cost
- Mixing/diluting into delivery fluids
  - **Do not recommend**, hinders ability to change fluid rate/deliver bolus, acting as compounding pharmacist (interactions, stability etc.)

Syringe Drivers

- https://www.syringepump.com
- https://www.psscientific.com/new-era-infusion-one-ne-300-just-infusion-syringe-pump
- 550 CDN

- https://www.bbraun-vetcare.com/en/products/b11/perfusor-space.html
- 2500 CDN

Dopamine 1600 mcg/ml				**Dopamine 800 mcg/ml**		
Dose	5	7	10	5	7	10
(mcg/kg/min)						
Weight	ml/hr	ml/hr	ml/hr	ml/hr	ml/hr	ml/hr
1	0.19	0.26	0.38	0.38	0.53	0.75
2	0.38	0.53	0.75	0.75	1.05	1.50
3	0.56	0.79	1.13	1.13	1.58	2.25
4	0.75	1.05	1.50	1.50	2.10	3.00
5	0.94	1.31	1.88	1.88	2.63	3.75
6	1.13	1.58	2.25	2.25	3.15	4.50
7	1.31	1.84	2.63	2.63	3.68	5.25
8	1.50	2.10	3.00	3.00	4.20	6.00
9	1.69	2.36	3.38	3.38	4.73	6.75
10	1.88	2.63	3.75	3.75	5.25	7.50
11	2.06	2.89	4.13	4.13	5.78	8.25
12	2.25	3.15	4.50	4.50	6.30	9.00
13	2.44	3.41	4.88	4.88	6.83	9.75
14	2.63	3.68	5.25	5.25	7.35	10.50
15	2.81	3.94	5.63	5.63	7.88	11.25
16	3.00	4.20	6.00	6.00	8.40	12.00
17	3.19	4.46	6.38	6.38	8.93	12.75
18	3.38	4.73	6.75	6.75	9.45	13.50
19	3.56	4.99	7.13	7.13	9.98	14.25
20	3.75	5.25	7.50	7.50	10.50	15.00
21	3.94	5.51	7.88	7.88	11.03	15.75

Practical use issues

- Proper “piggybacking” into primary fluid line
  - T-ports, extension sets, secured (tape, Luer lock ports), labelled
- Inadvertent bolus administration with changing primary fluid rate
- Infusions should be as close to IV catheter as possible, with **vasoactive products in closest port**
- Proper dilution/mixing of drugs
  - Ketamine 10 mg/mL, dexmedetomidine 50 mcg/mL, NE 10-50 mcg/mL
  - Compatibility, interactions, stability etc
  - Errors

Summary

- Continuous intravenous infusion can provide clinical benefit perioperative period
  - Analgesia, inhalant sparing, cardiovascular support
- Patient outcome & appropriate use scenarios, research ongoing
- Pharmacological understanding required
- Dedicated delivery devices are best
- Practical use considerations should be explored

Thank you!

5 Things to Consider Adding to your Anesthetic Toolbox

Craig Mosley DVM, MSc, DACVAA

VCA Canada 404 Veterinary Emergency & Referral Hospital

Thank you

Dechra

Is it time to add a few new tools?

- Zenalpha
- GV 20 Dexmedetomidine
- Acetaminophen
- Sevoflurane
- Low flow anesthesia
- Anesthetic equipment safety monitors
- Ventilator

Zenalpha

- Medetomidine (0.5 mg/ml)
  - Racemic mixture of two enantiomer, active dexmedetomidine & inactive levodexmedetomidine
- Vatinoxan (10 mg/ml)
  - Peripherally selective alpha2 antagonist

- Central effects dexmedetomidine (sedation-analgesia) with minimal peripheral (CV) side-effects

Zenalpha

- Development started over 25 years ago as MK-467 & alpha-2 agonists
- Drug with all positive effects of alpha-2 agonist without negative cardiovascular SE

- **Pagel PS, et al. A novel alpha 2-adrenoceptor antagonist attenuates the early, but preserves the late cardiovascular effects of intravenous dexmedetomidine in conscious dogs. J Cardiothorac Vasc Anesth. 1998 Aug;12(4):429-34.**
- **Enouri SS, Kerr CL, McDonell WN, O'Sullivan ML, Neto FJ. Effects of a peripheral alpha2 adrenergic-receptor antagonist on the hemodynamic changes induced by medetomidine administration in conscious dogs. Am J Vet Res. 2008 Jun;69(6):728-36.**
- **Rolfe NG, Kerr CL, McDonell WN. Cardiopulmonary and sedative effects of the peripheral α2-adrenoceptor antagonist MK 0467 administered intravenously or intramuscularly concurrently with medetomidine in dogs. Am J Vet Res. 2012 May;73(5):587-94.**

Zenalpha Label Use

- Sedation-analgesia for procedural sedation in **dogs IM**
- Dose (chart)
  - 1 mg/m^2 medetomidine (0.5 mg/mL) & 20 mg/m^2 vatinoxan (10 mg/mL)
  - 20 - 80 mcg/kg of medetomidine
  - 10 - 40 mcg/kg of dexmedetomidine
- NOT approved as a premedication prior to general anesthesia
- Atipamezole dose
  - 5 times dose of medetomidine
  - **0.5 mL for 1 mL of Zenalpha**

Zenalpha Extra-label Use

- **My dosing**
  - Base it on desired **dexmedetomidine equivalency**
  - 5 mcg/kg dexmedetomidine or 10 mcg/kg medetomidine (Zenalpha)
  - Volume Zenalpha twice that of dexmedetomine or medetomidine alone
- Administraion IV
  - Several articles use same ratio of drug IV, with at least one using the commercially available product
- Combined with an opioid
  - Good evidence of synergy
  - Combined in same syringe little data??

Does it have a place in your ”toolbox”

- Procedural sedation…
  - Some resistance due to lack of “expected” cardiovascular effects (normo to hypotension, high heart rates)
- **Procedural sedation for patients with MVD**
- Preanesthetic use?
  - CV side-effects of dexmedetomidine preferred to offset inhalant induced vasodilation & hypotension
  - Zenalpha hypotension seems difficult to treat
  - Possible oxygen delivery better with Zenalpha despite hypotension?
    - Is the result from the study clinically relevant!!!

GV 20 Dexmedetomidine

Effects of dexmedetomidine administered at acupuncture point GV20 compared to intramuscular route in dogs.

Pons A, Canfrán S, Benito J, Cediel-Algovia R, Gómez de Segura IA.

J Small Anim Pract. 2017 Jan;58(1):23-28. doi: 10.1111/jsap.12601. Epub 2016 Nov 14.

SQ sedation at Governing Vessel (GV) 20 increases duration & level of sedation compared to IM gluteal

GV 20 Dexmedetomidine

Comparison of sedation with dexmedetomidine/atipamezole administered subcutaneously at GV20 acupuncture point with usual routes of administration in dogs presented for orthopaedic radiographs.

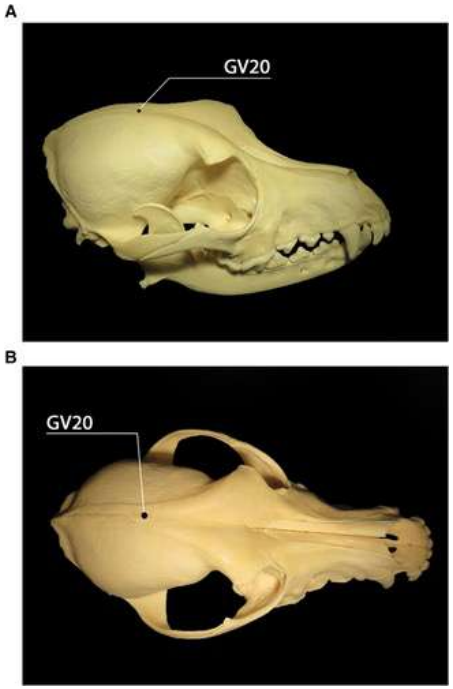
Leriquier C, Freire M, Llido M, Beauchamp G, Montasell X, Gagnon D, Benito J.

J Small Anim Pract. 2023 Dec;64(12):759-768. doi: 10.1111/jsap.13668. Epub 2023 Aug 9.

Use of a novel subcutaneous injection site in the region of acupuncture point GV20 for premedicating cats before general anesthesia.

Solash B, Cheema JS, Freire M, Benito J, Pang DSJ.

Can Vet J. 2025 May;66(5):537-545.

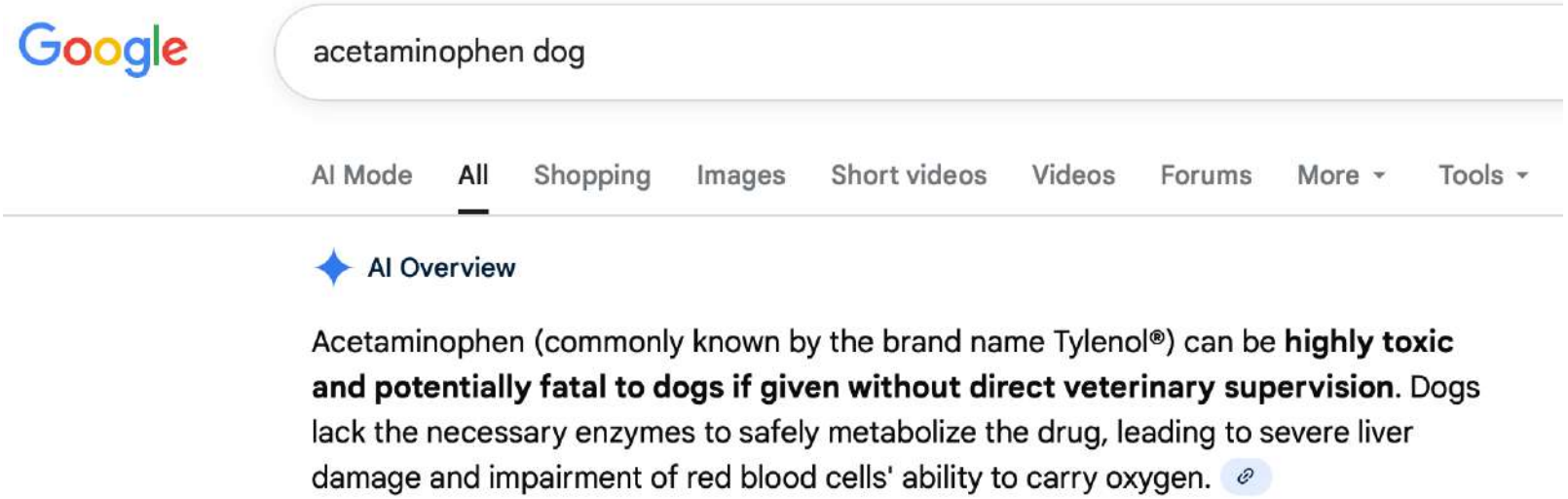


GV 20 Dexmedetomidine

- Clinically effective, easy but…
- Best with small volume
  - 25-22 ga needle
- May be less reactive to injection
- Injection around head/face of patient
  - Patient selection
- Use based upon personal preference

Acetaminophen

- Commonly used safely in Europe (paracetamol)
- Has stigma of toxicity attached to it in North America



Acetaminophen

- Toxic doses
  - dogs > 100 mg/kg, > 200 mg/kg methemoglobinemia
  - humans > 150 mg/kg
    - leading cause of acute liver failure in western society
  - **cats > 10 mg/kg**

- Primarily metabolized by glucuronidation & sulfation, lesser extent Cytochrome P450
- **Cats significantly reduced ability for glucuronidation**
- **Acetaminophen should <u>not</u> be used in cats**

Acetaminophen

- Non opioid analgesic & antipyretic
- Mainly acts on brain & spinal cord via..
- **Metabolite AM404, actions in cannabinoid system, potent activator of TRPV1 receptor**
- Dose - dogs & humans – 10-15 mg/kg (TID to BID)

Acetaminophen

- Option in NSAID intolerant patients
- Used concurrently with NSAID
- Extra-label
- Many formulations
- **Watch for additives i.e. xylitol**

Sevoflurane – Why Switch?

- Clinical use very comparable to isoflurane
  - Cardiopulmonary effects similar

- Faster mask inductions, anesthetic plane changes, quicker recoveries
  - Clinical significance?

- **Lower environmental impact**

Switching to sevoflurane

Physical characteristics of anesthetic gases in the atmosphere

AGENT	GWP_{100}	ATMOSPHERIC LIFETIME (YEARS)	MAC IN DOGS (%)
Isoflurane	510	3.2	1.3
Sevoflurane	130	1.1	2.3
Nitrous oxide	265	110	~235
Carbon dioxide	1	74	n/a

GWP_{100} – Global warming potential over 100 years; MAC – Minimum alveolar concentration

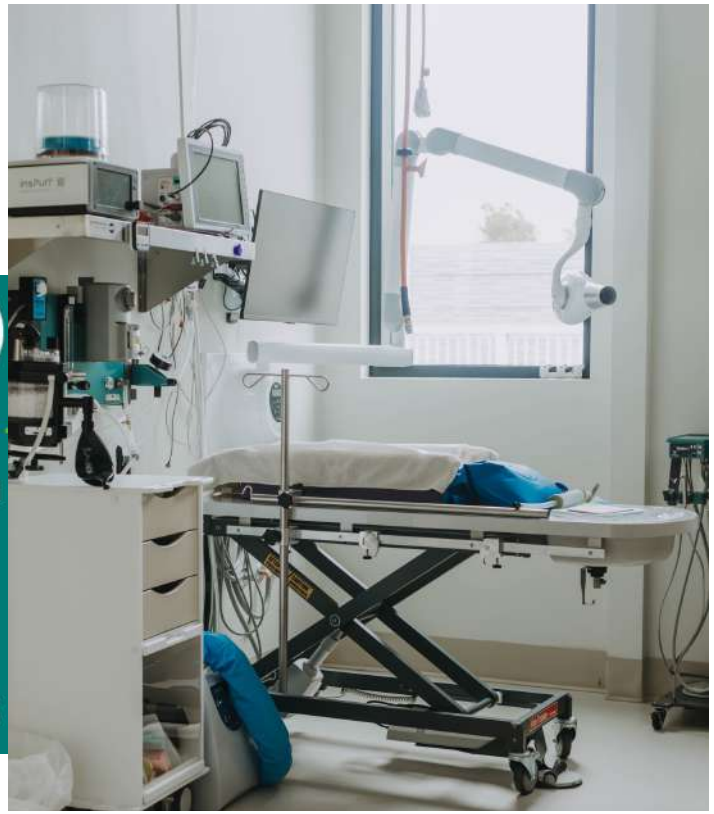
Switching to sevoflurane

- Reduce GWP by about 50%
- Expensive (relative to isoflurane):
  - $64 vs $20 for 250 mL bottle & use 2x as much
  - Cost can be offset by adopting low flow anesthetic techniques
- Requires purchase of agent specific vaporizer

Compound A production (low flow anesthesia)

- Result of interaction with strong base in carbon dioxide absorbents
- Thought to be potential nephrotoxin but….
  - No clinical evidence of toxicity in humans or animals
- Label in several countries recommend min FGF (> 2 L/min)
- **Concern largely mitigated using CO2 absorbents with no or minimal (<2.5%) strong base (KOH & NaOH)**

Does it have a place in your toolbox



Why low flow anesthesia?

- Most oxygen is wasted or unused by the patient
  - 90-98% – (50 – 200 ml/kg/min)
  - Metabolic oxygen consumption is only 3-5 ml/kg/min
  - No harmful environmental effects but oxygen costs $
- Most inhalant is released unchanged
  - 95-98.8% (sevoflurane,isoflurane)
  - Modern insoluble anesthetics are minimally metabolized
  - Harmful environmental effects & costs $
- Will decrease your green house gas contribution proportionately

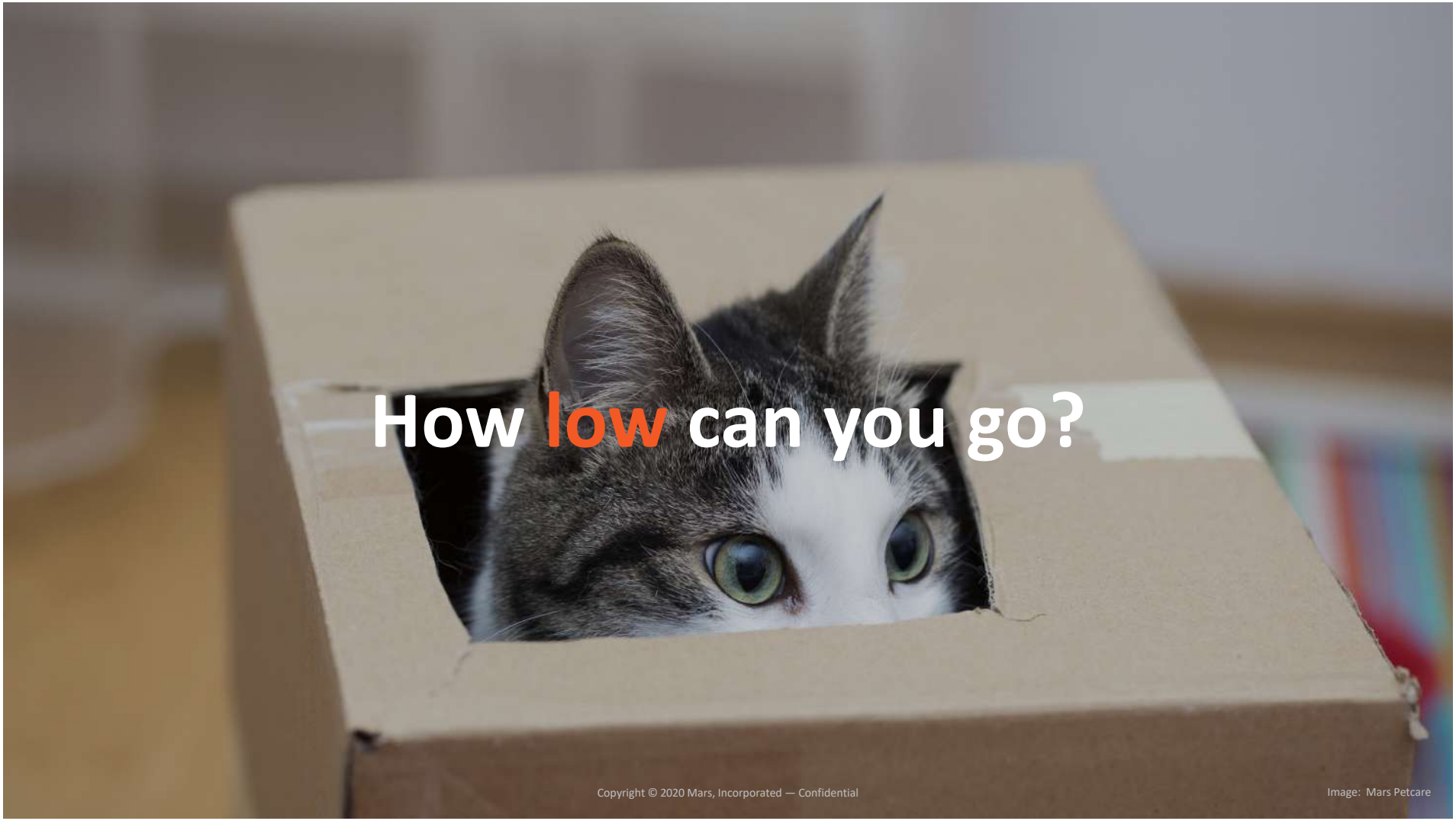


Image: Mars Petcare

Purpose of fresh gas flows (FGF)

- Sufficient **oxygen delivery**
  - Metabolic oxygen consumption 3-5 ml/kg/min

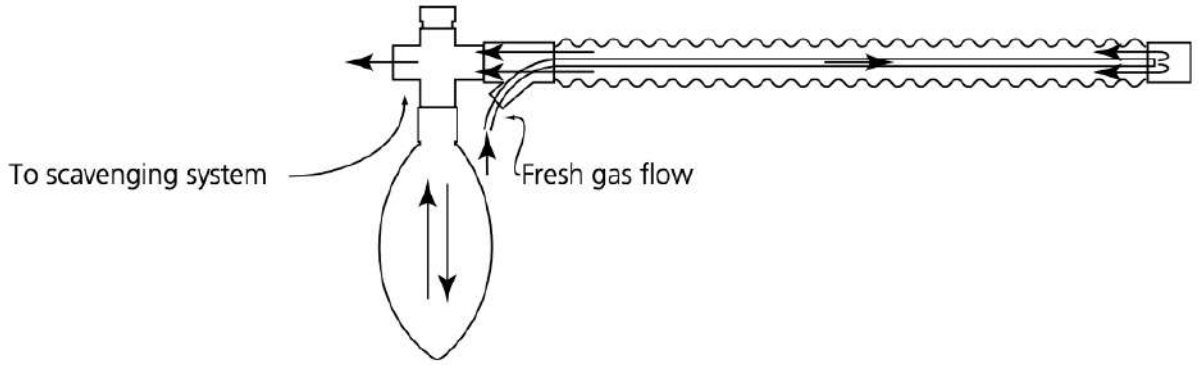
- **Inhalant gas** carrier
  - Higher flow rates more gas delivery

- Prevent rebreathing of CO2 (non-rebreathing system only)
  - Non-rebreathing - **flow dependent**
  - Bain, Ayre's T-piece, Jackson Rees etc..

Lowering fresh gas flows

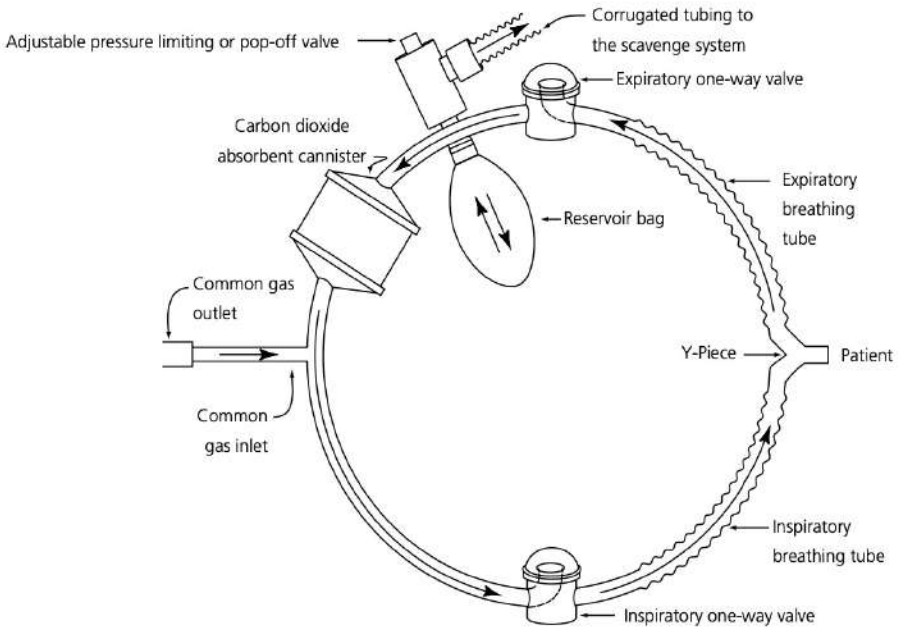
- **DO NOT recommend low flow anesthetic delivery when using a non-rebreathing system (i.e. Bain)**

Bain with Bain Mount and APL
(Mapleson D type configuration-coaxial)



Rebreathing system

- **Flow independent**
  - Rebreathing CO2 through **removal of CO2**
    - Unidirectional flow
    - CO2 absorbent
- Lowering FGF safe but..
  - Impacts oxygen & inhalant delivery



Circle system

Lowering fresh gas flow – Considerations

Insufficient depth

- Probably most significant risk, due to reduced gas delivery
  - Greater dilution of delivered gas
  - Slower time to effect when vaporizer changes are made

Overcome by

- Using higher initial vaporizer settings
- Increasing fresh gas flow when initiating changes in anesthetic depth

Min FGF – 0.5 L/min

My General Approach

- 1 L/min for first 15 min, then 0.5 L/min
- Do not normally adjust FGF for patient size, do not routinely adjust FGF based on patient size
  - Low flow (20-50 mL/kg/min)
  - 1 L/min for 20 kg patient is arguably low flow

- However consider consequences in various patient sizes
- 5 kg - 100 mL/kg/min
- 40 kg - 12 mL/kg/min

Low Flow Simulators

- ASPF simulator
  - https://www.apsf.org/apsf-technology-education-initiative/low-flow-anesthesia/

- GasMan simulator
  - https://www.gasmanweb.com

Anesthetic equipment safety monitors

- High airway pressure alarm
- Momentary closure, auto release popoff valves

Anesthetic equipment safety monitors

- High airway pressure alarm
- Momentary closure, auto release popoff valves

Why a ventilator?

- Facilitates smooth inhalant anesthetic delivery
  - Better depth control, more consistent anesthetic plane
- Allows easy & full control of CO2 levels ($ETCO_2$)
- Convenience
  - Free's up resources when ventilation is required/indicated
  - Limits distractions
  - May reduce potential for errors (i.e. closed pop-off)

Indications for Ventilation (absolute)

- CNS disease
  - Impaired ability to initiate respiration
- Neuromuscular disease or paralysis
  - Impaired respiratory muscle function (i.e. coon-hound paralysis)
  - Use of neuromuscular blocking agents
- Impaired respiratory mechanics
  - Loss of pleural negative pressure (i.e. open chest)

Indications for Ventilation (relative)

- Laparoscopy
  - Restriction of ventilation
  - Increased CO2 absorption
- Pulmonary disease
  - Improves gas delivery to entire lung
- **Unstable anesthetic depth**
  - Ventilation will ensure consistent & reliable delivery of anesthetic
- **Convenience**
  - Intermittent intrinsic respiratory pattern

Precautions for Ventilation

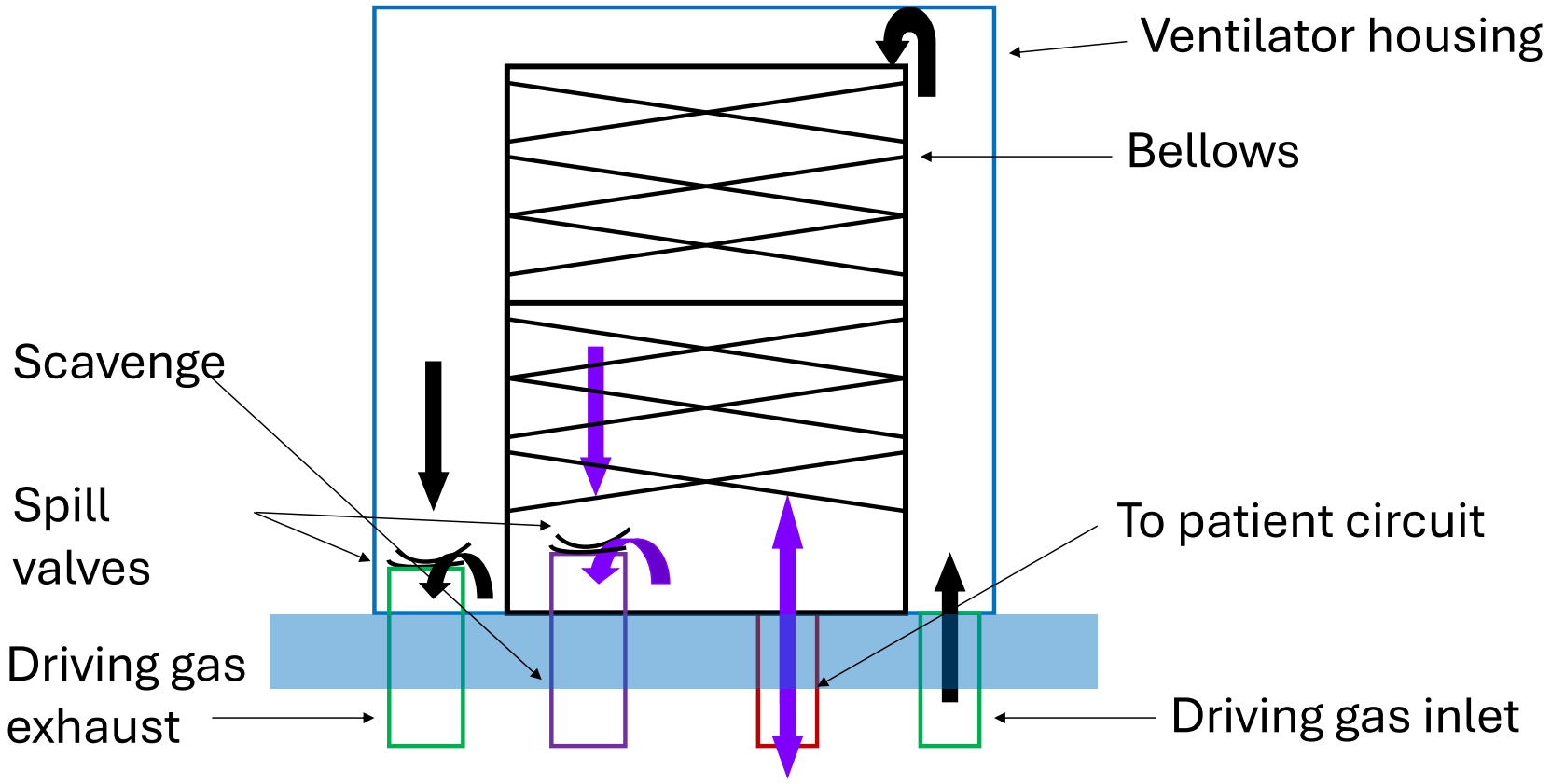
- Contraindications
  - Tension pneumothorax
  - Pre-existing pulmonary bullae (use caution)
  - Recent pulmonary trauma?
- Hypovolemia/hypotension?
  - PPV may contribute to hypotension

What Are Ventilators?

- Replace rebreathing bag, pop-off valve & your hands during IPPV
  - “Bag in a box”

- Most anesthesia ventilators operate based on same principle…
- Gas delivered into bellow housing at specific **rate** & **duration** to compress bellow, with variable duration **pause** between each cycle
  - Tidal volume, inspiratory time, expiratory time, respiratory rate

Ventilator (Schematic)



Practical Operation

- Most ventilators ultimately adjust primary variables
  - Inspiratory flow rate
  - Inspiratory time
  - Expiratory time

- Using respiratory rate, tidal volume & inspiratory:expiratory ratio
- **Adjustment in one variable may affects others**
  - Reducing respiratory rate may increase tidal volume
- Those with microprocessors can compensate for these changes

Dog & Cat

- Guideline values
  - V_T - 10-20 ml/kg
  - RR – 10-15 bpm
  - I:E - 1:2
  - **Peak airway pressure (PAP) < 20 cmH_20 (10-15 ideal)**
  - ETCO2 ~ 40-50 mmHg

  - Some ventilator will have V_E (minute volume rather than tidal volume
  - $V_E = V_T$ x RR

Practical Operation

- Calculate values
- Connect ventilator
  - Power source, driving gas, scavenge, hose to circuit (re-breathing bag), close “pop-off”
- Set calculated RR & I:E
- Set lower than anticipated V_T or V_E
  - Prevents accidental barotrauma
- **Evaluate airway pressures closely during initial set up & re-evaluate frequently particularly after changing settings**
- If any concerns use manual ventilation

Classification

- Power source
  - Compressed gas (Bird ventilator) vs **electronic**
- Drive mechanism
  - **Pneumatic** (compressed gas/turbine) vs mechanical (piston)

Turbine Driven

- Does not require compressed gas source
  - Cost saving, ease of setup
- Quieter

Classification

- Power source
  - Compressed gas (Bird ventilator) vs **electronic**
- Drive mechanism
  - **Pneumatic** (compressed gas/turbine) vs mechanical (piston)
- Cycling mechanism
  - Time vs **pressure vs volume**

- Function similarly with minor differences (i.e. method of adjustment) & features (i.e. spirometry, oxygen sensors, alarms)

Potentiator Adjusted

Electronically Adjusted

Complications

- High airway pressures (excess V_T)
  - Improperly connected, patient disease (pulmonary edema, tension pneumothorax)
  - Can lead to lung injury & death if extreme
- Hypotension
  - Positive pressure may compromise CO, impedes flow through lungs
  - Esp hypovolemic patients, when using high airway pressures
- Ineffective ventilation
  - Patient is too small (lower limit is ~ 50-100 ml)
  - Severe respiratory disease, manual delivery may be desirable

Does it have a place in your toolbox?

- Added level of convenience & control
- User friendly options available
- Up front costs significant but long-term usability/functionality
- Definitely not out of reach for the average progressive practice

Thank you!

1

Thank you

Dechra

2

Is it time to add a few new tools?

- Zenalpha
- GV 20 Dexmedetomidine
- Acetaminophen
- Sevoflurane
- Low flow anesthesia
- Anesthetic equipment safety monitors
- Ventilator

3

Zenalpha

- Medetomidine (0.5 mg/ml)
  - Racemic mixture of two enantiomer, active dexmedetomidine & inactive levodexmedetomidine
- Vatinoxan (10 mg/ml)
  - Peripherally selective alpha2 antagonist
- Central effects dexmedetomidine (sedation-analgesia) with minimal peripheral (CV) side-effects

4

Zenalpha

- Development started over 25 years ago as MK-467 & alpha-2 agonists
- Drug with all positive effects of alpha-2 agonist without negative cardiovascular SE

- **Pagel PS, et al. A novel alpha 2-adrenoceptor antagonist attenuates the early, but preserves the late cardiovascular effects of intravenous dexmedetomidine in conscious dogs. J Cardiothorac Vasc Anesth. 1998 Aug;12(4):429-34.**
- **Enouri SS, Kerr CL, McDonell WN, O'Sullivan ML, Neto FJ. Effects of a peripheral alpha2 adrenergic-receptor antagonist on the hemodynamic changes induced by medetomidine administration in conscious dogs. Am J Vet Res. 2008 Jun;69(6):728-36.**
- **Rolfe NG, Kerr CL, McDonell WN. Cardiopulmonary and sedative effects of the peripheral α2-adrenoceptor antagonist MK 0467 administered intravenously or intramuscularly concurrently with medetomidine in dogs. Am J Vet Res. 2012 May;73(5):587-94.**

5

Zenalpha Label Use

- Sedation-analgesia for procedural sedation in **dogs IM**
- Dose (chart)
  - 1 mg/m^2 medetomidine (0.5 mg/mL) & 20 mg/m^2 vatinoxan (10 mg/mL)
  - 20 - 80 mcg/kg of medetomidine
  - 10 - 40 mcg/kg of dexmedetomidine
- NOT approved as a premedication prior to general anesthesia
- Atipamezole dose
  - 5 times dose of medetomidine
  - **0.5 mL for 1 mL of Zenalpha**

6

Zenalpha Extra-label Use

- **My dosing**
  - Base it on desired **dexmedetomidine equivalency**
  - 5 mcg/kg dexmedetomidine or 10 mcg/kg medetomidine (Zenalpha)
  - Volume Zenalpha twice that of dexmedetomine or medetomidine alone
- Administraion IV
  - Several articles use same ratio of drug IV, with at least one using the commercially available product
- Combined with an opioid
  - Good evidence of synergy
  - Combined in same syringe little data??

7

Does it have a place in your "toolbox"

- Procedural sedation…
  - Some resistance due to lack of "expected" cardiovascular effects (normo to hypotension, high heart rates)
- **Procedural sedation for patients with MVD**
- Preanesthetic use?
  - CV side-effects of dexmedetomidine preferred to offset inhalant induced vasodilation & hypotension
  - Zenalpha hypotension seems difficult to treat
  - Possible oxygen delivery better with Zenalpha despite hypotension?
    - Is the result from the study clinically relevant!!!

8

GV 20 Dexmedetomidine

Effects of dexmedetomidine administered at acupuncture point GV20 compared to intramuscular route in dogs.

Pons A, Canfrán S, Benito J, Cediel-Algovia R, Gómez de Segura IA.

J Small Anim Pract. 2017 Jan;58(1):23-28. doi: 10.1111/jsap.12601. Epub 2016 Nov 14.

SQ sedation at Governing Vessel (GV) 20 increases duration & level of sedation compared to IM gluteal

9

GV 20 Dexmedetomidine

Comparison of sedation with dexmedetomidine/alfaxalone administered subcutaneously at GV20 acupuncture point with usual routes of administration in dogs presented for orthopaedic radiographs.

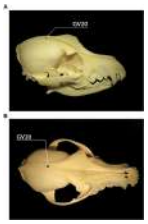
Leriquier C, Freire M, Lédo M, Beauchamp G, Monteiro X, Gagnon D, Benito J.

J Small Anim Pract. 2023 Dec;64(12):759-768. doi: 10.1111/jsap.13668. Epub 2023 Aug 9.

Use of a novel subcutaneous injection site in the region of acupuncture point GV20 for premedicating cats before general anesthesia.

Sulesh B, Cheema JS, Freire M, Benito J, Fang DSJ.

Can Vet J. 2025 May;66(5):537-545.



10

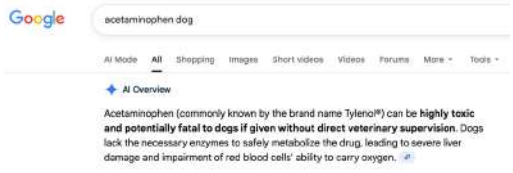
GV 20 Dexmedetomidine

- Clinically effective, easy but…
- Best with small volume
  - 25-22 ga needle
- May be less reactive to injection
- Injection around head/face of patient
  - Patient selection
- Use based upon personal preference

11

Acetaminophen

- Commonly used safely in Europe (paracetamol)
- Has stigma of toxicity attached to it in North America



12

Acetaminophen

- Toxic doses
  - dogs > 100 mg/kg, > 200 mg/kg methemoglobinemia
  - humans > 150 mg/kg
    - leading cause of acute liver failure in western society
  - **cats > 10 mg/kg**
- Primarily metabolized by glucuronidation & sulfation, lesser extent Cytochrome P450
- **Cats significantly reduced ability for glucuronidation**
- **Acetaminophen should <u>not</u> be used in cats**

13

Acetaminophen

- Non opioid analgesic & antipyretic
- Mainly acts on brain & spinal cord via..
- **Metabolite AM404, actions in cannabinoid system, potent activator of TRPV1 receptor**
- Dose - dogs & humans – 10-15 mg/kg (TID to BID)

14

Acetaminophen

- Option in NSAID intolerant patients
- Used concurrently with NSAID
- Extra-label
- Many formulations
- **Watch for additives i.e. xylitol**

15

Sevoflurane – Why Switch?

- Clinical use very comparable to isoflurane
  - Cardiopulmonary effects similar
- Faster mask inductions, anesthetic plane changes, quicker recoveries
  - Clinical significance?
- **Lower environmental impact**

16

Switching to sevoflurane

Physical characteristics of anesthetic gases in the atmosphere

AGENT	GWP_{100}	ATMOSPHERIC LIFETIME (YEARS)	MAC IN DOGS (%)
Isoflurane	510	3.2	1.3
Sevoflurane	130	1.1	2.3
Nitrous oxide	265	110	~235
Carbon dioxide	1	74	n/a

GWP_{100} – Global warming potential over 100 years; MAC – Minimum alveolar concentration

18

Switching to sevoflurane

- Reduce GWP by about 50%
- Expensive (relative to isoflurane):
  - $64 vs $20 for 250 mL bottle & use 2x as much
  - Cost can be offset by adopting low flow anesthetic techniques
- Requires purchase of agent specific vaporizer

19

Compound A production (low flow anesthesia)

- Result of interaction with strong base in carbon dioxide absorbents
- Thought to be potential nephrotoxin but….
  - No clinical evidence of toxicity in humans or animals
- Label in several countries recommend min FGF (> 2 L/min)
- **Concern largely mitigated using CO2 absorbents with no or minimal (<2.5%) strong base (KOH & NaOH)**

20

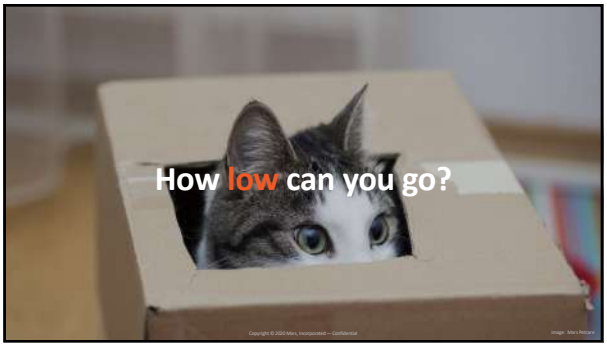
Does it have a place in your toolbox

21

Why low flow anesthesia?

- Most oxygen is wasted or unused by the patient
  - 90-98% – (50 – 200 ml/kg/min)
  - Metabolic oxygen consumption is only 3-5 ml/kg/min
  - No harmful environmental effects but oxygen costs $
- Most inhalant is released unchanged
  - 95-98.8% (sevoflurane,isoflurane)
  - Modern insoluble anesthetics are minimally metabolized
  - Harmful environmental effects & costs $
- Will decrease your green house gas contribution proportionately

22



23

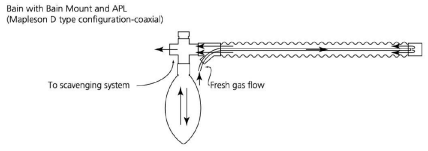
Purpose of fresh gas flows (FGF)

- Sufficient **oxygen delivery**
  - Metabolic oxygen consumption 3-5 ml/kg/min
- **Inhalant gas** carrier
  - Higher flow rates more gas delivery
- Prevent rebreathing of CO2 (non-rebreathing system only)
  - Non-rebreathing - **flow dependent**
  - Bain, Ayre's T-piece, Jackson Rees etc..

24

Lowering fresh gas flows

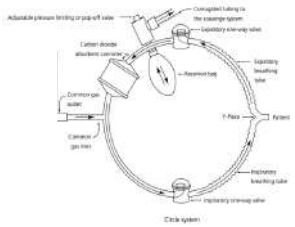
- **DO NOT recommend low flow anesthetic delivery when using a non-rebreathing system (i.e. Bain)**



25

Rebreathing system

- **Flow independent**
  - Rebreathing CO2 through **removal of CO2**
    - Unidirectional flow
    - CO2 absorbent
- Lowering FGF safe but..
  - Impacts oxygen & inhalant delivery



28

Lowering fresh gas flow – Considerations

Insufficient depth

- Probably most significant risk, due to reduced gas delivery
  - Greater dilution of delivered gas
  - Slower time to effect when vaporizer changes are made

Overcome by

- Using higher initial vaporizer settings
- Increasing fresh gas flow when initiating changes in anesthetic depth

Min FGF – 0.5 L/min

30

My General Approach

- 1 L/min for first 15 min, then 0.5 L/min
- Do not normally adjust FGF for patient size, do not routinely adjust FGF based on patient size
  - Low flow (20-50 mL/kg/min)
  - 1 L/min for 20 kg patient is arguably low flow
- However consider consequences in various patient sizes
- 5 kg - 100 mL/kg/min
- 40 kg - 12 mL/kg/min

31

Low Flow Simulators

- ASPF simulator
  - https://www.apsf.org/apsf-technology-education-initiative/low-flow-anesthesia/
- GasMan simulator
  - https://www.gasmanweb.com

32

Anesthetic equipment safety monitors

- High airway pressure alarm
- Momentary closure, auto release popoff valves

33

Anesthetic equipment safety monitors

- High airway pressure alarm
- Momentary closure, auto release popoff valves

34

Why a ventilator?

- Facilitates smooth inhalant anesthetic delivery
  - Better depth control, more consistent anesthetic plane
- Allows easy & full control of CO2 levels ($ETCO_2$)
- Convenience
  - Free's up resources when ventilation is required/indicated
  - Limits distractions
  - May reduce potential for errors (i.e. closed pop-off)

35

Indications for Ventilation (absolute)

- CNS disease
  - Impaired ability to initiate respiration
- Neuromuscular disease or paralysis
  - Impaired respiratory muscle function (i.e. coon-hound paralysis)
  - Use of neuromuscular blocking agents
- Impaired respiratory mechanics
  - Loss of pleural negative pressure (i.e. open chest)

36

Indications for Ventilation (relative)

- Laparoscopy
  - Restriction of ventilation
  - Increased CO2 absorption
- Pulmonary disease
  - Improves gas delivery to entire lung
- **Unstable anesthetic depth**
  - Ventilation will ensure consistent & reliable delivery of anesthetic
- **Convenience**
  - Intermittent intrinsic respiratory pattern

37

Precautions for Ventilation

- Contraindications
  - Tension pneumothorax
  - Pre-existing pulmonary bullae (use caution)
  - Recent pulmonary trauma?
- Hypovolemia/hypotension?
  - PPV may contribute to hypotension

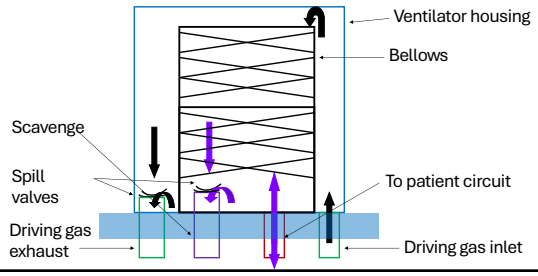
38

What Are Ventilators?

- Replace rebreathing bag, pop-off valve & your hands during IPPV
  - "Bag in a box"
- Most anesthesia ventilators operate based on same principle…
- Gas delivered into bellow housing at specific **rate** & **duration** to compress bellow, with variable duration **pause** between each cycle
  - Tidal volume, inspiratory time, expiratory time, respiratory rate

39

Ventilator (Schematic)



45

Practical Operation

- Most ventilators ultimately adjust primary variables
  - Inspiratory flow rate
  - Inspiratory time
  - Expiratory time
- Using respiratory rate, tidal volume & inspiratory:expiratory ratio
- **Adjustment in one variable may affects others**
  - Reducing respiratory rate may increase tidal volume
- Those with microprocessors can compensate for these changes

47

Dog & Cat

- Guideline values
  - V_T - 10-20 ml/kg
  - RR – 10-15 bpm
  - I:E - 1:2
  - **Peak airway pressure (PAP) < 20 cmH_20 (10-15 ideal)**
  - ETCO2 ~ 40-50 mmHg
  - Some ventilator will have V_E (minute volume rather than tidal volume
  - $V_E = V_T$ x RR

48

Practical Operation

- Calculate values
- Connect ventilator
  - Power source, driving gas, scavenge, hose to circuit (re-breathing bag), close "pop-off"
- Set calculated RR & I:E
- Set lower than anticipated V_T or V_E
  - Prevents accidental barotrauma
- **Evaluate airway pressures closely during initial set up & re-evaluate frequently particularly after changing settings**
- If any concerns use manual ventilation

49

Classification

- Power source
  - Compressed gas (Bird ventilator) vs **electronic**
- Drive mechanism
  - **Pneumatic** (compressed gas/turbine) vs mechanical (piston)

53

Turbine Driven

- Does not require compressed gas source
  - Cost saving, ease of setup
- Quieter

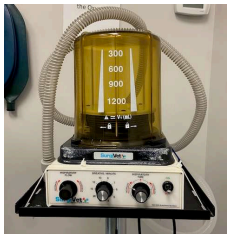
54

Classification

- Power source
  - Compressed gas (Bird ventilator) vs **electronic**
- Drive mechanism
  - **Pneumatic** (compressed gas/turbine) vs mechanical (piston)
- Cycling mechanism
  - Time vs **pressure vs volume**
- Function similarly with minor differences (i.e. method of adjustment) & features (i.e. spirometry, oxygen sensors, alarms)

55

Potentiator Adjusted



56

Electronically Adjusted

57

Complications

- High airway pressures (excess V_T)
  - Improperly connected, patient disease (pulmonary edema, tension pneumothorax)
  - Can lead to lung injury & death if extreme
- Hypotension
  - Positive pressure may compromise CO, impedes flow through lungs
  - Esp hypovolemic patients, when using high airway pressures
- Ineffective ventilation
  - Patient is too small (lower limit is ~ 50-100 ml)
  - Severe respiratory disease, manual delivery may be desirable

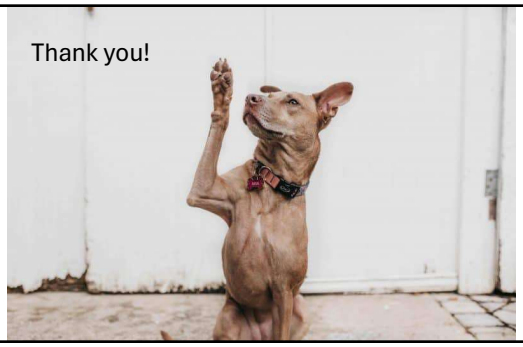
58

Does it have a place in your toolbox?

- Added level of convenience & control
- User friendly options available
- Up front costs significant but long-term usability/functionality
- Definitely not out of reach for the average progressive practice

59

Thank you!



61

Anesthesia for Commonly Presented Dental Patients

Craig Mosley DVM, MSc, DACVAA

VCA Canada 404 Veterinary Emergency & Referral Hospital

Thank you

Dechra

”Typical” Dental Patient

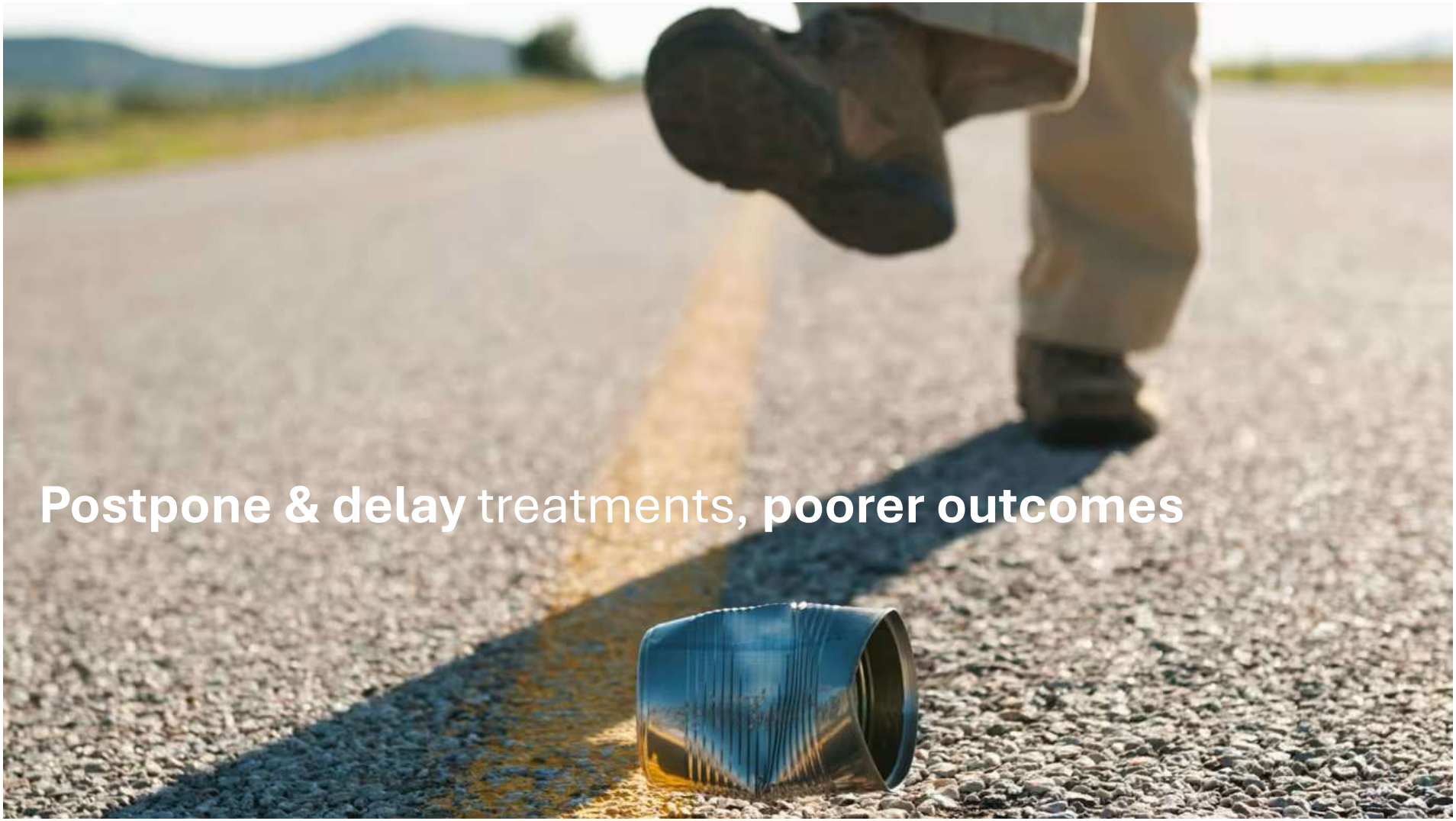
- Geriatrics (42-52% of dog population >7yrs)
  - Decline in organ function or reserve, “elderly normal”
- Patients with comorbid conditions
  - Cardiovascular, renal, respiratory
- Longer procedures

Goals

- Postponing dental care is detrimental
- Clinical decision making is hard but…
  - Common things are common
- Simple, yet informed approaches are safe & effective
- Build confidence & ability managing complex cases

Geriatrics & Anesthesia

- **Greater risk of anesthetic** morbidity & mortality
  - Decline in organ function or reserve
  - Less able to respond to stress of surgery/anesthesia
- **Age-related concurrent disease**
  - **Main cause of increased mortality in geriatric humans**


Postpone & delay treatments, **poorer outcomes**


Today is Worse than
Yesterday
But
Better than
Tomorrow.

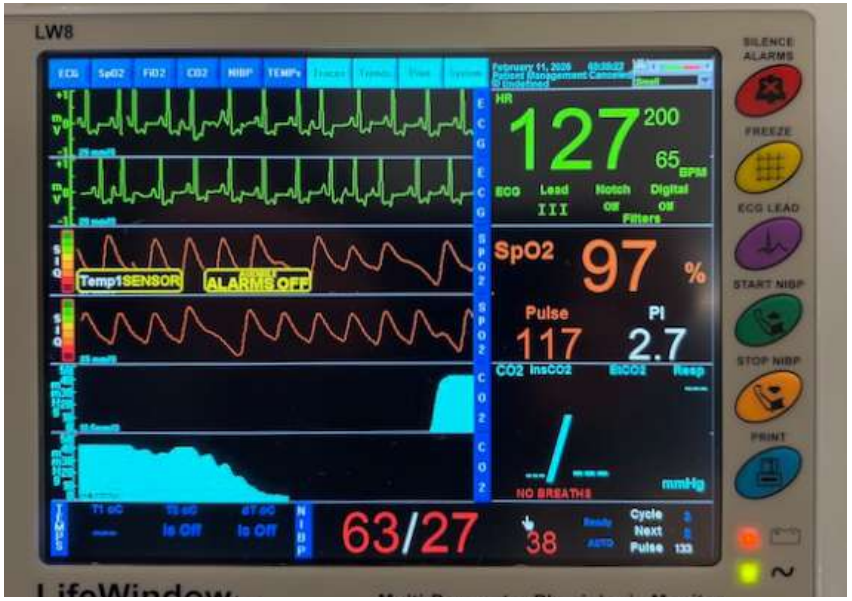
Geriatrics & Anesthesia

- **Greater risk of anesthetic** morbidity & mortality
- **Predictable physiologic changes**
- **Early intervention might help stabilize & mitigate concurrent disease**

Physiological Changes

May not be directly correlated with chronological age

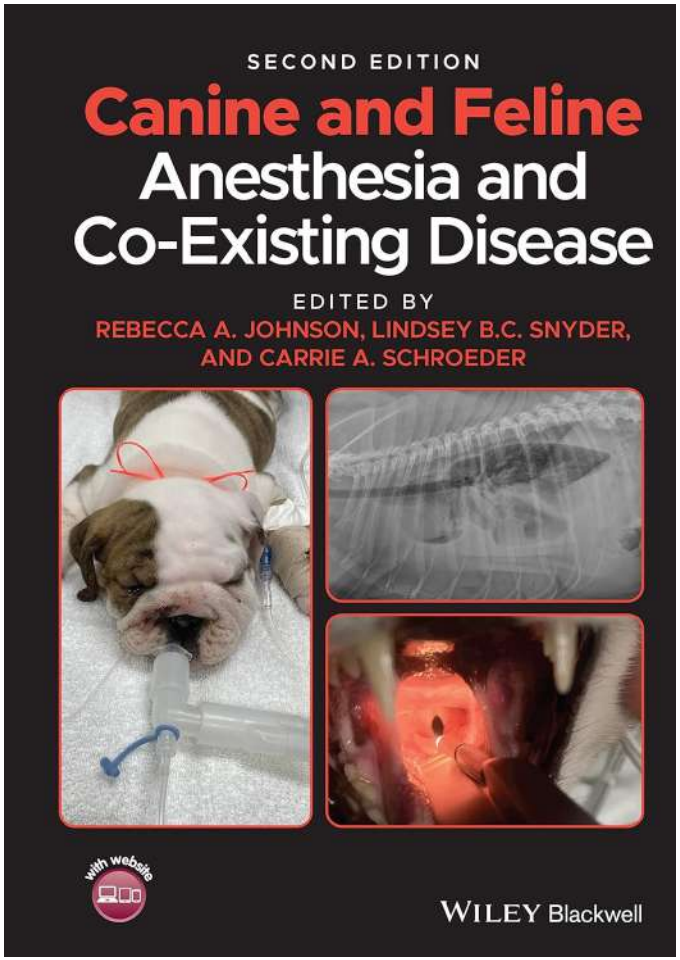
- Cardiovascular – arrhythmias, hypotension
- Respiratory – hypoxia, hypercarbia, apnea
- Renal – less reserve, less tolerant of hypovolemia & dehydration
- Hepatic – qualitatively normal, body composition alters distribution of drugs
- CNS – more sensitive to sedatives & anesthetics
- General considerations - hypothermia, patient positioning, pain


LW8
HR
127
200
65
BPM
ECG
Lead
III
Notch
Off
Digital
Filters
Off
SpO2
97
%
Pulse
117
PI
2.7
CO2
insCO2
EtCO2
Resp
NO BREATHS
mmHg
Temp1SENSOR
ALARMS OFF
63/27
38
Cycle
Next
Pulse
133
SILENCE ALARMS
FREEZE
ECG LEAD
START NIBP
STOP NIBP
PRINT

Geriatric Anesthesia

- More susceptible to anesthetic induced cardiopulmonary depression
  - More support required (blood pressure, arrhythmia, respiratory depression, thermoregulation etc)
- Greater & more prolonged effects, lower doses
  - Proper planning & knowledge, more important than specific drug
- Co-existing conditions
  - Greater attention to detail
  - Prepared to manage & optimize based on specific co-existing condition

Anesthesia and Coexisting Conditions



“Heart Disease”

- Incidental heart murmur, most common presenting feature
- Arrhythmias, dyspnea, syncope – far less common

- Refer to cardiologist for complete cardiac work up


Welcome To
THE REAL WORLD
POPULATION:
EVERYONE BUT YOU

Clinical Decision Making

- Every clinical decision has implications
- Maximize benefit & minimize cost
  - Forget “gold standard” thinking, embrace spectrum of care options
  - Think holistically, think value-based
- Too often decisions in veterinary medicine are made with an emphasis on minimizing risk (based on “belief”)
  - Impossible to minimize risk to zero & every decision has its own inherent risks
- **Should be guided by evidence & be patient/client centered**

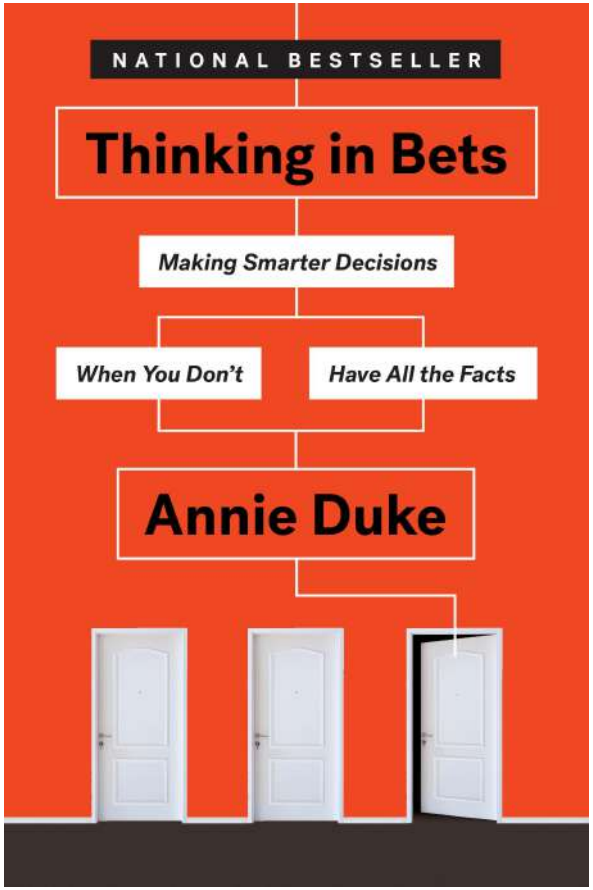
Risk based decision making

- Routine bloodwork on all patients prior to anesthesia
  - No evidence, costs, 95% CI
- Bloodwork on all patients prior to NSAID administration
  - No evidence, costs, risk withholding care
- CT on all patients prior to exploratory laparotomy
  - Costs, risk of V.O.M.I.T., probability (will it change diagnosis)
- Echocardiogram on all patients with a heart murmur
  - Costs, limited resource, probability (will it change diagnosis)

Thinking in Bets

Probabilistic & Strategic Thinking

- Most small dogs with new murmurs
  - **MVD**
- Most large dogs with new murmurs
  - Unknown, breed, arrhythmias, clinical signs, echo
- Most cats
  - **HCM or DRVOTO**
  - Anesthetic management unlikely to change



Management of incidentally detected heart murmurs in dogs and cats

Etienne Côté, DVM; N. Joel Edwards, DVM; Stephen J. Ettinger, DVM; Virginia Luis Fuentes, VetMB, PhD; Kristin A. MacDonald, DVM, PhD; Brian A. Scansen, DVM, MS; D. David Sisson, DVM; Jonathan A. Abbott, DVM

JAVMA, Vol 246, No. 10, May 15, 2015

- Value of additional testing/workup
  - 10 yr, min poodle, 3/6 murmur, no other clinical signs
  - 7 yr, GSD, 3/6 murmur, “lazy”
  - 14 yr, DSH, 2/6 murmur, no other clinical signs
  - 14 yr, DSH, 3/6 murmur, gallop rhythm, thyroid nodule, weight loss

Summary/Suggestions (Dogs)

- Diastolic, continuous, accompanied other abnormal heart sound or arrhythmia **– recommend echo**
- Puppies soft murmur (1-2), likely innocent/functional, insignificant
- Small breed <20 kg, normal heart size & absence of clinical signs, insignificant MVD, **consider serial thoracic rads**
- Large breed >20 kg, specific diagnosis difficult with auscultation & rads alone **– recommend echo**

Summary/Suggestions (Cats)

- If greater than 4/6, diastolic, continuous, arrhythmia or gallop – **recommend echo**

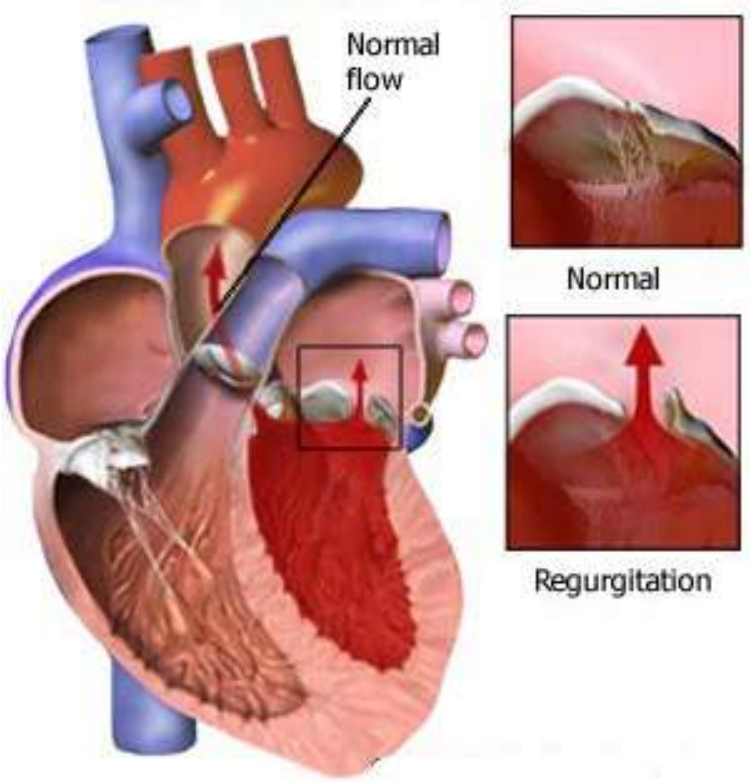
- Grade 1/3 – 3/6 systolic, underlying cause & clinical significance not easily predicted from auscultation alone (most either HCM or DRVOTO)
  - Consider ABP
  - Thyroid assessment
  - Measure NT-BNP (low value clinically significant cardiomyopathy unlikely)
  - Radiographs limited sensitivity
- **Consider echo**

Mitral Valve Disease

- Small breed <20 kg with incidental heart murmur
- Thoracic rads - normal heart size & no clinical signs
  - Insignificant MVD

- Monitor with serial thoracic radiographs
- Consider referral to cardiologist
  - Owner preference

Mitral Valve Disease



Hemodynamic Goals

- Minimize regurgitation of blood & maintain forward flow (SV & CO)
  - Normal to slightly ↑ heart rate
  - Avoid drugs that will ↑ SVR (afterload)
    - Increase regurgitant fraction
    - Directly decreases cardiac output
  - Maintain preload
    - Optimal ventricular filling during diastole
  - Optimize contractility

Premedication Options

- None
- Opioid alone
- Benzodiazepine (midazolam) + opioid
- Acepromazine + opioid
- Dexmedetomidine + opioid

Acepromazine + opioid

- Predictable sedation, anti-arrhythmic, anesthetic sparing, reduces SVR (hypotension)
  - Afterload reduction desirable for managing MMVD (ACE inhibitors)
- Use **cautiously in hypovolemic/dehydrated patients**
  - Those relying on vasoconstriction for maintaining blood pressure
- Prepared to manage & support hypotension with **dopamine**
- Low dose can improve recovery

Dexmedetomidine + opioid

- Very predictable sedation, arrhythmogenic, anesthetic sparing
- Increases SVR, bradycardia & reduces CO
  - Exactly what you don't want to do!!
- Very poor choice "contra-indicated"

Premedication Options

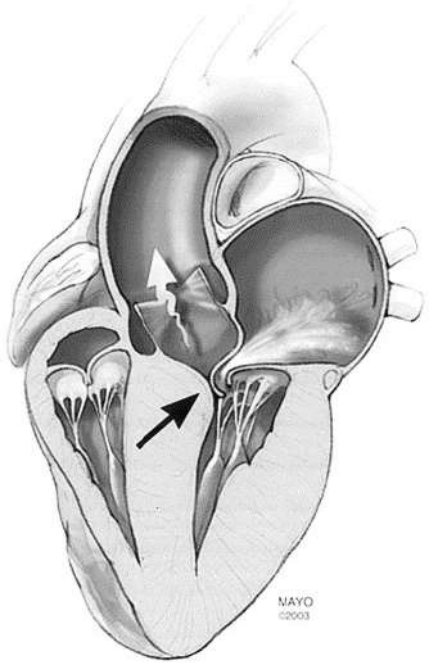
- None
- Opioid alone
- Benzodiazepine (midazolam) + opioid
- Acepromazine + opioid
  - 0.01-0.02 mg/kg IM
- Dexmedetomidine + opioid

Hypertrophic Cardiomyopathy (HCM)

- Middle age cat +- spicy
- New or pre-existing systolic murmur, no rhythm disturbance, no gallop
- Presumptive diagnosis HCM or DRVOTO (physiologic)
  - R/O hyperthyroidism, anemia, hypertension
  - Restrictive uncommon – unlikely to impact anesthetic selection/management
- Referral to cardiologist
  - Owner preference

Hypertrophic Cardiomyopathy

- Diastolic dysfunction, reduced SV & CO
  - Hypertrophic ventricles, small chamber volume
  - Impaired ventricular relaxation (lusiotropy)
- Dynamic LVOT obstruction during systole
  - Exaggerated with increased pressure gradient across outflow tract
  - ↑ contractility, ↓ SVR
- Hypertrophy may predispose to ischemia
  - Sufficient time for myocardial perfusion



Hemodynamic Goals

- Optimize diastolic ventricular volume
  - Adequate preload
  - Minimize tachycardia
    - More time for ventricular filling & myocardial perfusion
- Avoid exacerbating LVOT obstruction
  - Avoid drugs increasing contractility
  - Avoid excessive vasodilation

Options

- Opioid alone
- Midazolam + opioid
- Acepromazine + opioid
- Ketamine + midazolam/acepromazine + opioid
- Dexmedetomidine + opioid
- Alfaxalone IM

Options

- Ace IM ±
  - Minimal sedation, reduces afterload, **may increase LVOT obstruction**

Options

- Ace IM ±
  - Minimal sedation, reduces afterload, may increase LVOT obstruction
- Ketamine IM ±
  - Effective, increases heart rate & contractility, **may increase LVOT obstruction**

Options

- Ace IM ±
  - Minimal sedation, reduces afterload, may increase LVOT obstruction
- Ketamine IM ±
  - Effective, increases heart rate & contractility, may increase LVOT obstruction
- Dexmedetomidine IM ±
  - Effective, increases afterload, **may decrease LVOT obstruction**
  - Improve myocardial perfusion? (lower HR longer diastolic time)
  - May not be ideal for cardiac examinations

Doppler echocardiographic effects of medetomidine on dynamic left ventricular outflow tract obstruction in cats

Leigh A. Lamont, DVM, MS; Barret J. Bulmer, DVM; David D. Sisson, DVM, DACVIM; Kurt A. Grimm, DVM, MS, DACVA, DACVCP; William J. Tranquilli, DVM, MS, DACVA

JAVMA, Vol 221, No. 9, November 1, 2002

Alfaxalone IM

- Can be used as a premed/restraining drug (sedative)
- Cardiopulmonary effects well tolerated
- Better when combined with opioid and/or benzodiazepine
- Large volume of injectate
- Short duration of action
- Twitchiness can be seen
- Higher doses associated with general anesthesia

Options

- Opioid alone
- Midazolam + opioid
- Acepromazine + opioid
- Ketamine + midazolam/acepromazine + opioid
- Dexmedetomidine + opioid
- Alfaxalone IM

Optimizing Catheterization Conditions

- Chill protocols
  - Trazodone
  - Gabapentin
- EMLA cream prior to IVC
  - Eutectic mixture of local anesthetic (EMLA)
  - Transdermal lidocaine & prilocaine
  - Ideal for facilitating catheter placement
    - Lightly sedated patients
    - Novice/new nurses

Current Cardiovascular Meds

- General suggestions
  - ACE-I withhold day of surgery, may increase intraoperative hypotension
  - Clopidogrel – D/C 5-7 days prior to surgery, cost benefit
  - Pimobenden, beta-blockers, diuretics & others – continue

- Always be prepared to manage & address hypotension

Induction

- Alfaxalone or propofol
  - Very similar induction characteristics
  - Minimal hypotension/apnea when titrated to effect

- Ketamine/diazepam
  - Less potential for hypotension/apnea
  - Higher heart rates??
  - **Less ideal in patients with suspected HCM**
  - **Fine in patients with MVD**

Fluid Rates

- ~~Reduce rates, half regular maintenance rate~~
  - Largely based on opinion (risk avoidance) rather than evidence

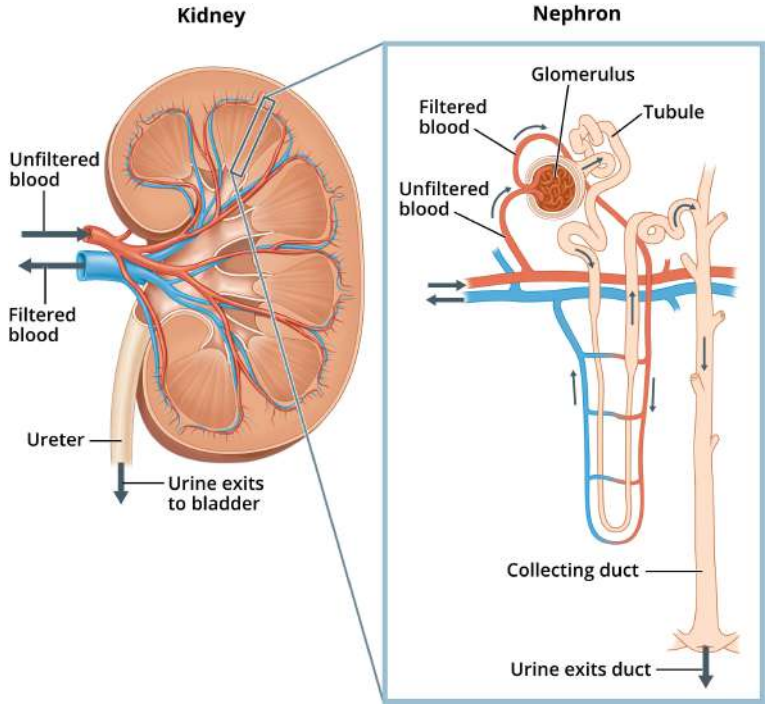
- General trend towards using lower fluid rates
  - Less reliance on fluids for maintenance of blood pressure
  - AAHA guidelines 3-5 mL/kg/hr (surgical maintenance)
    - Supporting data largely extrapolated from human medicine

Fluid Rates (my approach)

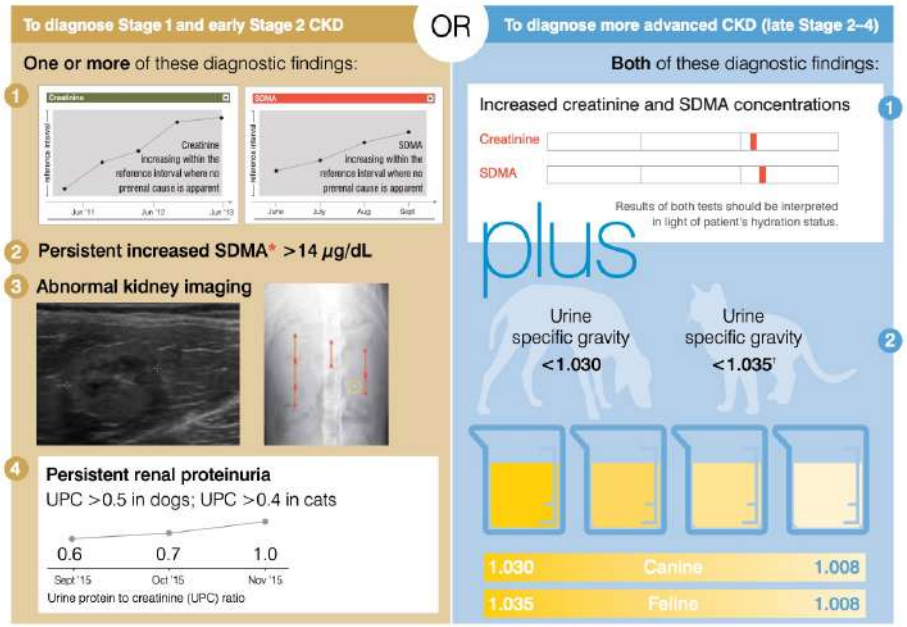
- Standard 5-10 mL/kg/hr with decreasing rate over time
- If evidence of failure (imaging, clinical evidence) and/or currently on diuretic may reduce by 50% but….
  - Preoperative assessment of patient
  - PCV/TP
  - Urine production & USG
- Cats seem more prone to fluid overload (my experience)

Chronic Kidney Disease

- Elevated creatinine & SDMA & low USG
  - **Idiopathic, associated with aging**
  - R/O - chronic infections, immune-mediated, urolithiasis, toxin, hypertension, genetic, cancer etc…



Staging CKD



	Stage 1 No azotemia (Normal creatinine)	Stage 2 Mild azotemia (Normal or mildly elevated creatinine)	Stage 3 Moderate azotemia	Stage 4 Severe azotemia
Creatinine in mg/dL Stage based on stable creatinine — Canine	Less than 1.4 (125 µmol/L)	1.4–2.8 (125–250 µmol/L)	2.9–5.0 (251–440 µmol/L)	Greater than 5.0 (440 µmol/L)
Feline	Less than 1.6 (140 µmol/L)	1.6–2.8 (140–250 µmol/L)	2.9–5.0 (251–440 µmol/L)	Greater than 5.0 (440 µmol/L)
SDMA* in µg/dL Stage based on stable SDMA — Canine	Less than 18	18–35	36–54	Greater than 54
Feline	Less than 18	18–25	26–38	Greater than 38
UPC ratio Substage based on proteinuria — Canine	Nonproteinuric **<0.2**	Borderline proteinuric **0.2–0.5**	Proteinuric **>0.5**	
Feline	Nonproteinuric **<0.2**	Borderline proteinuric **0.2–0.4**	Proteinuric **>0.4**	
Systolic blood pressure in mm Hg Substage based on blood pressure	Normotensive **<140**	Prehypertensive **140–159**	Hypertensive **160–179**	Severely hypertensive **≥180**

Staging CKD & Anesthesia Risk

- Severity of disease (prognosis), direct therapy
  - Stage 1, >3 yrs
  - Stage 2, 2-3 yrs
  - Stage 3, 1.5-2 yrs
  - Stage 4, < 6 mos

Cats

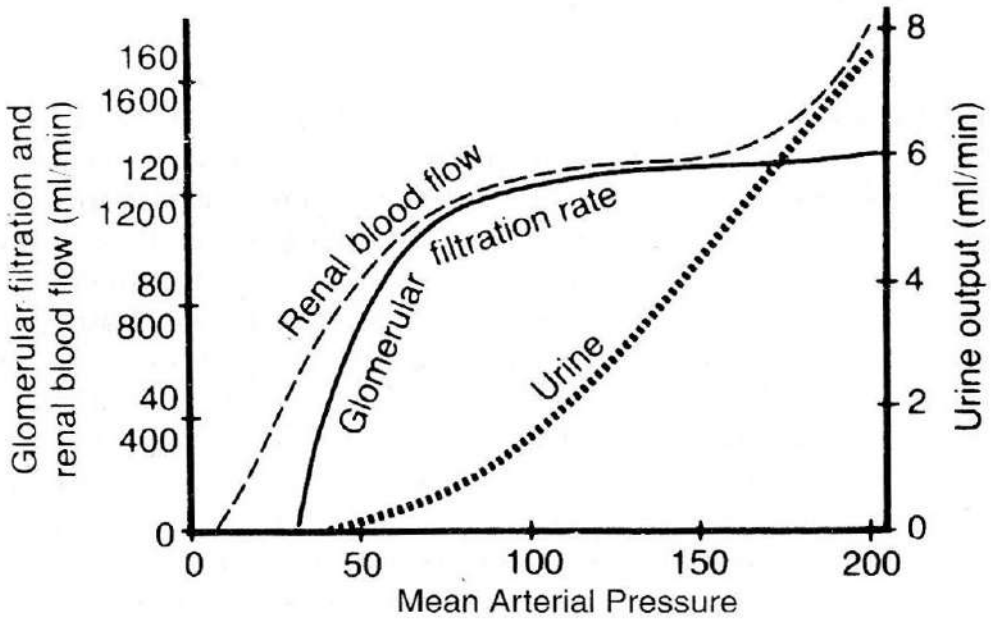
- Reasonable to manage any patient with evidence of “pre-clinical” CKD (IRIS 1) to minimize further kidney insult

- If present manage proteinuria, hypertension

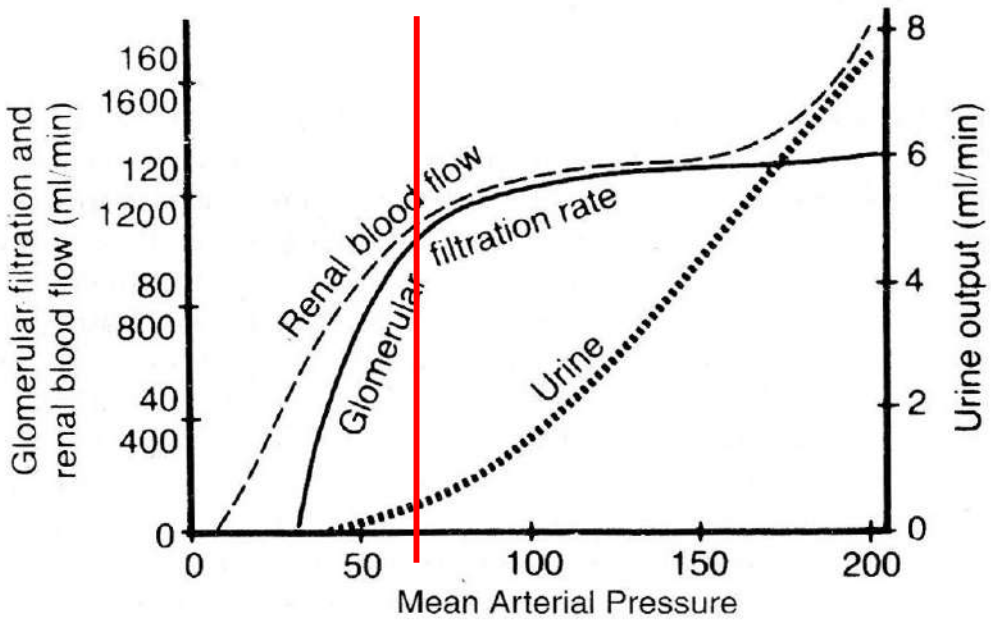
Anesthetic Plan/Goals

- Avoid drugs that can potentiate nephropathy
  - Aminoglycosides, NSAID's – PG dependent kidney only
    - PG dependent – hypotension, hypovolemia
- Avoid drugs requiring renal excretion or metabolism for clearance
  - Ketamine?
- Optimize renal blood flow (RBF) & GFR
  - Adequate blood pressure
  - Minimize renal vasoconstriction
- Minimize renal metabolic demands
  - Diuresis

Regulation of Renal Blood Flow



Regulation of Renal Blood Flow



Alterations to Renal Blood Flow

- Anesthetic induced hypotension
- Catecholamine induced α_1 adrenoreceptor activation
  - Renal vasoconstriction
- Impaired autoregulatory mechanisms
  - Renal disease and/or concurrent drugs (i.e. NSAID's)

Premedication Options

- Opioid alone
- Midazolam + opioid
- Acepromazine + opioid
- Dexmedetomidine + opioid
- Alfaxalone (select cases, small patients)

Acepromazine + opioid

- Hypotension decrease renal blood flow?
  - Mild in normovolemic patients, low doses
- MAC sparing – less inhalant hypotension
  - Maintains renal blood flow & GFR despite hypotension
- Reno-protective (α1 adrenergic blocking)?
  - Anesthetic induced hypotension
  - Maintains renal blood flow & GFR despite hypotension
  - Minimize catecholamine induced vasoconstriction

Dexmedetomidine + opioid

- Decrease CO --> RBF
  - RBF better than saline control & vasopressin significantly reduced in isoflurane anesthetized dogs given medetomidine (20 & 40 mcg/kg IV)
- Inhibits vasopressin, promotes diuresis
  - May protect kidneys during ischemia (dog), ischemia-reperfusion injury (rodents)

Lower Stress Levels

Minimize catecholamine induced vasoconstriction

- Preoperatively - prearrival sedation
  - Trazadone
  - Gabapentin
- IV placement & IM drug administration
  - Gentle handling, attentive to patient cues
  - Topical local anesthetics (EMLA cream)
- Intraoperatively
  - Appropriate depth of anesthesia
- Postoperatively
  - Sufficient analgesia

Concurrent Kidney Medications

- May contribute to refractory hypotension
  - Angiotensin converting enzyme (ACE) – Inhibitors
    - Benazapril, enalapril
  - Calcium channel blockers
    - Amlodipine
  - Angiotensin II receptor antagonists/blockers (ARB)
    - Telmisartan
- No literature - on kidney specific effects

Intraoperative Support/Goals

- **Optimize oxygen delivery**
  - Fluids
  - Dopamine
  - RBC
- **Minimize oxygen demand**
  - Fluids
  - Diuresis
- Prevent renal vasoconstriction
  - Adequate anesthetic depth, avoid stress
- Assess urine output
  - Urinary catheter
  - Estimate, assess bladder size changes
  - **USG**

Fluid Rates (my approach)

- **Hydration (always access to water)**
  - Often place on fluids for several hours prior to procedure
  - 1.5-2x maintenance for 3-4 hrs

- Standard 5-10 mL/kg/hr with decreasing rate over time based on perioperative evidence
  - Preoperative hydration assessment of patient
  - PCV/TP
  - Urine production & USG

NSAID & CKD

- NSAID associated AKI predominantly **hemodynamically mediated** in PG dependent kidney
  - **Hypotensive, hypovolemic, dehydrated**

- **Non-PG dependent, limited risk NSAID induced kidney injury**

- Cost vs benefit
  - Short prescriptions in well hydrated CKD patients
  - Chronic pain & CKD benefits may far outweigh risks
  - Owner compliance & informed consent

Thank you!