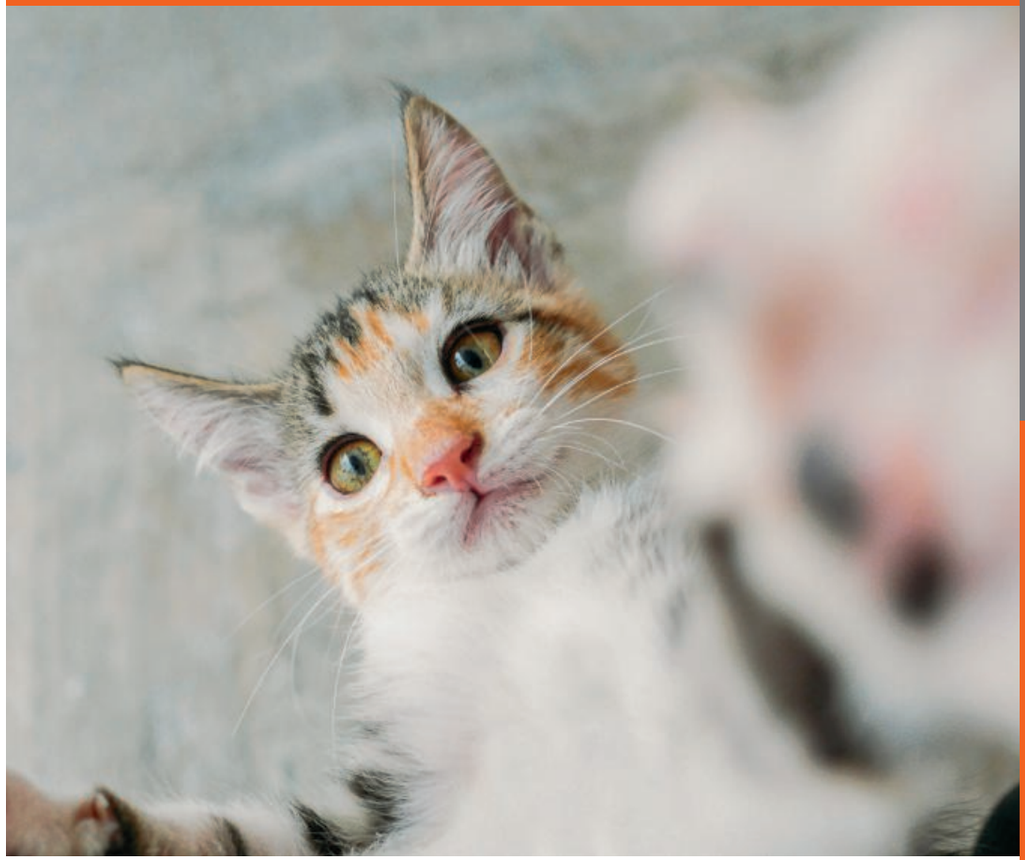
Banfield PET HOSPITAL

Book 2 | 2nd Edition



Anesthesia and Analgesia

for the Veterinary Practitioner: Canine and Feline

Banfield PET HOSPITAL

The Individualized Anesthesia and Analgesia Plan

Sedation and Immobilization

Induction, Monitoring and Recovery

Definitions

The following definitions are provided to ensure clarity and facilitate communication among hospital teams.

General anesthesia refers to a procedure that is performed after administration of a medication(s) that results in analgesia, paralysis and unconsciousness. General anesthesia begins with the preanesthetic evaluation and lasts until complete anesthetic recovery is attained.

Sedation involves the administration of a pharmaceutical to facilitate the performance of nonpainful procedures and to reduce pet anxiety. The patient may be ambulatory and all reflexes are intact. The pet cannot be intubated.

Immobilization is defined as a nonsurgical plane of anesthesia. The pet is nonambulatory but can be roused with minimal effort. Laryngeal and withdrawal reflexes are intact. Immobilization may be used for nonpainful procedures that are expected to last <10 minutes and cannot be used for brachycephalic pets.

An **anesthetic procedure** may refer to and is inclusive of sedation, immobilization and general anesthesia.

Anesthetic recovery is defined as that time when a patient is normothermic (T 100 - 102.5° F), normotensive (mean arterial pressure (MAP) 80 - 100 mm Hg), oxygenating normally (SpO_2 >95 - 100 percent), mentally appropriate, in sternal recumbency, with pain controlled, after extubation.

Direct supervision is defined as the physical presence of a licensed veterinarian with visual contact of the procedure.

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Preface

- Individual state practice act requirements and DEA regulations must be met or exceeded in all instances.
- Follow Medical Quality Standards. Meet or exceed all Clinical Essentials.

State regulations

- At all times, every medical team must comply with individual state practice acts.
- It is each doctor's responsibility to know and understand the requirements of their specific state, as well as Banfield policies and procedures.
- The doctor must ensure compliance with state regulations regarding but not limited to the following:
  - Handling and administration of controlled substances
  - Intubation of pets
  - Anesthetic monitoring
  - Drug administration documentation
  - Which hospital associates can legally perform dental prophylaxis and all other medical procedures
  - Off-label usage of medications

This publication may contain information that is not within the current FDA-approved labeling for several products for companion animals.

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Induction, monitoring, and recovery

The individualized anesthesia and analgesia plan

Bonnie L. Hay Kraus, DVM, DACVS, DACVAA

Abbreviations

ABCB1 ATP binding cassette subfamily B member 1 = updated name for the MDR1 gene
AMPA α-amine-3-hydroxy-5-methyl-4-isoxazolepropionic acid
ASA American Society of Anesthesiologists
AV atrioventricular
BP blood pressure
BPM beats per minute or breaths per minute
CNS central nervous system
CO_2 carbon dioxide
COX cyclooxygenase
CPR cardiopulmonary resuscitation
CRI constant rate infusion
CSF cerebrospinal fluid
CT computed tomography
$EtCO_2$ end-tidal carbon dioxide
GABA gamma-aminobutyric acid
GI gastrointestinal
HR heart rate
IM intramuscular
IPPV intermittent positive pressure ventilation
IT intratracheal
ITP inferior-temporal palpebral
IV intravenous
LA local anesthetic
MAC minimum alveolar concentration
MAOI monoamine oxidase inhibitor
MAP mean arterial pressure
MDR multidrug resistant
NK neurokinin
NMDA N-methyl-D-aspartate
NRB non-rebreathing
NSAID nonsteroidal anti-inflammatory drug
O_2 oxygen
OA osteoarthritis
OVH ovariohysterectomy
PNS peripheral nervous system
RR respiratory rate
SC subcutaneous
S-Cd sacral-caudal
SpO_2 peripheral capillary oxygen saturation
SSRI selective serotonin reuptake inhibitor
TPR temperature, pulse, respiration

Introduction

The process of selecting medications for an anesthetic procedure begins with review of the patient history and physical examination. Additional considerations include:

- Patient comorbidities (American Society of Anesthesiologists (ASA) status)
- Knowledge of concurrent medications
- Possible medication interactions

It is imperative for the anesthesia team to have a working knowledge of anesthetic and analgesic drugs, including advantages, disadvantages and potential side effects.

The team should also be aware of anticipated or potential complications based on the patient status, underlying disease, procedure and drug selection and have a plan of action should they occur, without compromising patient safety.

Drug selection should be individualized to each patient. Considerations include:

- Stress or anxiety reduction
- Anticipated analgesic needs and ability to increase or decrease based on patient response
- Patient status as it relates to drug metabolism capabilities
- Drug reversibility

Clinical essential

Utilize multi-modal analgesic therapy. Identify and address presurgical, immediate and postoperative pain

Emergency drugs

Emergency supplies and protocols should be ready and available prior to general anesthesia. An emergency drug dose chart specific to each pet should be completed prior to each procedure to allow the anesthetic team to be prepared for adverse anesthetic events or pet intervention. Veterinarians should be familiar with the most current recommendations for cardiopulmonary cerebral resuscitation (CPR) and appropriate drugs and equipment should be stocked, accessible and in proper functioning order.

Table 2.1

Emergency drug dosing

Drug		Low dose	High dose	Notes
Atropine 0.54 mg/mL		0.02 mg/kg	0.04 mg/kg	
Dexamethasone SP 4 mg/mL		0.1 mg/kg	0.4 mg/kg	Use low dose initially
Diphenhydramine 50 mg/mL		1 mg/kg	2.2 mg/kg	Maximum dose 1 mL (50 mg)
Dopamine 40 mg/mL		1 **mcg**/kg/min	10 **mcg**/kg/min	Administer as CRI
Epinephrine 1 mg/mL		0.01 mg/kg	0.2 mg/kg intratracheal (IT)	Dilute IT dose and administer via red rubber catheter
Glycopyrrolate 0.2 mg/mL		0.005 mg/kg	0.01 mg/kg	
Lidocaine bolus 20 mg/mL	**Canine**	2 mg/kg	4 mg/kg	Maximum dose 8 mg/kg
	Feline	0.2 mg/kg	N/A	Maximum dose 1 mg/kg

Reversal agents

Drug	Low dose	High dose	Notes
Atipamezole 5 mg/mL	100 **mcg**/kg	Equal to amount of dexmedetomidine administered if dose was higher than 10 **mcg**/kg	Alpha-2 adrenergic agonist reversal
Butorphanol 10 mg/mL	0.05 mg/kg	0.1 mg/kg	Opioid (full mu-agonist) partial reversal
Flumazenil 0.1 mg/mL	0.01 mg/kg	Repeat every hour if needed	Benzodiazepine reversal
Naloxone 0.4 mg/mL	0.04 mg/kg	N/A	Opioid reversal Highest affinity for mu receptor

Reversal agents may also reverse analgesic properties. Ensure patient analgesic needs are met.

Perioperative drugs

Premedication drugs should be utilized in all anesthetic procedures and individualized to each pet. Administration of premedication drugs should meet the following objectives:

- Calm the pet and reduce stress
- Prevent or decrease nausea and vomiting
- Decrease the dose of induction and maintenance drugs
- Improve induction and recovery quality
- Provide pre-emptive and multimodal analgesia

The following charts and information are meant to provide a summary of currently available references and serve as a guide in medication selection.

Anticholinergics

The decision to include an anticholinergic with anesthetic premedication is based on the pet's signalment, the coadministration of vagotonic drugs (such as acepromazine, opioids and the use of propofol for induction) and the veterinarian's personal preference.

Atropine*	
Class	Anticholinergic
Uses	Coadministration of vagotonic medications, cardiovascular support
Onset of Action	>1 minute (IV)
Side Effects	Dose-related effects of anticholinergic treatment: tachycardia, urinary retention, CNS stimulation, etc.
Reversal Agent	No
Supplemental Information	■ Higher incidence of sinus tachycardia than glycopyrrolate ■ See supplemental information in *glycopyrrolate*

Drug Legend: * extra-label # FDA labeled

Glycopyrrolate #	
Class	Anticholinergic
Uses	Coadministration of vagotonic medications, cardiovascular support
Onset of Action	3–5 minutes (IV)
Side Effects	Dose-related effects of anticholinergic treatment: tachycardia, urinary retention, CNS stimulation, etc.
Reversal Agent	No
Supplemental Information	■ **Not all pets exhibiting sinus bradycardia require treatment**; some can compensate by increasing stroke volume to maintain mean arterial pressure (MAP) ■ IV route is associated with increased risk of arrhythmias. IV administration may cause second degree atrioventricular (AV) block. An additional IV dose can be given to treat the AV block, which may lead to sinus tachycardia. ■ An advantage of the IM route is that it may allow the prevention of vagal-induced arrhythmias (sinus bradycardia, AV block). Prevention may be preferable to treatment if arrhythmias occur. ■ Young pets (less than 1 year of age) have immature cardiovascular and autonomic systems and are more likely to experience hypotension associated with bradycardia. ■ Brachycephalic breeds may have high vagal tone due to upper airway obstruction, which can be exacerbated by premedication drugs. ■ Geriatric pets may have subclinical cardiac disease and decreased cardiac reserve. Therefore, judicious use of anticholinergics may be warranted to avoid sinus tachycardia, which will increase myocardial work and oxygen (O_2) consumption.

Drug Legend: * extra-label # FDA labeled

Antiemetic

Maropitant #	
Class	Neurokinin-1 antagonist that blocks Substance P, a neurologic chemical that causes emesis and is involved in pain nociception
Uses	Prevents or treats vomiting and nausea from a variety of etiologies Used preoperatively as an antiemetic/anti-nausea medication before administration of mu-agonist opioids[5]
Onset of Action	1 hour (SC)
Side Effects	Swelling and pain at injection site most commonly reported
Reversal Agent	No
Supplemental Information	■ May be used preoperatively to prevent nausea/emesis from opioids ■ Provides adjunct analgesia in an ovariohysterectomy (OVH) dog and cat pain model[12] ■ Provides faster return to feeding postoperatively[16] ■ IV administration additional label (2016) ■ Give slowly over 2–5 minutes and monitor blood pressure (BP).

Drug Legend: * extra-label # FDA labeled

Notes

Sedatives/tranquilizers

Acepromazine #	
Class	Phenothiazine. Alpha-1 antagonist that can cause vasodilation
Uses	Provides anti-nausea and antiemetic action through its effect on dopamine receptors Sedative/Tranquilizer
Onset of action	Onset of action slow, peak effect 30 - 60 minutes It is important to wait at least 30 minutes for the full effect when using as a premedication
Side effects	Vasodilation effects may cause hypotension in dehydrated, very young, geriatric, ill or compromised pets Metabolized by the liver, highly protein bound
Reversal agent	No
Supplemental information	■ **Decrease or avoid in pets with liver disease, ABCB1 mutations, or sighthounds and giant breeds** ■ Current recommendations include 25% reduction in heterozygous ABCB1 pets and 50% reduction in homozygous ABCB1 pets.[18] ■ Not for use in stressed/fractious pets (see *Stressed/Fractious Pet* protocol for details) ■ Can be diluted to 1.0 mg/mL for easier and more accurate dosing (see *Appendix* for directions). **Advantages:** ■ More mild sedative effects compared to dexmedetomidine ■ Synergistic effect with opioids ■ Decreases the minimum alveolar concentration (MAC) of inhalant anesthetics ■ Long duration of action helps smooth recovery from anesthesia **Disadvantages:** ■ Long duration of action, not reversible ■ Vasodilation effects may cause hypotension in dehydrated, very young, geriatric, ill or compromised pets. ■ Little to no anxiolytic effects.

Drug legend: * extra-label # FDA labeled

Dexmedetomidine #	
Class	Alpha-2 agonist
Uses	Provides sedation, immobilization and adjunct analgesia. Always use in conjunction with opioids for painful procedures.
Onset of action	5–15 minutes (IM)
Side effects	Cardiac output (CO) decreases by up to 40%. ■ Decreased sympathetic outflow from the central nervous system (CNS) eventually may lead to bradycardia and hypotension. ■ Expect to see significant decrease in heart rate (HR), blanching or paleness of mucous membranes and decreased respiratory rate (RR).
Reversal agent	Atipamezole (full or partial reversal)
Supplemental information	■ Combination with opioid allows better analgesia and use of lower doses of both medications. ■ Eye lubricant should be administered when using dexmedetomidine. ■ Pets under the influence of dexmedetomidine can still be roused if stimulated and may be able to bite, so safe pet handling techniques should be followed. ■ Used in combination with ketamine gives better restraint, enhances analgesia, and blunts the decrease in HR seen with dexmedetomidine alone (although CO is not improved). ■ Cardiovascular effects: • Initial peripheral vasoconstriction and baroreceptor reflex bradycardia, which are dose dependent, so initial normal-high MAP is seen with a low HR (50 - 60 bpm in dogs, but as low as 30 - 40 bpm; 90 - 100 bpm in cats, but as low as 80 bpm). • Many pets are mildly hypoxemic. Therefore ALL pets administered dexmedetomidine should receive flow-by O2 supplementation (100 mLs/kg/min) and monitoring of oxygen saturation (SpO2).9 • Significantly decreases dose of induction agent and inhalant requirements (45 - 90% depending on dose). • **Usage limited to pets with ASA status I – II.** ***See Appendix for comprehensive dosing instructions.***

Drug legend: * extra-label # FDA labeled

*Midazolam**	
Class	Benzodiazepine
Uses	Potentiates the action of gamma-aminobutyric acid (GABA), resulting in varying degrees of sedation/hypnosis, anxiolysis, anterograde amnesia, anticonvulsant activity and spinal-cord-mediated skeletal muscle relaxation
Onset of action	Minutes (IM - dog)
Side effects	Can cause paradoxical excitement, agitation and hyper-responsiveness in young, healthy dogs and cats
Reversal agent	Flumazenil
Supplemental information	■ Metabolized in the liver to active metabolites which are excreted by the kidney ■ Can afford good sedative effects in pets that are very young (<3months of age), geriatric and debilitated or critically ill pets • Due to its mild cardiovascular effects, it is a good choice, along with an opioid, for sedation or anesthetic premedication for these pets.

Drug legend: * extra-label # FDA labeled

Opioids

The choice of opioid analgesic is primarily based on a pre-emptive pain scoring system but also the pet's signalment, underlying disorders or comorbidities. The pre-emptive pain score uses a simple descriptive scale which involves simply assigning a degree of pain based on the procedure performed and the amount of tissue trauma involved.

- No pain
- Mild pain
- Moderate pain
- Severe pain

This allows for pre-emptive, intraoperative and postoperative analgesia planning. The limitations are that it is not tailored to the individual pet and is not useful in assessing response to therapy. Therefore, monitoring and regular assessment are needed to evaluate the effectiveness of the original analgesic plan and to allow modification according to the individual pet's needs.

***Buprenorphine**#*	
Class	Opioid agonist (mu) and antagonist (kappa)
Uses	Provides analgesia for MODERATE pain
Onset of action	Slow, 30–60 minutes
Side effects	Does not cause nausea and vomiting; less respiratory depression and bradycardia than pure mu-agonists
Reversal agent	No
Supplemental information	■ Ceiling effect for analgesic properties, *i.e.*, higher doses (>0.04 mg/kg) do not afford more analgesia. ■ Transmucosal absorption in dogs is variable and higher doses are needed; therefore this route is not recommended.[1] ■ Metabolized in the liver, excreted in urine and feces ■ Less sedative effects than butorphanol but longer lasting and stronger analgesia ■ Difficult to reverse due to its high affinity or "stickiness" to the mu receptor

Buprenorphine – long acting #	
Class	Opioid agonist (mu) and antagonist (kappa)
Uses	Once daily analgesia for MILD to MODERATE surgical pain in cats
Onset of action	One hour
Side effects	Hyperactivity (opioid excitement, euphoric or dysphoric responses) may be observed for up to eight hours after anesthetic recovery. Hyperthermia (>104⁰ F) may be seen and cats should be monitored every two hours during onset of action and every 12 hours thereafter. Discontinue use and administer alternative analgesic if T >104⁰ F
Reversal agent	No
Supplemental information	■ Long-acting buprenorphine ■ Approved for daily administration x3 days

Drug legend: * extra-label # FDA labeled

Buprenorphine – transdermal solution#	
Class	Opioid agonist (mu) and antagonist (kappa)
Uses	Once for MILD to MODERATE surgical pain in cats
Onset of action	1-2 hours
Side effects	Hyperthermia (>102.5) may be seen especially within the first few hours after administration. Constipation may be seen and is usually mild and transient
Reversal agent	No
Supplemental information	■ Must be applied to healthy skin at the base of the head. ■ Allow 30 minutes to completely dry before touching. ■ Gloves, glasses, and coat are required to apply.

Butorphanol*	
Class	Opioid agonist (kappa) and antagonist (mu)
Uses	Provides MILD analgesia effects via kappa and sigma opioid receptors Does not cause nausea and vomiting.
Onset of action	Within 10–15 minutes (IM)
Side effects	Less respiratory depression and bradycardia than pure mu-agonists
Reversal agent	Naloxone – rarely used
Supplemental information	■ Doses higher than 0.4 mg/kg do not provide more analgesia (ceiling effect) but may cause adverse effects such as panting or dysphoria. ■ Metabolized in liver, metabolites excreted in urine and feces ■ Better sedative effects than buprenorphine, but shorter lasting and less effective analgesia ■ Mu-antagonist – can be used to partially reverse full mu-agonists (hydromorphone, fentanyl) • Dilute 1 mg (0.1 mL) butorphanol in 0.9 mLs IV fluid of choice and administer 0.2 mg (0.2 mL) IV every 3–5 minutes for desired effect in reversing sedation, respiratory depression or dysphoria from mu-agonist opioids.

Drug legend: * extra-label # FDA labeled

*Fentanyl**	
Class	Opioid agonist (mu)
Uses	Provides analgesia for MODERATE to SEVERE pain, depending on dose
Onset of action	Immediate
Side effects	More respiratory depression and bradycardia than agonist/antagonists or partial agonists BUT also more MAC sparing effect on inhalant anesthetics Bradycardia may require anticholinergic treatment if also associated with hypotension (MAP less than 60 mm Hg).
Reversal agent	Naloxone (full), butorphanol (partial)
Supplemental information	■ Only use IV with loading dose followed by constant rate infusion (CRI). ■ Does not have a ceiling effect; higher doses result in greater analgesic effects as well as greater side effects. • Monitor end-tidal carbon dioxide ($EtCO_2$) intra-op; mechanical or manual intermittent positive-pressure ventilation (IPPV) may be required. • Monitor SpO_2 at transition from 100% O_2 to room air at recovery; provide supplemental O_2 (100 mLs/kg/min) until able to maintain SpO_2 greater than 93–95%. ■ Highly lipid soluble so rarely causes vomiting ■ Metabolized in the liver ■ IV use does not cause histamine release. ■ The reported analgesic plasma levels of fentanyl in dogs are 1–2 **ng/mL**; there may be considerable inter-individual variation in plasma levels and pain threshold for different pets. • Imperative that pets be regularly assessed for pain and level of sedation (arousability) in order to titrate the fentanyl CRI to the pet's analgesic needs.

Drug legend: * extra-label # FDA labeled

*Hydromorphone**	
Class	Opioid agonist (mu)
Uses	Provides analgesia for MODERATE to SEVERE pain, depending on dose
Onset of action	15 minutes (IM)
Side effects	Nausea, vomiting, panting, vocalization, dysphoria More respiratory depression and bradycardia than agonist/antagonists or partial agonists BUT also more MAC sparing effect on inhalant anesthetics.
Reversal agent	Nalaxone (full) or butorphanol (partial)
Supplemental information	■ Metabolized in the liver, excreted by the kidney ■ Does not have a ceiling effect; higher doses result in greater analgesic effect (true for pure mu-agonists) ■ May be used for MAC sparing effects in less painful pets with less cardiac or organ reserve; sedative/respiratory depressant effects can be fully or partially reversed at recovery. ■ IV use does not cause histamine release. ■ Re-dosing, if needed, should occur roughly every 3 hours.

Drug legend: * extra-label # FDA labeled

*Methadone**	
Class	Opioid agonist (mu) and antagonist (kappa)
Uses	Provides analgesia for MODERATE to SEVERE pain
Onset of action	15 minutes (IM)
Side effects	Panting, vocalization, sedation, defecation Less sedation or vomiting than morphine
Reversal agent	Naloxone
Supplemental information	■ Metabolized in the liver, excreted by kidney ■ May cause less panting than other opioid agonists ■ Re-dosing can occur every 4-6 hours depending on patient need.

Induction Agents

Prior to induction of general anesthesia, complete the *Anesthesia Machine Checklist*. Complete the *Pre-Induction Timeout Checklist* if utilized by the anesthetic team. Pre-oxygenation at 100 mLs/kg/min for three to five minutes prior to anesthetic induction helps delay the onset of hypoxemia from 30–60 seconds to up to five minutes during anesthetic induction.[11]

Follow administration instructions closely to minimize risks associated with anesthetic induction. Accurately document volume and time of administration of induction agents.

Alfaxalone #	
Class	Sedative/hypnotic (neuroactive steroid)
Uses	Induction agent Sedation and Immobilization
Onset of action	Immediate
Side effects	Dose dependent cardiovascular and respiratory depression; apnea; may decrease tear production (use with caution)
Reversal agent	No
Supplemental information	■ Negligible analgesic properties ■ Hepatic metabolism and excretion via cytochrome p450 ■ Use of premedications lowers induction dose necessary. ■ Administer IV incrementally over 60 seconds until intubation can be achieved. ■ Canine and feline induction dose: 1–4 mg/kg IV over 60 seconds • See *package insert* for details Alfaxan Multidose (alfaxalone) may be retained and used within 56 days of broaching the vial.

Drug legend: * extra-label # FDA labeled

Propofol #*	
Class	Sedative/hypnotic
Uses	Induction agent Immobilization/chemical restraint Anesthetic maintenance
Onset of action	Immediate
Side effects	Dose and rate dependent respiratory depression to the point of apnea, hypotension and bradycardia
Reversal agent	No
Supplemental information	■ Does not provide analgesia ■ Metabolized primarily in the liver, but has extra-hepatic sites of metabolism (lung, gastrointestinal (GI) tract) ■ Non-irritating if IV extravasation is encountered ■ Do not use propofol CRI or multiple dosing in cats. • Cats have defective glucuronidase and therefore do not metabolize benzylalcohol well. ■ Use with premedications to lower induction dose.

Drug Legend: * extra-label # FDA labele

Proper Propofol Handling

- Formulation contains benzylalcohol as a preservative and bacteriostatic agent
- Has a shelf life of 28 days after the vial is opened
- STRICT ADHERENCE to sterile technique is STILL required to avoid contaminating the vial. ALWAYS use a NEW needle and syringe for each dose
- Once the vial is opened, disinfect the top of the vial with isopropyl alcohol before inserting the needle
- Draw up propofol as close to injection time as possible
- Label the vial with “date opened” and “use by” dates
- Store in covered container at room temperature
- DO NOT refrigerate
- Use within 28 days from the date the vial was first opened

Supplemental dosing instructions for Propofol:

- Induction agent prior to inhalant anesthetic
  - Dosing: With premedications: 4–6 mg/kg IV; without premedications: 6–8 mg/kg IV
  - **Optimal dosing to limit cardiopulmonary depression (apnea and hypotension): Propofol 1 mg/kg is administered slowly over 15 seconds, then continued with increments of approximately 0.5 mg/kg over 15 seconds until intubation can be achieved.**
  - After induction, keep remaining propofol in the event the pet arouses or awakens during inhalant anesthesia; a small dose 0.5–1 mg/kg IV slowly can be given to bring pet to unconsciousness.
    - This should only be used when the pet is on a re-breathing system since the time for changing of circuit concentration will be longer than with a non-rebreathing (NRB) circuit.
- Immobilization/chemical restraint for short (less than 10 minute) procedures:
  - Radiology positioning
  - Examinations or diagnostic procedures
  - MUST provide additional appropriate analgesia for painful conditions or procedures
  - Must "convert" to general anesthesia if procedure lasts longer than 10 minutes
  - Flow-by O_2 support (100 mLs/kg/min) and SpO_2 monitoring required
  - Equipment for intubation and IPPV should be readily available if necessary
- Anesthetic maintenance
  - When intubation is not possible (tracheoscopy, bronchoscopy)
  - Status epilepticus that is refractory to diazepam/midazolam or phenobarbital
  - CRI: 0.2–0.5 mg/kg/min – can be combined with fentanyl to provide analgesia and decrease the amount of propofol required (see *Appendix* for CRI instructions)
  - Anesthetic monitoring requirements are unchanged

Dissociatives

Dissociative agents may be used to provide anesthesia and immobilization, and are always used in combination with other medications. Depending on the agent chosen, analgesia may also be provided. Medications may be administered IM, so are reasonable choices when IV access is not available. Numerous side effects are recognized and cautious use is advised.

Ketamine* #	
Class	Dissociative anesthetic; *N*-methyl-D-aspartate (NMDA) antagonist with analgesic properties
Uses	Immobilization and anesthesia when combined with other medications Provides adjunct analgesia for MODERATE to SEVERE pain (as part of multimodal therapy)
Onset of action	Minutes
Side effects	Respiratory depression and neurologic side effects, including seizures and blindness
Reversal agent	No
Supplemental information	■ Use should be avoided in cats with known or suspected hypertrophic cardiomyopathy. ■ Contraindications and relative contraindications to use: • Increased cerebrospinal fluid (CSF) pressure • Significant hypertension or heart failure • Pre-existing seizure disorder • Increased intraocular pressure or globe injuries

Drug legend: * extra-label # FDA labeled

Tiletamine HCl and Zolazepam HCl #	
Class	Anesthetic tranquilizer combination
Uses	Restraint/anesthesia combined with some degree of analgesia
Onset of action	Within seven minutes
Side effects	Respiratory depression and pain with IM injection have been seen; recovery may be rough.
Reversal agent	No
Supplemental information	■ Similar to the combination of ketamine and benzodiazepine ■ Minimal analgesia so appropriate analgesics should be administered concurrently ■ Protect and lubricate eyes after administration. ■ Zolazepam is a benzodiazepine and has a duration of action of 1–2 hours in dogs and 3–4 hours in cats. ■ Tiletamine is a dissociative like ketamine and has a duration of action of 2–3 hours in dogs and 1.5–2 hours in cats. ■ Zolazepam is metabolized slower in cats, therefore they have a smoother recovery than dogs. ■ Dogs experiencing a rough recovery from Tiletamine/Zolazepan may be administered 0.05–0.1 mg/kg midazolam IV or dexmedetomidine 1 **mcg**/kg IV for a smoother transition.

Drug legend: * extra-label # FDA labeled

Inhalants

General anesthesia is maintained by the use of inhalant anesthetic agents. These agents are characterized by rapid action and quick recovery. Side effects may be seen and are considered to be dose related, thus astute patient monitoring is essential. Careful maintenance of vaporizers to ensure effectiveness of minute dosing adjustments is required.

Sevoflurane #	
Class	Inhalant anesthetic
Uses	Maintenance of general anesthesia
Dosing	1–4% (inhaled)
Route	Pulmonary
Onset of action	Minutes
Peak effect	Minutes
Side effects	Dose dependent cardiovascular depression
Duration of action	Minutes
Reversal agent	No
Supplemental information	■ MAC of sevoflurane **Canine:** 2.1 **Feline:** 2.58 ■ Has a lower blood gas solubility than other inhalant agents (sevoflurane = 0.62 vs. isoflurane 1.27), potentially resulting in a faster induction of anesthesia, and changes in depth and recovery from anesthesia ■ Less airway irritation and breath holding than other inhalants ■ Approximately 3–5% is metabolized by the liver ■ Sevoflurane may react with desiccated carbon dioxide (CO_2) absorbents causing heat production and chemical instability (see *Equipment* chapter for additional information).

Drug legend: * extra-label # FDA labeled

Table 2.2 – Injectable Perioperative Medications Chart

Anticholinergics

Drug	Dose	Peak effect	Duration of action	Route	Caution
Atropine	0.02–0.04 mg/kg	Unknown	Approximately 45–60 minutes	IM, IV	**May cause sinus tachycardia** **Use judiciously in geriatric pets** **Hypothermia reduces effectiveness**
Glycopyrrolate	0.005–0.01 mg/kg	30–45 minutes (IM)	Approximately 90–120 minutes	IM, IV	

Anti-emetic

Drug	Dose	Peak effect	Duration of action	Route	Caution
Maropitant	1.0 mg/kg	<1 hour (SC)	24 hours	IV, SC	**IV dosing should be administered over 2 – 5 minutes and monitor BP**

Sedatives

Drug	Dose		Peak effect	Duration of action	Route	Caution
Acepromazine	**Canine**	0.005–0.05 mg/kg **maximum dosage 2 mg**	30–60 minutes	4–8 hours	SC, IM, IV	**Decrease dose or avoid in pets with liver disease, sight hounds and pets with ABCB1 mutations. Extreme caution in brachycephalic pets. Not for use in stressed/fractious pets**
	Feline	0.01–0.1 mg/kg **maximum dosage 1 mg**				
Dexmedetomidine	**Canine**	Sedation or premedication (with opioid): 2–5 **mcg**/kg	15–60 minutes	3 hours	IM, IV	**Causes significant decrease in CO. Monitor BP closely. Flow-by O_2 and SpO_2 monitoring required. Additional analgesics necessary for painful procedures**
	Feline	Sedation or premedication (with opioid): 5–10 **mcg**/kg IM				
	Fractious or fearful pets: see *Stressed/Fractious Pet* protocol					
Midazolam	0.1–0.3 mg/kg		10–15 minutes	1–2 hours	IM, IV	**Can cause paradoxical excitement**

Opioids

Drug	Dose		Peak effect	Duration of action	Route	Caution
Buprenorphine	**Canine:**	0.005–0.02 mg/kg	30–60 minutes	**Canine:** 4–10 hours	IM, IV, transmucosal	**Transmucosal route not recommended in dogs. Difficult to reverse.**
	Feline	0.01–0.02 mg/kg Up to 0.04 mg/kg for acute pain		**Feline:** 6–12 hours		
Buprenorphine (long acting)	**Feline:**	0.24 mg/kg (dose on lean body weight)	Variable	24 hours	**SC only**	**May cause hyperactivity and hyperthermia**
Buprenorphine (transdermal)	**Feline**	8mg tube: cats weighing 1.2–3kg 20mg tube: cats weighing >3–7.5kg	1–2 hours	4 days	Transdermal	**May cause hyperthermia. Human exposure risk.**
Butorphanol	0.2–0.4 mg/kg		10–15 minutes (IM)	60–90 minutes	IM, IV, SC	**Provides mild analgesia with ceiling effect. Sedation lasts longer than analgesia.**
Fentanyl	See *Appendix* for details		Immediate	<20 minutes	IV	**No ceiling effect – higher doses result in greater analgesic effects as well as side effects**
Hydromorphone	**Canine:**	0.1–0.2 mg/kg **OR** 0.05 mg/kg every 2–4 hours	15 minutes (IM)	2–4 hours	IM, IV, SC	**May cause vomiting and panting. Hyperthermia may be seen in cats. Use extreme caution in pets with head trauma.**
	Feline	0.05–0.1 mg/kg **OR** 0.05 mg/kg every 2–6 hours				
Methadone	0.1–0.5 mg/kg (decrease dose if IV)		10–20 minutes (IM)	4–6 hours	Canine: IM, IV Feline: IM, IV, transmucosal	**May cause hyperexcitability in cats.**

Dissociatives

Drug	Dose	Peak effect	Duration of action	Route	Caution
Alfaxalone	1–5 mg/kg over 60 seconds to effect, until intubation can be achieved	1–2 minutes	5–10 minutes	IV	**Cardiopulmonary depression, hypotension, apnea, hypoxia, death may result**
Ketamine	See *Appendix* for details	10 minutes (IM)	1 hour	IM, IV	**Do not use in cats with hypertrophic cardiomyopathy**
Propofol	4–6 mg/kg IV Induction with premedications	Immediate	<5–10 minutes	IV	**No analgesic effects. May cause apnea and bradycardia. Administer only to effect.**
Tiletamine/ Zolazepan	1–2 mg/kg	30–60 minutes	**Canine:** 1 - 2 hours **Feline:** 3–4 hours	IM, IV	**May cause "rough" recovery in dogs**

References:
1. Plumb DC. *Plumb's Veterinary Drug Handbook*. 8th edition. Ames, Iowa. Wiley-Blackwell. 2015.
2. Papich M. *Saunders Handbook of Veterinary Drugs, Small and Large Animal*. 4th edition. St. Louis, Mo. Elsevier. 2016.
3. Individual drug package inserts.

Additional information

Additional anesthetic agents and combinations are commercially available and offer options for more critical (American Society of Anesthesiologists (ASA) status IV - V pets and higher-risk anesthetic procedures. This information is not included here. Medical Quality Standards state that these pets should receive appropriate preanesthetic medical management to mitigate anesthetic risk and anesthetic procedures should be cancelled or referred as clinically indicated.

Multi-use vial handling

Multi-dose vials are labeled as such by the manufacturer and typically contain an antimicrobial preservative. The preservative has no effect on viruses and does not protect against contamination if personnel fail to follow safe injection practices.

- When opened, the date of first puncture and date of expiration (usually 28 days) should be written on the vial.
- Sterile needles and syringes should be used every time the vial is punctured.
- The top of the vial should be cleaned prior to puncture.

Intraoperative analgesic plan

Pain management general concepts

Pain management is an important part of any anesthetic procedure where the pet will experience pain and/or inflammation. It is not appropriate to forgo pain management for any reason and it is the attending veterinarian's responsibility to ensure that appropriate pain management is employed throughout the procedure and recovery.

For optimal pet care, it is important that the anesthesia team has an understanding of the basic tenets of pain management.

Basic tenets of pain management:

- Pre-emptive analgesia
- Classification of the severity of pain via pre-emptive pain scoring
- Classification of the types of pain
- Multimodal pain management
- Pet assessment

The goal of all of these tenets is to decrease peripheral and central sensitization and "wind-up."

- **Peripheral sensitization** happens when tissue damage releases chemical mediators which recruit inflammatory cells. This so-called "sensitizing soup" decreases the excitation threshold of nociceptors and activates silent nociceptors, which increases nociceptive input to the CNS. Good surgical technique and tissue handling, along with nonsteroidal anti-inflammatory drugs (NSAIDs), help decrease this inflammation.

- **Central sensitization** results from frequent, severe or prolonged activation of nociceptors. This can lead to increased excitatory neurotransmitters, such as glutamate and Substance P, in the dorsal horn of the spinal cord. Activation of NMDA, neurokinin (NK) and α-amine-3-hydroxy-5-methyl-4-isoxazolepropionic acid (AMPA) receptors may lead to an increase in signal molecules, gene expression and chronic pain.

Pre-emptive analgesia entails administering analgesics BEFORE the painful stimulus to prevent peripheral nervous system (PNS) and CNS sensitization. Adequate pain management must also follow through the intraoperative and postoperative period.

Classification of the severity of pain allows the veterinarian to devise a pre-emptive and intraoperative analgesia plan. A pre-emptive pain score assigns a degree of pain based on the pet's underlying pathology, the procedure being performed and the amount of tissue trauma involved.

The classifications are:

- No pain
- Mild pain
- Moderate pain
- Severe pain

Keep in mind that the procedure the pet is undergoing may not be very painful, however, it may have an underlying condition which is very painful. Take, for example, a pet undergoing imaging for an invasive tumor. The imaging procedure is not painful but invasive neoplasia is painful and warrants appropriate analgesic therapy.

Remember, analgesia plans formulated based on pre-emptive pain scoring are not tailored to the individual pet, nor do they assess the pet's response to therapy. A "one size fits all" approach may not work for all pets. The veterinarian must assess the pet's response to therapy and reassess the analgesic plan as needed.

Classification of the types of pain is also helpful when devising a pre-emptive and intraoperative analgesia protocol. This will also help take advantage of the adjunct benefits of certain drugs, such as prevention/treatment of CNS wind-up and sensitization, neuroprotection, anti-inflammatory or GI prokinetic properties.

- **Somatic pain** originates from damage to bones, joints, muscle or skin and is described as localized, constant and sharp.
- **Visceral pain** arises from stretching, distention or inflammation of viscera and is described as deep, aching and without good localization.
- **Neuropathic pain** originates from injury or involvement of the PNS or CNS and is described as burning or shooting and may be associated with neurological deficits.
- **Chronic pain** is often defined as any pain that has lasted more than 12 weeks.

Multimodal pain management uses a variety of drugs and techniques which affect different receptors and different aspects of the pain pathway. This strategy results in more effective analgesia and allows use of lower doses of each individual drug. Using lower doses can decrease the side effects of the drugs. This strategy also requires the veterinarian to have a broad knowledge base of the analgesic drugs available including the onset and duration of action, which is necessary for adequate timing of administration, the site(s) of action along the pain pathway and receptors involved to avoid interference and side effects.

When using a multimodal pain management approach, it is helpful to recall the steps of the pain pathway and where each analgesic drug exerts its effect.

- **Transduction** occurs at the tissue level, where tissue damage results in the release of local inflammatory mediators. These mediators stimulate nociceptors to transform mechanical, thermal and chemical stimuli into action potentials. Analgesic drugs that work at this level include local anesthetics (LA), NSAIDs and intra-articular opioids.
- **Transmission:** The action potential is then transmitted by the sensory nerves to the dorsal root ganglion and then, via the dorsal root nerves, to the grey matter of the spinal cord. Analgesic drugs that work at this level include LA, +/- alpha-2 agonists and opioids.

- **Modulation**: Synapse occurs with neurons in the dorsal horn of spinal cord grey matter. This is where impulses can be amplified (central sensitization) or suppressed (with analgesics). Neurotransmitters can act on excitatory or inhibitory receptors (AMPA, NMDA/GABA, glycine). This is where the majority of analgesic drugs have their effects including opioids, alpha-2 agonists, NMDA antagonists, NSAIDS, LA, tricyclic antidepressants and anticonvulsants.
- **Perception:** The integration, processing and recognition of painful sensory information occurs in multiple areas of brain. There are multiple drugs that work at this level to decrease the perception of pain including general anesthetics (inhalants, injectables), benzodiazepines (midazolam), phenothiazines (acepromazine), opioids, alpha-2 agonists, NK-1 antagonists, tricyclic antidepressants, anticonvulsants and NMDA antagonists.

Remember:

Unless a drug also has analgesic properties, it is only blocking the perception of the pain. All other levels of the pain pathway are being activated.

Therefore, relying only on these drugs (such as inhalants) will not provide adequate analgesia.

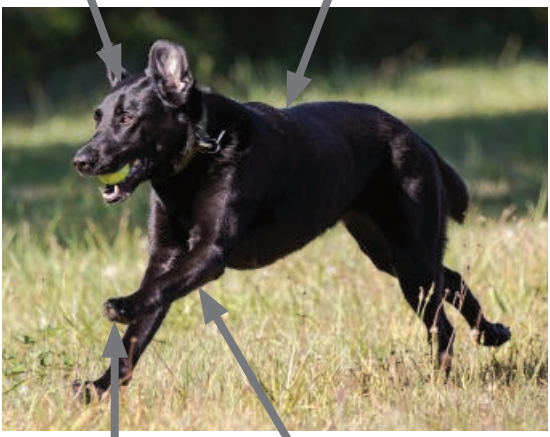
Notes

Figure 2.1

Steps of the pain pathway

Inhibit perception
- Inhalant anesthetics
- Opioids
- Alpha-2 agonists
- Benzodiazepines
- Acepromazine

Modulation of spinal pathways inhibit central sensitization
- Opioids
- Alpha-2 agonists
- Local anesthetics
- NSAIDs
- NMDA receptor antagonists
- Tricyclic antidepressants (tramadol – one mechanism)
- Anticonvulsants (gabapentin)



Inhibit transduction
- NSAIDs
- Local anesthetics
- Opioids

Inhibit transmission
- Local anesthetics
- Alpha-2 agonists

Important points to remember:

- The intraoperative analgesic plan should be based on the pet's signalment, underlying disease and physical status, pre-emptive pain score and types of pain involved
- Use a multimodal approach
- Recognize that individual pets will have different responses to analgesic drugs/plans and different pain tolerance. Therefore, a one-size-fits-all approach to pain management may not be adequate.
- It is important to recognize signs of intraoperative pain, including increased HR, BP, RR and the necessity for high levels of inhalant (greater than 1.5 MAC). For sevoflurane, this is roughly 3.1 (dog) and 3.8 (cat).
- Use a pain assessment tool to regularly assess pet pain and overall comfort and well-being postoperatively

Intraoperative analgesia

Adequate pain management must also follow through the intraoperative and postoperative period. Therefore, it is necessary that veterinarians have a good working knowledge of the duration of action of opioid analgesics used for premedication and pre-emptive analgesia and plan for provision of continued analgesia throughout the procedure and recovery.

- Butorphanol should only be used for non-or mildly painful procedures and should be redosed at approximately 60 minutes.
- Hydromorphone's duration of action is approximately two to four hours and typically requires redosing at approximately three hours.
- Fentanyl is very short acting (approximately 15 minutes) and therefore requires CRI administration.

Constant rate infusions

Administration of analgesics via CRI should only be considered in those instances where:

- Pain cannot be controlled with conventional dosages and administration
- Hospital teams have the personnel, training and equipment (*e.g.*, syringe pump) to safely administer these medications

See CRI information located in Appendix for detailed instructions.

Local anesthesia and analgesia

Local anesthetics are the only analgesic drugs which completely block transmission of nociceptive impulses transmitted from the periphery to the CNS. Given systemically, they can help treat inflammatory or neuropathic pain and may have neuroprotective properties. Local anesthetics are also comparatively inexpensive. These characteristics provide a great opportunity to incorporate these drugs and techniques into a balanced, multimodal approach to perioperative pain management.

Mechanism of action

Local anesthetics exert their effect by binding to the sodium channel, thereby preventing sodium influx and depolarization of nerves. They also provide anti-inflammatory effects by reducing production of eicosanoids, thromboxane, leukotriene, histamine and inflammatory cytokines and the scavenging of O_2 free radicals.

Specific drugs

Drug	Dose	Onset of action	Duration
Lidocaine	2 mg/kg	Quick	1–2 hours
Bupivacaine	1.5 mg/kg	10–15 minutes	3–6 hours
Ropivacaine	1.5–2 mg/kg	20 minutes	3–6 hours

There is no advantage to mixing lidocaine and bupivacaine; in fact, doing so has been found to shorten the duration of action of bupivacaine.[10] Therefore, it is recommended to choose the drug that best addresses the pet's analgesic needs. Bupivacaine is the LA of choice for any procedure where moderate pain is expected to extend into the postoperative period. Blocks using bupivacaine should be performed once the pet is under general anesthesia and the first of three sterile skin preps has been performed (sterile preparation is not required for dental blocks).

Bupivacaine is only available as a **preservative-free** formulation, therefore, aseptic technique should be followed.

Bupivacaine is highly toxic and should **NEVER** be given IV.

Dilution: If the calculated dose of an LA is an insufficient volume, it is recommended that the drug be diluted with **non-sodium** containing fluid such as sterile water. Saline products may interfere with the action of the LA.

Local injection guidelines		
Canine	0.5–1.0 mL per site	Up to the maximum cumulative mg dose amount appropriate for that patient
Feline	0.2–0.3 mL per site	

Toxicity:

Overdose of LA or inadvertent IV administration can be fatal.

Important techniques to avoid complications of LA therapy:

- Observe and double-check dosages, including species differences
- Perform careful medication calculations
- Aspirate prior to injection to check for vessel penetration

CNS symptoms of toxicity (tremors, excitation, muscle twitching, seizures and coma) usually occur before cardiovascular signs but early neurologic signs of toxicity can be masked by sedation and general anesthesia.

Cardiovascular signs include tachycardia, arrhythmias, direct myocardial depression, hypotension, bradycardia, cardiovascular collapse and cardiac arrest refractory to resuscitation and death.

TOXIC DOSE – DO NOT EXCEED

Lidocaine
Canine: 10 mg/kg
Feline: 5 mg/kg

Bupivacaine
Canine: 4 mg/kg
Feline: 2 mg/kg

Ropivacaine
Canine: 3 mg/kg
Feline: 2 mg/kg

- Bupivacaine is the most toxic of the LA. The toxic dose is lower; arrhythmias and cardiovascular collapse can be seen at the same time or before early warning signs of toxicity; mortality rates are higher with overdose.

Intra-articular administration of LA has been found to cause chondronecrosis in cattle, horses, dogs and humans and is, therefore, NOT recommended.

Long-acting Bupivacaine Liposome Injectable (Nocita)

Nocita is approved as a one dose, long-acting local anesthetic, providing up to 72 hours of analgesia for cranial cruciate ligament repair surgery in dogs.

- Do not administer concurrently with other local anesthetics.
- Nocita is administered by infiltration into all tissues of each surgical layer.
- Until more data and labeling become available, any use outside of CCL should be avoided.

Intratesticular blocks

Intratesticular blocks should be employed in canine and feline castration and will greatly decrease the inhalant anesthetic requirement and the response to clamping of the spermatic cord during castration. Lidocaine (2 mg/kg) is used for this procedure since the testicles will be removed and not be a source of postoperative pain. A 25-gauge needle should be used to limit trauma and the possibility of hematoma formation.

Procedure

- Perform initial surgical preparation
- Grasp testicle and tense against scrotal skin
- Insert the needle into the caudal pole of the testicle and advance toward the center of the testicle
- Aspirate to ensure intravascular injection does not occur
- Inject slowly one-half of the volume or until the testicle feels turgid
- Repeat with the second testicle and finish surgical preparation

Line blocks

Line blocks can be very effective for incisional pain, particularly abdominal incisions, and should be employed in ovariohysterectomies. Abide by dosing guidelines (lidocaine 2 mg/kg, bupivacaine 1.5 mg/kg) and dilute with sterile water if more volume is needed. Blocks are most effective when performed before the surgical incision is made but can also be performed at the end of surgery when the linea has been closed.

Ring blocks

Ring blocks were most often employed for feline procedures but can also be used for canine dewclaw removal, digit mass removal or digit amputation.

Table 2.2

Specific local anesthetic techniques

Name	Nerves/ tissues affected	Major landmark(s)	Indications	Agent and dose	Volume	Comments
Intratesticular	Testicular (spermatic cord)	Caudal pole of testicle	Castration	2 mg/kg lidocaine	Inject slowly ½ of volume or until testicle feels turgid	Use 25-gauge needle to limit trauma and possibility of hematoma formation
Line block	Intercostals and others	Linea alba	Abdominal incision	2 mg/kg lidocaine OR 1.5 mg/kg bupivacaine	**Canine:** 0.5–1.0 mL/site **Feline:** 0.2–0.3 mL/site Dilute with sterile water if more volume needed	Most effective when performed before the surgical incision is made but can also be performed at the end of surgery when the linea has been closed
Ring block	Radial (superficial branches) and Ulnar (medial, dorsal, and palmar branches)	Accessory carpal pad and proximal carpus	Digit mass removal/ amputation	1–1.5 mg/kg bupivacaine	**Canine:** 0.5–1.0 mL/site **Feline:** 0.2–0.3 mL/site Dilute with sterile water if more volume needed	Remember doses are cumulative. Do not administer IV.

Field blocks

Field blocks are an excellent technique to provide analgesia for small, superficial mass removals. They can also be helpful in providing multimodal analgesia for larger mass removals under general anesthesia. **Use caution to not exceed the recommended dose.**

Splash blocks

Splash blocks are considered inconsistent and of limited efficacy.

Dental nerve blocks

- Oral procedures can be quite painful; therefore, analgesia should be part of these protocols. Dental nerve blocks should be used as part of a multimodal analgesia/anesthesia plan. Local anesthetics have limited duration of action and the concurrent use of other parenteral analgesic agents is indicated.
- The commonly used blocks include mental, inferior alveolar (mandibular), infraorbital and caudal maxillary.
- A 25-gauge needle is commonly used but needle size should be adjusted to patient size and dental block performed.
- **Bupivacaine** is the drug of choice for veterinary dentistry.
  - The typical volume per injection site is 0.5 - 1 mL for dogs and 0.2 - 0.3 mL for cats.
  - An additional 50% may be administered for the infraorbital block.
  - Dilute with sterile water if more volume is required.

BEWARE OF CUMULATIVE DOSE LEVELS

  - Always calculate maximum cumulative dose: 2 mg/kg for dogs and 1.5 mg/kg for cats
  - The addition of buprenorphine (0.003–0.005 mg/kg) can enhance the analgesic duration of effect for bupivacaine when used in regional anesthetic blocks.
  - Mix the total dose of buprenorphine, with the total dose of bupivacaine and divide between the injection sites.

Table 2.3

Dental nerve blocks

Name	Foramen	Major landmark(s)	Tissues blocked on infiltrated side	Comments
Caudal Maxillary – infraorbital approach	Infraorbital	Maxillary indentation dorsal to distal root of third premolar (dogs) and second premolar (cats)	Bone, teeth, soft tissue and palate	Use longer needle and increase volume by 50% compared to infraorbital
Caudal Maxillary – maxillary tuberosity approach	Pterygopalatine fossa	Notch where zygomatic arch meets maxilla	Bone, teeth, soft tissue and palate	Maxillary artery, ocular globe, zygomatic salivary gland and deep facial vein in close proximity
Inferior Alveolar (mandibular) – extraoral approach	Mandibular	Palpable notch on ventral mandible cranial to angular process	Bone, teeth, soft tissue and tongue	Use intraoral approach if notch cannot be palpated
Inferior Alveolar (mandibular) – intraoral approach	Mandibular	Two thirds of the distance from last molar to angular process	Bone, teeth, soft tissue and tongue	Foramen is one-half to one inch from ventral surface of mandible in dogs (one-quarter inch in cats)
Infraorbital	Infraorbital	Maxillary indentation dorsal to distal root of third premolar (dogs) and second premolar (cats)	Bone, teeth, soft tissue rostral to upper fourth premolar	Canal is very short in cats and brachycephalic dogs
Mental	Middle mental	Mesial root of lower second pre-molar	All oral tissues rostral to second premolar	Difficult to palpate in cats and small dogs. Consider inferior alveolar (mandibular) in these pets

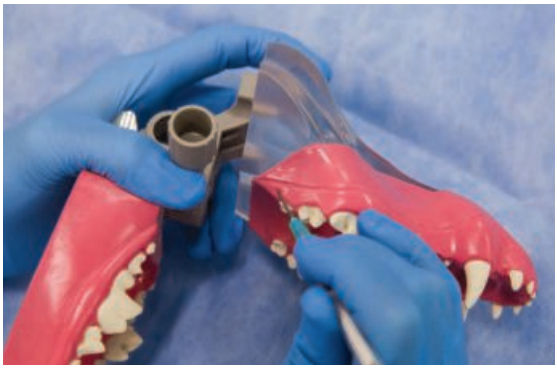
Typical volume of bupivacaine per injection site is 0.5 - 1.0 mL for dogs and 0.2 - 0.3 mL for cats.
Always calculate maximum cumulative dose. Bupivacaine: 2 mg/kg for dogs and 1.5 mg/kg for cats.

Caudal maxillary nerve block

This block anesthetizes the bone, teeth, soft tissue and palate on the infiltrated side. It involves blind placement of LA into the pterygopalatine fossa. There are two approaches: maxillary tuberosity and infraorbital. For either approach, the nerve is blocked before it enters the caudal aspect of the infraorbital foramen.

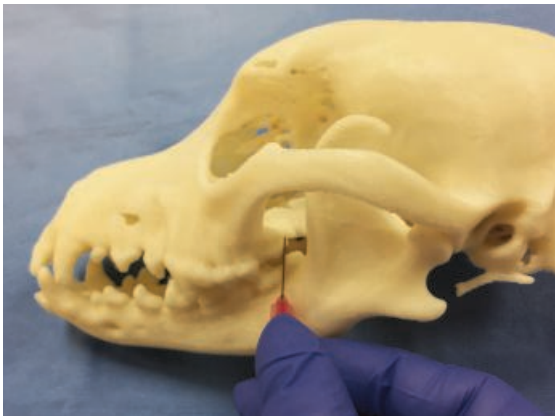
BE AWARE! The nerve runs close to the maxillary artery, ventral to the ocular globe, zygomatic salivary gland and deep facial vein.

Figure 2.2



Caudal maxillary nerve block on a dog model.

Figure 2.3



Caudal maxillary nerve block on a dog skull.

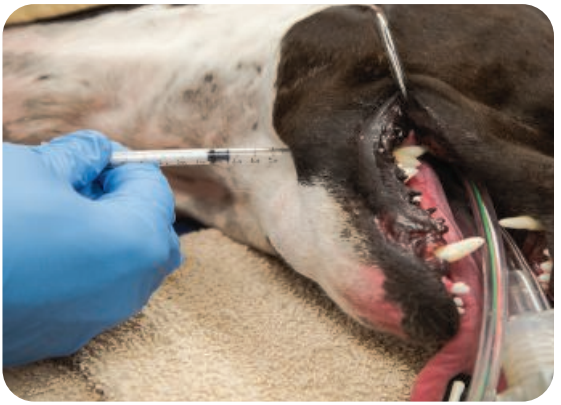
Photo used with permission from Bonnie L. Hay Kraus, DVM, DACVS, DACVAA.

- **The infraorbital approach** is comparable to the infraorbital nerve block with the exception that a longer needle is used to insert into the infraorbital foramen to approximately the level of medial canthus and the volume of LA injected is increased by about 50%.
- **The maxillary tuberosity approach** is an intraoral approach: Palpate the notch where the zygomatic arch meets the bone surrounding the last upper molar. Insert the needle directly adjacent to the bone at this level, keeping the needle perpendicular to the hard palate. Advance the needle dorsally to the level just beyond root tips of the last molar. Aspirate and inject slowly. (Figures 2.2–2.3)

Inferior alveolar (mandibular) nerve block

This block anesthetizes the bone, teeth, soft tissue and tongue on the infiltrated side. There are two techniques: extraoral and intraoral.

Figure 2.4



Extraoral approach to Inferior alveolar (mandibular) block in a dog.

Extraoral technique
(Figure 2.4)
There is a palpable notch on the ventral mandible cranial to the angular process. Insert and advance the needle dorsally along the lingual aspect of the mandible to a midpoint between the ventral and dorsal borders of the mandible. This is the location of the mandibular foramen, where the inferior alveolar nerve enters the mandibular canal. Alternatively, a finger can be placed inside mouth along the mandible to palpate the foramen and help guide the location of the needle. Keep the needle close to the mandible with the bevel directed toward the bone. Aspirate and inject slowly. If the notch cannot be palpated (cats and some dogs) select a point on the ventral mandible that is located on a vertical plane with the lateral canthus. Or use the intraoral approach.

Notes

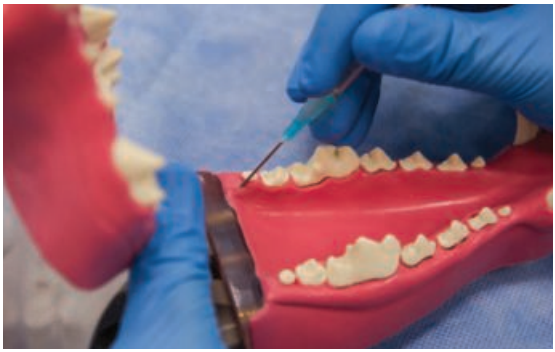
Intraoral technique

The mandibular foramen is located two-thirds of the distance from the last molar to the angular process. The foramen is approximately one-quarter inch from the ventral surface of the mandible in cats. Palpate the angular process extraorally (it is the most caudal and ventral projection of the mandible) and palpate the mandibular foramen intraorally on the lingual surface of mandible. Insert the needle just caudal to the last molar through the mucosa directed ventrocaudally towards the angular process of the mandible and along the lingual surface of the mandible adjacent to the foramen. Aspirate and inject slowly. (Figures 2.5–2.7)

Infraorbital block

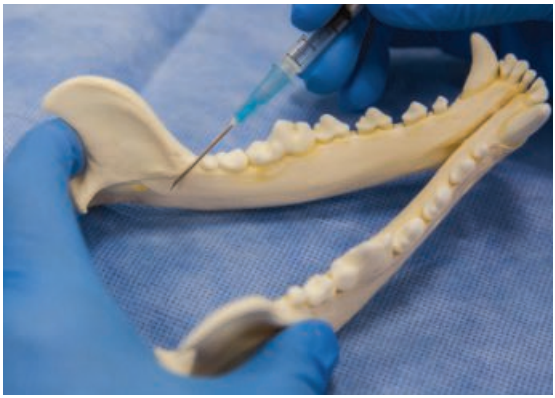
The infraorbital block anesthetizes bone, soft tissue and teeth rostral to the upper fourth premolar. In dogs, the infraorbital foramen, which contains the nerve, can be palpated as an indentation at

Figure 2.5



Intraoral approach to the Inferior alveolar nerve block on a dog model.

Figure 2.6



Intraoral approach to the Inferior alveolar nerve block on a dog skull.

Figure 2.7

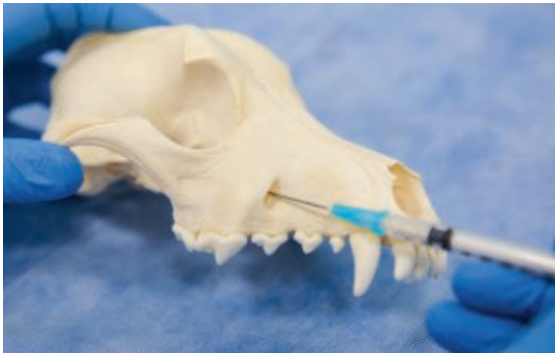
Intraoral approach to the Inferior alveolar nerve block on a cat skull.

the bony ridge in the maxilla just dorsal to the distal root of the third premolar. In cats, the foramen can be palpated as a bony ridge dorsal to the second premolar just ventral to the eye, where the zygomatic arch meets the maxilla. The needle is inserted through the buccal mucosa in a caudal direction parallel to the dental arcade and advanced through the foramen and into the canal. Aspirate and inject slowly. (Figures 2.8–2.10)

Species/breed differences

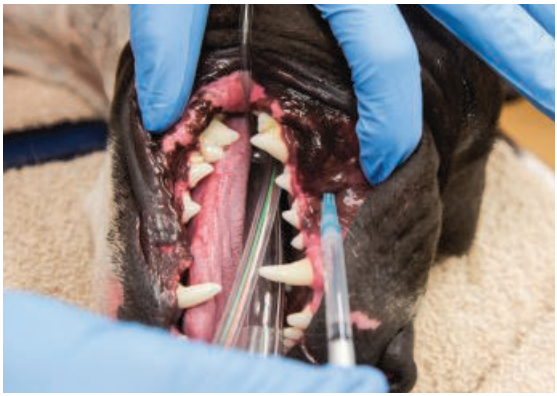
The infraorbital canal is much shorter and only a few millimeters long in cats and brachycephalic dogs. Administration of LA agent into the canal likely places it adjacent to the pterygopalatine nerves and the caudal superior nerves, essentially resulting in the same effect as the caudal maxillary nerve block.

Figure 2.8



Infraorbital nerve block on a dog skull.

Figure 2.9



Infraorbital nerve block in a dog.

Figure 2.10

Infraorbital nerve block on a cat skull.

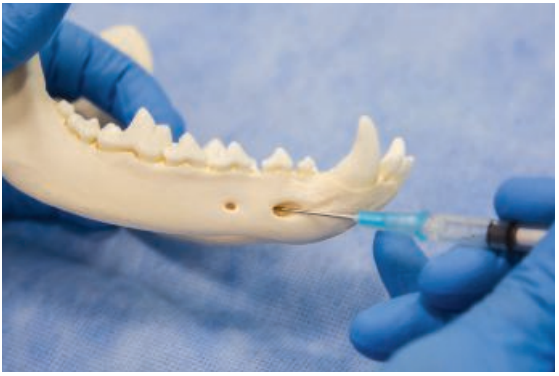
Anatomy
The areas affected by the infraorbital nerve block depend on degree of caudal diffusion of anesthetic agent. Knowledge of the anatomy of the maxillary and infraorbital nerves, including branches, is important when performing this block. The infraorbital nerve is the rostral continuation of the maxillary nerve. The caudal superior alveolar nerve branches off before entering the infraorbital canal and supplies the maxillary fourth premolar and molars. Within the canal, the middle superior alveolar nerves innervate the rest of the premolars. Unless LA diffuses beyond the caudal borders of the infraorbital canal, anesthesia is not provided to the maxillary fourth premolar and molars. Therefore, **except in cats and brachycephalic dogs**, the maxillary nerve block is recommended for anesthesia of the caudal cheek teeth and/or hard and soft palate.

Notes

Mental nerve block

The mental nerve block anesthetizes all oral tissues rostral to the second premolar on the infiltrated side. The middle mental foramen is the largest of the three foramina and is used most often. It can be palpated ventral to the mesial root of the lower second premolar, just caudal to the mandibular labial frenulum. It is difficult to palpate/locate in cats and small dogs; therefore, the inferior alveolar (mandibular) should be considered in those pets. Insert and advance the needle into the opening of the foramen in rostral-to-caudal direction, aspirate and slowly inject. (Figures 2.11–2.12)

Figure 2.11



Middle mental nerve block on a dog skull.

Figure 2.12

Middle mental nerve block in a dog.

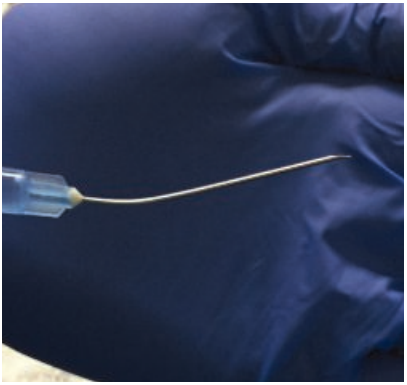
Ocular – retrobulbar block

The retrobulbar block provides regional anesthesia for enucleation, evisceration and prosthesis and/or intraocular surgery. The inferior-temporal palpebral (ITP) technique is the preferred method for retrobulbar administration of anesthetic agent in dogs because it is efficacious, easiest to perform and provides thorough coverage of the intraconal retrobulbar space. (Figures 2.13 - 2.16)

Technique for retrobulbar block:

- Use a one and one-half inch, 22-gauge needle bent at an approximately 20 degree angle (Figure 2.13)
- Clip lower eyelid hair or use a transconjunctival approach (Figure 2.14)
- Perform routine ophthalmic surgical preparation
- The landmarks are the lateral canthus and middle of lower eyelid
- Position needle midway between these points, along the lower eyelid at the orbital rim (Figure 2.15)
- Advance the needle until slight popping sensation is detected (piercing of orbital fascia)
- Direct needle slightly dorsal and nasally toward apex of orbit and advance approximately 1 - 2 cm (Figure 2.16)
- Aspirate prior to injection
- If resistance to injection is felt, draw back and redirect slightly

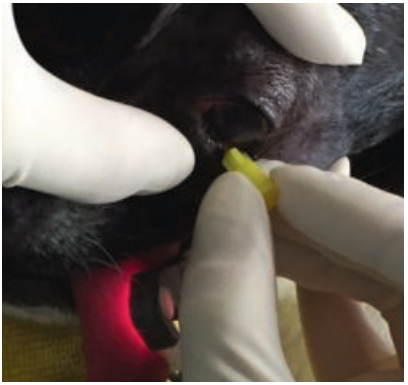
Figure 2.13



Correct needle angle for ITP technique for retrobulbar block.

Photo used with permission by Dr. Bonnie L. Hay Kraus, DVM, DACVS, DACVAA.

Figure 2.14



Transconjunctival approach for ITP technique.

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Figure 2.15

Percutaneous approach for ITP technique.

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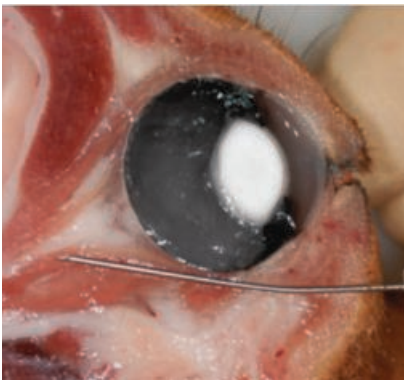
Figure 2.16



Cross section showing proper needle placement.

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Intercostal Blocks

These are an excellent technique to provide comfort and analgesia for fractured ribs, chest tube placement or thoracotomy. Two intercostal spaces cranial and two intercostal spaces caudal to the site of incision or tube placement should be blocked. The injection should be placed on the caudal aspect of the ribs as proximal as possible. Vessels run close to the intercostal nerves on the caudal aspect of the ribs, so always aspirate prior to injection to ensure intravascular injection is not occurring.

Lumbo-Sacral (LS) epidural

Epidural analgesia allows delivery of analgesic drugs in close proximity to their site of action, resulting in more profound analgesia and the ability to lower drug dosages, leading to fewer systemic side effects. It provides pre-emptive analgesia and decreases the inhalant anesthetic requirement and therefore results in less cardiovascular depression. Epidural analgesia with morphine can provide postoperative analgesia for up to 18–24 hours. Inclusion of LA (typically bupivacaine) will also provide anesthesia.

Contraindications

- Bleeding disorders (coagulopathy, thrombocytopenia)
  - Hemorrhage may cause spinal compression, neurologic deficits and pain
- Infection or neoplasia at injection site
  - Risk of introducing infection/neoplasia into spinal cord or CSF
- Hypovolemia/hypotension, if using LA
  - Local anesthetics block motor, sensory and autonomic fibers, resulting in vasodilation
- Pre-existing neurologic deficits in area to be blocked
  - Difficult to assess progression of deficits
- Septicemia
  - Problem if vessel penetrated (controversial)
- Congenital or traumatic anatomic abnormalities if anatomic landmarks cannot be identified

Equipment

Medium to large dogs	20-gauge spinal needles in varying lengths (1.5–3.5 inches)
Small dogs and cats	22-gauge spinal needles in varying lengths (1.5–3.5 inches)

Preparation

The injection site should be clipped of hair and receive a surgical preparation to avoid infection/abscess of the epidural space and discospondylitis.

Positioning

Pets may be positioned in either sternal or lateral recumbency. Sternal recumbency has several advantages as it is easier for the veterinarian to keep the spinal needle in the correct planes with respect to cranial/caudal and side-to-side orientation. It also allows use of the "hanging drop" technique for confirmation of correct needle placement.

The hind limbs may be positioned in one of two ways while the pet is in sternal recumbency:

1. "Frog-legged" with the hind limbs resting on the stifle and the feet extended posteriorly. This position may allow easier palpation of anatomical landmarks in obese patients.
2. Rostral extension of the hindlimbs. A recent computed tomography (CT) study indicated that rostral extension of the hind limbs significantly increases lumbo-sacral (LS) and L6–L7 distance and LS angle and may enhance the ease of lumbo-sacral epidural injection in sternally recumbent anesthetized dogs.

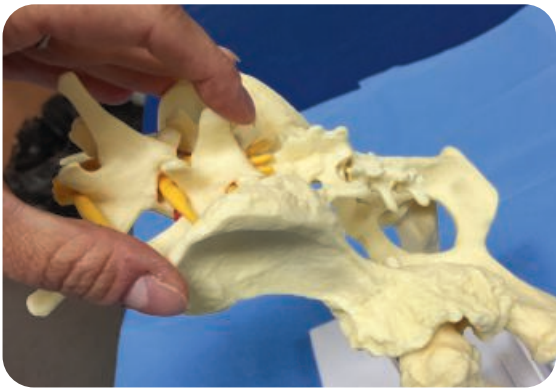
Lumbo-sacral epidurals may also be administered in pets in lateral recumbency. In cases not amenable to sternal positioning, such as fermoral fracture or severe, multiple pelvic fractures, the hind limbs are taped or held in a rostral position by an assistant.

Notes

Anatomic landmarks

The thumb and third finger of the veterinarian's non-dominant hand are used to palpate the cranial border of the iliac crests. The index finger is placed on the pet's midline and palpates the LS space as a depression on the midline. The index finger is also used to confirm the proper space by palpating cranially (the dorsal spinous process of L6 is larger than L7) and caudally (the sacrum does not have intervertebral spaces). (Figures 2.17–2.18)

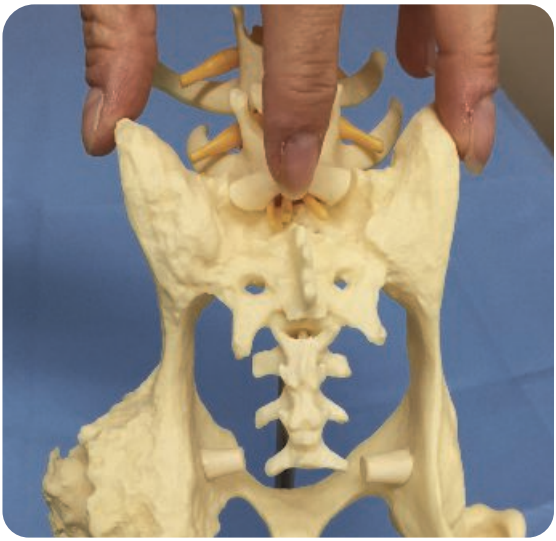
Figure 2.17



Anatomic specimen depicting palpation of landmarks.

Used with permission from Bonnie L. Hay Kraus, DVM, DACVS, DACVAA.

Figure 2.18



Anatomic specimen depicting palpation of landmarks.

Used with permission from Bonnie L. Hay Kraus, DVM, DACVS, DACVAA.

Technique

The spinal needle is inserted on the midline, caudal to L7 approximately in the middle of the LS space. The needle is positioned perpendicular to the pelvis with the bevel of the needle directed cranially. The needle will traverse through the skin, subcutaneous tissue and interspinous ligament and the stylet is removed. If the "hanging drop" technique is being used, the hub of the needle is filled with the drug to be administered to be used as a "hanging drop" (see *Confirmation of proper needle placement* below). As the needle is then advanced, a "popping" sensation may be felt as the needle penetrates

the ligamentum flavum (interarcuate ligament). The tail may twitch if the needle comes in contact with the cauda equina. If the veterinarian feels he/she is "hitting bone," reassess the angle of the needle placement and adjust to increase or decrease the angle for proper placement. If the angle seems correct, the needle may be embedded in the ventral aspect of the vertebral canal. In this instance, careful, slight retraction of the needle may allow the "hanging drop" to be drawn into the space.

Confirmation of proper needle placement

Proper epidural placement can be confirmed by use of the "hanging drop" technique. The "hanging drop" technique can only be used when the pet is positioned in sternal recumbency. The hub of the spinal needle is filled with saline or the drug to be delivered before penetration of the ligamentum flavum. Once the ligament is penetrated, the solution is drawn into epidural space due to negative pressure.

Injection

Prior to injection, the hub of the spinal needle should be observed for the presence of CSF or blood. If blood is observed, the spinal needle should be withdrawn and the epidural can be attempted again with a new spinal needle. DO NOT inject drugs intended for epidural administration if blood is observed as inadvertent IV injection of LA is the most common cause of systemic toxicity (convulsions, cardiovascular depression). Bupivacaine, which is a commonly used LA for epidural administration, may cause non-resuscitatable cardiac arrest due to its increased cardiotoxicity. Therefore, it is recommended to **always aspirate before injection**.

Cerebrospinal fluid may be observed in the hub of the spinal needle after placement. This indicates that a subarachnoid puncture has occurred and that spinal anesthesia/analgesia, rather than epidural, will be achieved with drug injection. **Subarachnoid administration will result in more cranial migration of drugs and more rapid onset of anesthesia/analgesia.** Therefore, the calculated dose should be reduced to one-quarter to one-half of that intended for epidural administration.

Size differences

There are species and size/age differences with respect to where the spinal cord ends. The spinal cord typically ends at L7 in medium/large adult dogs, however, in cats and in small or young dogs, the spinal cord and meninges may extend to the LS space.

Drugs

The most commonly used drugs for epidural administration are opioids, LA or a combination of the two drugs.

- **Local anesthetics**

  The site of action for LA administered in the epidural space is primarily the spinal nerve roots. Local anesthetics result in autonomic, sensory and motor blockade. Bupivacaine is the most commonly used LA due to its longer duration of action of four to six hours. Since bupivacaine is preservative-free, a new vial should be opened for each pet and sterile technique used. Local anesthetics should be injected slowly as injection rate may affect cranial migration of the drug.

  Bupivacaine dosing: 0.2 mL/kg blocks up to L1, onset of action may take 20–30 minutes; the surgical side should be placed in a dependent position.

- **Opioids**

  The site of action for epidurally-administered opioids is the opioid receptors in the dorsal horn of the spinal cord. They provide segmental analgesia without sensory, sympathetic or motor blockade. Morphine is the most widely used and studied since its lipid solubility profile makes it the most optimal for epidural administration. It is the least lipid-soluble of the commonly used opioids and, therefore, has the slowest onset of action (up to 60 minutes) but the longest duration of action (up to 24 hours). The more lipid-soluble opioids, such as fentanyl, provide a faster onset of action. However, since they also have more rapid systemic uptake, they have a shorter duration of action and require higher doses, similar to systemic doses. Preservative-free morphine is recommended.

  Morphine dosing: 0.1–0.3 mg/kg (0.1–0.3 mL/kg)

- **Local anesthetic/opioid combinations**

  Using the two drug classes together is reported to have a synergistic effect with improved degree and duration of analgesia at subanalgesic doses.

  Combination dosing: The total dose is divided in half for each drug administered (0.1 mL/kg of morphine + 0.1 mL/kg of bupivacaine). **The maximum suggested volume of injection regardless of protocol is 6 mL.**

Complications

Reported complications with the epidural administration of opioids include respiratory depression, pruritus (reported in humans), delayed hair regrowth and urinary retention. Urinary bladder management should include emptying the bladder at the time of surgery (expression or urinary catheterization) and monitoring bladder size every four to six hours postoperatively until the pet is able to urinate. Since opioids can decrease urine production and increase urinary sphincter tone, if a pet is not urinating on its own by the morning following surgery, the cause must be investigated. Caution should be used when attempting to express a full bladder in a pet that has had an epidural. **Passing a urinary catheter or partial/full opioid reversal may be preferred to avoid urinary bladder rupture.**

Notes

Caudal epidural block (sacro-coccygeal block)

Indications

- This technique was developed to facilitate passage of urinary catheters in cats with urinary blockage but it can also be used in dogs or cats for perineal procedures (*e.g.*, hernias, anal sacculectomy).[13]
- Urethral obstruction (common presentation in male cats)

Rapid relief of the obstruction is the primary goal of treatment.

- General anesthesia or heavy sedation is necessary in most cases to avoid urethral trauma or rupture during the unblocking process.
- The electrolyte and acid/base abnormalities, along with dehydration, put these pets at increased risk for anesthetic complications, including cardiac arrest.
- A caudal epidural is a relatively simple and quick procedure to perform that provides anesthesia/analgesia to the perineum, penis, urethra, colon and anus by blocking the pudendal, pelvic and caudal nerves.
- Typically, there is no loss of motor function to hind limbs unless large doses are used or the pet is placed in a "head down" position during the surgical procedure.

Equipment

Very large or obese dogs	22-gauge, 1.5-inch spinal needle
Small to medium dogs	22-gauge, 1-inch spinal needle
Cats	25-gauge, 1-inch spinal needle

Preparation

Clip hair, perform sterile preparation and wear sterile gloves.

Positioning

This procedure should be performed under sedation or general anesthesia except in the rare event the pet is obtunded.

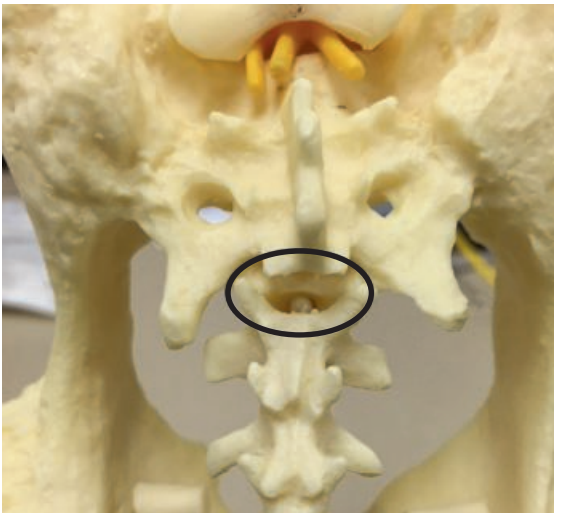
Place pet in sternal recumbency with hindlimbs in a neutral position or frog-legged.

Anatomic landmarks

The injection site is caudal to the end of the spinal cord (spinal cord ends at approximately S1 in cats and L7 in dogs) and this lowers the risk of many of the complications that can be associated with LS epidurals.

Palpate the space between the sacrum - Cd1 or Cd1–Cd2, which can be easily identified by having a team member move the tail up and down. The sacral crest is immobile but the mobility of the coccygeal vertebra can be palpated when the tail is moved. (Figures 2.19–2.20)

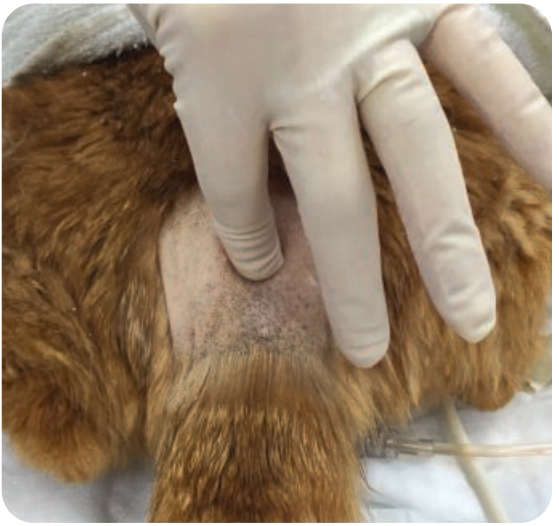
Figure 2.19: Caudal epidural



This figure shows a dorsal view of the sacral caudal 1 (S-Cd1) intervertebral space.

Photo used with permission by Dr. Bonnie L. Hay Kraus, DVM, DACVS, DACVAA.

Figure 2.20



Base of the tail and caudal sacral area are clipped of hair and a sterile prep performed. The veterinarian palpates the sacral-caudal 1 (SCd1) space while a team member moves the tail gently up and down.

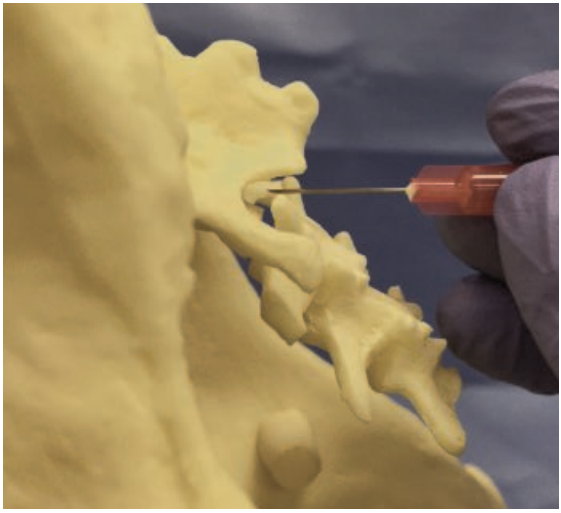
Photo used with permission by Dr. Bonnie L. Hay Kraus, DVM, DACVS, DACVAA.

Technique

Identify the most mobile joint caudal to the sacrum with the nondominant index finger. A team member should mobilize the tail to avoid breaking sterility. The dominant hand is used to place the needle.

Insert the needle on midline at a 30–45 degree angle (Figure 2.21). The needle penetrates the skin at the midline and advanced through the interarcuate ligament/ligamentum flavum. The index finger may serve as guide for needle placement.

Figure 2.21: Caudal epidural



This figure shows a lateral view of a dog pelvis model illustrating the needle angle for a caudal epidural at the sacral caudal 1 (S-Cd1) intervertebral space.

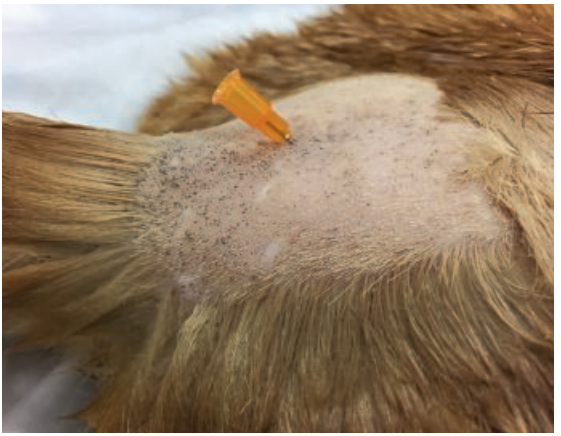
Photo used with permission by Dr. Bonnie L. Hay Kraus, DVM, DACVS, DACVAA.

Notes

Confirmation of proper needle placement

The palpable "pop" may be encountered but is not as evident as with LS epidurals. The needle is advanced into the epidural space. Bone may be encountered if the needle is too superficial to the spinal canal (and should be redirected) or if it has advanced through the epidural space to the floor of the vertebral canal. (Figures 2.22 –2.23)

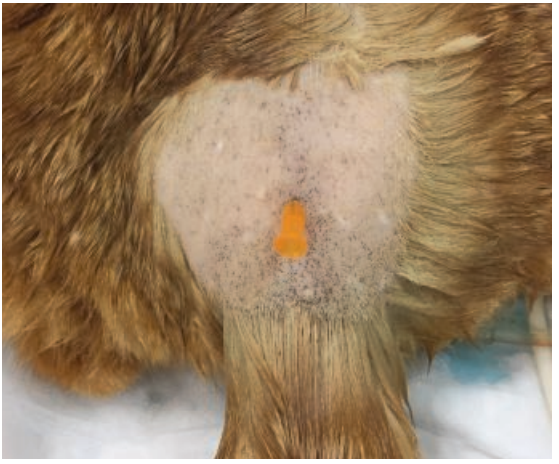
Figure 2.22



Lateral view with the needle in place at the sacrococcygeal space.

Photo used with permission by Dr. Bonnie L. Hay Kraus, DVM, DACVS, DACVAA.

Figure 2.23



Dorsal view of the needle in place at the sacrococcygeal space.

Photo used with permission by Dr. Bonnie L. Hay Kraus, DVM, DACVS, DACVAA.

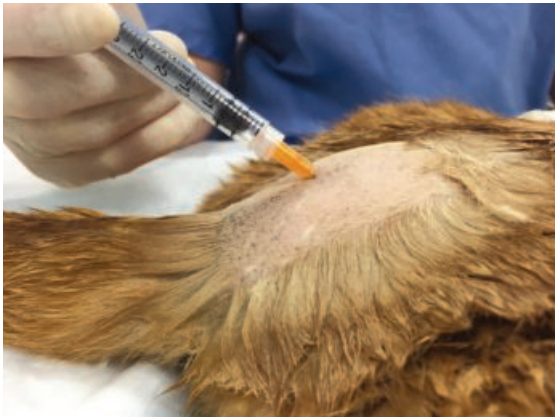
Injection

Attach syringe, aspirate for blood and inject slowly (Figure 2.24). There should be minimal resistance to injection.

If resistance is encountered, the veterinarian should redirect the needle for proper placement.

If blood is encountered, the needle should be removed and a second attempt can be performed with a new sterile needle. If the block is being performed to facilitate passage of a urinary catheter, the rectum and tail should be observed for relaxation prior to attempting catheterization. Pinching of the tail or perianal region can be used to elicit a response from the pet to confirm successful placement of the block.

Figure 2.24



If no blood is encountered, the LA is injected. No resistance to injection should be encountered.

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Notes

Drugs

- Use preservative-free lidocaine or bupivacaine.
- A new bottle should be opened for each patient and aseptic technique used for drawing up the LA. Remember to calculate maximum dosages. The higher end of the dose may result in hind limb weakness, especially in larger cats or dogs.

Dosing: 0.1–0.2 mL/kg (average volume of 0.5 - 1.0 mL per 5 kg cat)

- The onset of action of lidocaine is quick (approximately 5 minutes).
- Lidocaine's duration of action is approximately 60–90 minutes.
- Bupivacaine's onset of action may take a bit longer; however, a recent study indicated that the onset may be as quick as 5–10 minutes.
- Bupivacaine's duration of action is 2.5–6 hours, which makes it ideal for longer anesthesia/analgesia to prevent discomfort if the urinary catheter is maintained in place, prevent urethral spasm or for post-op analgesia after surgery.

Complications

If relaxation is not observed within five minutes, the block may have been injected outside of the epidural space. A second dose may be attempted. Hind limb weakness may be encountered in cases where higher doses or repeat injections are administered.

Notes

Postoperative analgesic plan

Adequate pain management must also follow through into the postoperative period and proper planning is required for transitioning through recovery. Opioid analgesics should be continued postoperatively and dosed according to pharmacokinetic recommendations and pet pain assessment.

- Opioids are typically administered by intermittent injection
- Fentanyl requires CRI due to short duration of action (See *fentanyl CRI* in *Appendix*)
- Multimodal CRIs – See *Appendix*
- Fentanyl patch – See *Appendix*

Nonsteroidal anti-inflammatory drugs (NSAIDs)

NSAIDs act as non-selective inhibitors of the enzyme cyclooxygenase (COX) and, thereby, the synthesis of prostaglandins and thromboxanes from arachidonic acid, which is derived from the cellular phospholipid membrane by phospholipid A. Most NSAIDs inhibit the activity of COX-1 and COX-2 to varying degrees, depending on the specific drug. Cyclooxygenase-1 produces prostaglandins that support platelet function and protect the stomach and GI system. COX-2 produces prostaglandins that promote inflammation and pain. Blocking this isoform leads to the anti-inflammatory, analgesic and antipyretic effects of NSAIDs.

The clinical response to a particular drug is individualistic and pets may respond favorably to one drug and not another. If the desired clinical response is not achieved, try a different NSAID once the appropriate washout period has been achieved.

Advantages of NSAIDs:

- Can be used for soft tissue and/or orthopedic pain
- Can be used for acute and/or chronic pain
- Have a long duration of action
- Are relatively economical
- Are not controlled substances
- Do not cause sedation, respiratory or cardiovascular depression

Precautions/contraindications of NSAIDs:

- Should not be used in severely dehydrated pets, pets with acute blood loss, liver, renal, GI, coagulation or platelet dysfunction or pregnant pets
- Should not be used in conjunction with other NSAIDs or corticosteroids
- Pets should be monitored closely for GI upset (vomiting, diarrhea), abnormal bleeding and lethargy.

The use of NSAIDs in premedication protocols or intraoperative administration is not recommended and should be done with EXTREME caution.

- NSAIDs can affect renal pressures. Any hypotension during surgery can decrease renal blood flow and GFR, precipitating renal disease.
- Peak plasma concentration after SC administration is delayed. Anesthetic sparing and pain control is more beneficial from an opioid.

Notes

Carprofen #		
Class	COX-2 selective	
Uses	Approved in oral and injectable formulation to treat postoperative and osteoarthritis (OA) pain and inflammation	
Dosing	**Canine only**	2–2.2 mg/kg every 12 hours
		4–4.4 mg/kg every 24 hours
Route	PO, SC	
Peak effect	1–3 hours	
Side effects	Primarily associated with the GI tract; idiosyncratic hepatotoxicosis has been associated with carprofen (incidence less than 0.06%). Clinical signs include anorexia, vomiting and icterus with increased hepatic enzymes. Most dogs recover with discontinuation of the drug and supportive care.	
Elimination half-life	8 hours (may not be good predictor of duration of effect)	
Reversal agent	No	
Supplemental information	■ Is only approved for use in dogs in the United States ■ Does not appear to affect platelet function or cause excessive bleeding in surgical procedures ■ Has not been shown to alter renal function or hemostasis in healthy dogs undergoing anesthesia	

Drug legend: * extra-label # FDA labeled

Deracoxib #		
Class	COX-2 selective	
Uses	Oral formulation approved for use in dogs for pain and inflammation associated with OA and postoperative pain associated with orthopedic surgery	
Dosing	**Canine only**	3–4 mg/kg every 24 hours for postoperative pain
		1–2 mg/kg postoperative every 24 hours for OA
Route	PO	
Peak effect	2 hours	
Side effects	Typically related to the GI system, especially at higher doses (3–4 mg/kg) or with concurrent corticosteroid or other NSAID use	
Elimination half-life	Dependent on dose; roughly 3 hours	
Reversal agent	No	

Meloxicam #		
Class	COX-2 selective	
Uses	Approved for use in dogs for the control of pain and inflammation-associated surgery and OA	
Dosing	**Canine**	0.2 mg/kg on day 1 then 0.1 mg/kg every 24 hours
	Feline	0.3 mg/kg SC once, with NO oral dosing 0.1–0.2 mg/kg SC once, followed by oral dosing
Route	PO, SC	
Peak effect	Roughly 7–8 hours	
Side effects	Primarily related to the GI tract	
Elimination half-life	**Canine**	24 hours
Reversal agent	No	
Supplemental information	Approved for use in cats for a single dose to control pain inflammation associated with orthopedic surgery, OVH and castration.	

Oral dosing is extra-label in cats

Drug legend: * extra-label # FDA labeled

Robenacoxib #			
Class	COX-2 selective		
Uses	Approved for use in cats for 3 days for postoperative pain		
Dosing	**Canine**	2 mg/kg SC	Once daily for a maximum of 3 total doses over 3 days
	Feline	1 mg/kg PO	Once daily for a maximum of 3 total doses over 3 days
		2 mg/kg SC	
Route	PO, SC		
Peak effect	Roughly 30 minutes		
Side effects	GI side effects most commonly reported, may be more common in cats with dehydration or pre-existing organ disease		
Elimination half-life	Roughly 1.7 hours (cats)		
Reversal agent	No		
Supplemental information	For use in cats greater than 2.5 kg and over 4 months of age Large safety margin in cats		

Drug legend: * extra-label # FDA labeled

Table 2.4

Nsaid half lives

Drug	Serum Half Life	
Carprofen	8 hours (oral)	
	22–23 hours (injectable)	
Deracoxib	3 hours	
Meloxicam	**Canine**	12–36 hours
	Feline	15 hours
Robenacoxib	1.2–1.7 hours	

Wait 5 – 10 half-lives between NSAIDs when changing medications. See product labels for complete prescription information.

Other Analgesic Options:

*Gabapentin**	
Class	Structural analog of gamma-aminobutyric acid (GABA) ■ Anti-convulsant drug ■ Binds to voltage-gated calcium channels
Uses	May be used as an adjunctive treatment in multimodal analgesic protocols and to treat neuropathic pain. Can be used as an anxiolytic/sedative, especially in cats.
Dosing	5–10 mg/kg (up to 20 mg/kg) every 8–12 hours
Route	PO
Peak effect	2 hours
Side effects	Sedation
Duration of action	Elimination half-life roughly 2–4 hours
Reversal agent	No
Supplemental information	■ Can be increased 25–50% per week in pets with chronic pain until an acceptable comfort level is achieved ■ Liquid formulations **must** be compounded by a licensed compounding pharmacy as the commercially available formulation contains **xylitol** ■ Controlled substance in some states, follow local guidelines.

Drug legend: * extra-label # FDA labeled

Notes

*Tramadol**		
Class	An atypical or weak mu-receptor agonist	
Uses	Chronic use analgesia	
Dosing	**Canine**	5 mg/kg every six hours or 2.5 mg/kg every 4 hours
	Feline	2–4 mg/kg every 6 hours
Route	PO	
Peak effect	Variable	
Side effects	**Canine**	Side effects may be similar to, but of less degree than other opioid drugs and may include constipation, diarrhea, inappetence, vomiting, excess sedation, agitation, anxiety, tremors and dizziness
	Feline	Dose-dependent opioid-like effects can be seen, such as dilated pupils, euphoria (excessive playfulness, kneading, friendliness), sedation, excessive salivation, vomiting, dysphoria and facial itch (evidenced by facial scratching and rubbing)
Duration of action	Variable due to number of metabolites formed; total body half-life roughly: **Canine:** 1.7 hours **Feline:** 2.5 hours	
Reversal agent	No	
Supplemental information	Decreases reuptake of norepinephrine and serotonin in the CNS. Contraindicated to use with other selective serotonin reuptake inhibitors (SSRIs; *e.g.*, fluoxetine) or with monoamine oxidase inhibitors (MAOIs; *e.g.*, selegiline) since it may lead to serotonin syndrome. Selective serotonin reuptake inhibitors can also inhibit metabolism of tramadol and decrease its efficacy.[15] ■ Has active metabolites ● O-desmethyltramadol is the M1 metabolite which is responsible for the analgesic effects in human patients. □ In dogs the formation of the M1 metabolite is very low. Dogs primarily form M2 and M5 metabolites. The M2 metabolite is inactive but M5 may have some u-opioid receptor activity. Therefore, the analgesic activity of tramadol in dogs should be regarded as low. □ In cats the primary metabolite formed is M1. ■ Oral tramadol has not been shown to provide effect postoperative analgesia in dogs. ■ Analgesia may be improved when administered in conjunction with NSAIDs, especially in pets with chronic pain conditions.	

Drug legend: * extra-label # FDA labeled

Postoperative pain assessment

It is very important to provide adequate analgesia in the postoperative period. Each pet is an individual and will have varying degrees of pain tolerance and varying responses to drugs. Stress and anxiety are also important factors to consider as they have a significant negative effect on overall pet well-being and the behavior responses can be difficult to distinguish from pain.

Postoperative pain management must be tailored to each individual pet's needs. Pain assessment tools, such as the *Colorado State University (CSU) Acute Pain Scales*, can assist in postoperative monitoring of analgesia. As the "fourth vital sign" in veterinary medicine, pets should be assessed for adequate analgesia at regular intervals in concert with temperature, pulse, respiration (TPR) and the pain score noted in the medical record. Reassessment of the pet's analgesic plan should occur when a score of greater than 1.5 is noted. (Figures 2.25–2.26)

Clinical essential

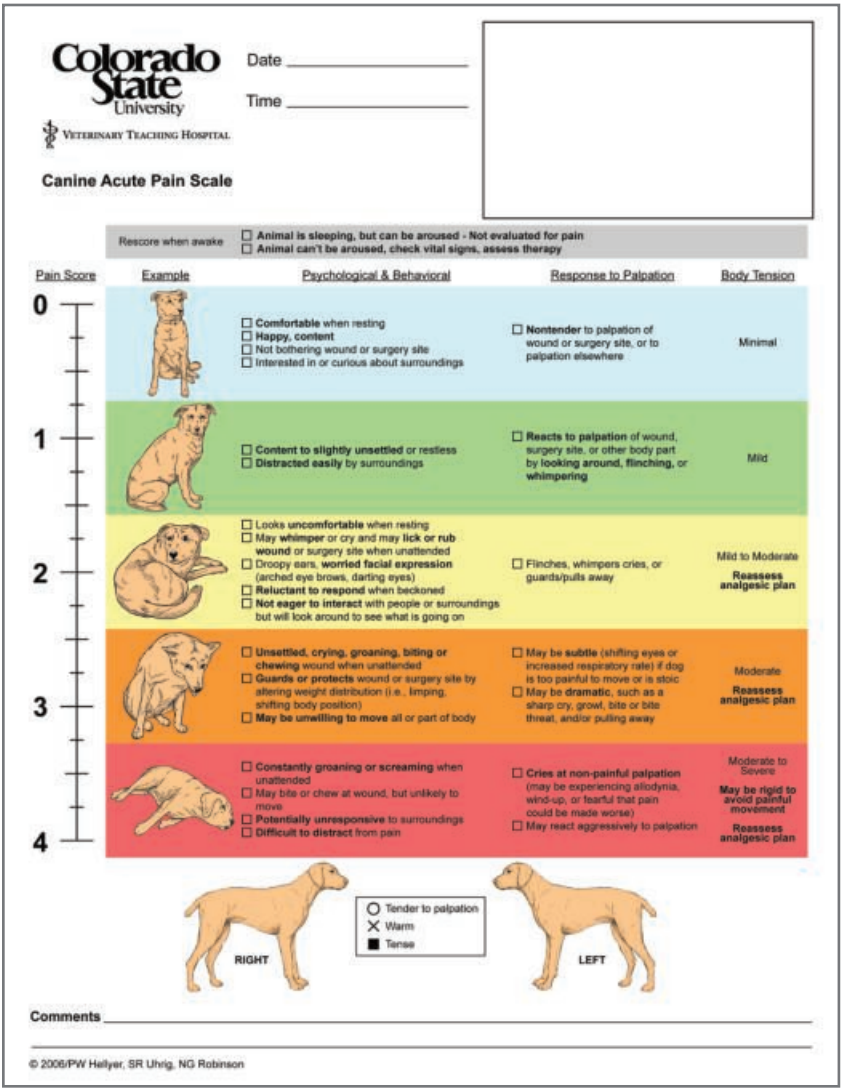
Identify and address immediate and postoperative pain

Instructions for using the CSU acute pain scale

The CSU Acute Pain Scale is intended primarily as a teaching tool and to guide observations of clinical patients. The scale has not been validated and should not be used as a definitive pain score. Use of the scale employs both an observational period and a hands-on evaluation of the patient. In general, the assessment begins with quiet observation of the patient in its cage at a relatively unobtrusive distance. Afterwards, the patient as a whole (wound as well as the entire body) is approached to assess reaction to gentle palpation, indicators of muscle tension and heat, response to interaction, etc.

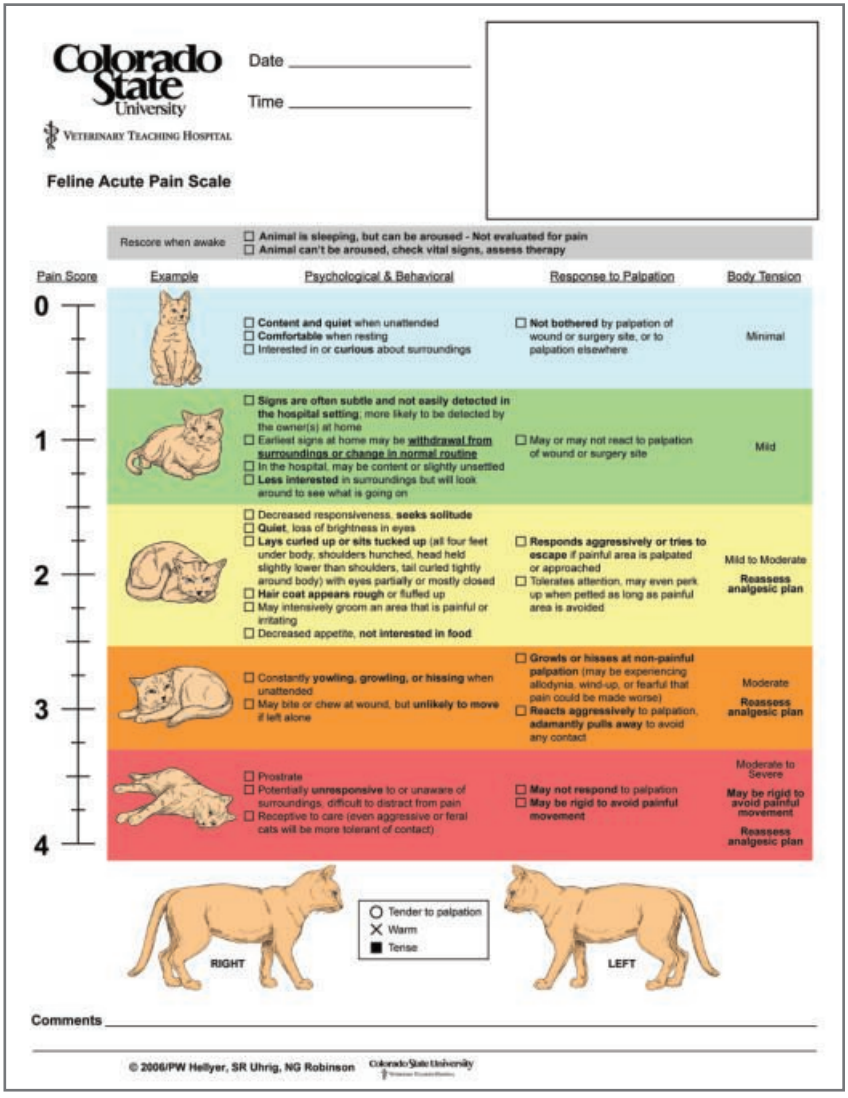
1. The scale utilizes a generic 0–4 scale with quartermarks as its base along with a color scale as a visual cue for progression along the 5-point scale.
2. Realistic artist's renderings of animals at various levels of pain add further visual cues. Additional drawings provide space for recording pain, warmth, and muscle tension; this allows documentation of specific areas of concern in the medical record. A further advantage of these drawings is that the observer is encouraged to assess the overall pain of the patient in addition to focusing on the primary lesion.
3. The scale includes psychological and behavioral signs of pain as well as palpation responses. Further, the scale uses body tension as an evaluation tool, a parameter not addressed in other scales.
4. There is a provision for non-assessment in the resting patient. To the authors' knowledge this is the only scale that emphasizes the importance of delaying assessment in a sleeping patient while prompting the observer to recognize patients that may be inappropriately obtunded by medication or a more serious health concern.
5. Advantages of this scale include ease of use with minimal interpretation required. Specific descriptors for individual behaviors are provided which decreases interobserver variability. Additionally, a scale is provided for both the dog and the cat.
6. A disadvantage of this scale is a lack of validation by clinical studies comparing it to other scales. Further, its use is largely limited to and is intended for use in acute pain.

Figure 2.25



Instruction and pain scales are provided courtesy of Colorado State University Teaching Hospital.

Figure 2.26



Instruction and pain scales are provided courtesy of Colorado State University Teaching Hospital.

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Sedation and immobilization

Jo Ann Morrison, DVM, MS, DACVIM

Abbreviations

BP	blood pressure
ECG	electrocardiogram
IM	intramuscular
IV	intravenous
MAP	mean arterial pressure
O_2	oxygen
PCV	packed cell volume
$PaCO_2$	partial pressure of carbon dioxide in arterial blood
PaO_2	partial pressure of oxygen in arterial blood
SC	subcutaneous
SpO_2	pulse oximetry
T	temperature
TPR	temperature, pulse, respiration

Introduction

Pets may periodically be placed under sedation or be immobilized for diagnostic or therapeutic purposes. Informed client consent, including a review of risks, is required for all sedative and immobilization procedures. Sedation and immobilization may not provide any analgesia, depending on the agents chosen. Therefore, if some degree of pain is anticipated with the procedure, appropriate analgesia must be provided.

Definitions and indications

Definitions

	Sedation	Immobilization
Uses	■ Non-painful procedures and to decrease anxiety	■ Non-surgical plane of anesthesia
Pet status	■ Ambulatory	■ Non-ambulatory
Reflexes	■ All intact	■ Laryngeal and withdrawal reflexes intact ■ Pet roused with minimal effort
Examples	■ Otoscopic examination ■ Blood collection	■ Clipping matted hair ■ Radiographic positioning ■ Pedicure in aggressive pets
Additional information	■ Pet CANNOT be intubated	■ Procedure is **non-painful** and lasts **less than 10 minutes*** ■ Cannot be used in brachycephalic pets

*If immobilization lasts longer than 10 minutes, procedure must be converted to general anesthesia.

Indications

Indications for sedation and immobilization focus primarily on pet and associate safety and quality. Consider if **patient safety** and/or medical **quality** will be enhanced by sedation or immobilization.

Safety

- In some cases, the use of a sedative or immobilizing agent may result in less physical restraint by an associate, dampened stress responses in the pet and a shorter time in the hospital.
- If a sedation or immobilization protocol is to be followed, the providing team is encouraged to think ahead.
  - Plan, set up and communicate among associates the diagnostic and/or therapeutic procedures prior to sedating or immobilizing to minimize stress to the pet and hasten recovery.
  - Ensure that all necessary equipment is functioning appropriately and available for use (e.g., pulse oximetry (SpO2), oxygen (O2) if required, etc.).

Quality

- Pet movement, fear or stress may negatively impact the quality of diagnostic procedures and the effectiveness of therapeutic interventions.
- Consider the impact of the following examples on medical quality:
  - Pet movement on a radiographic study
  - Clinical pathology results from a struggling, stressed pet
  - The inability to:
    - Obtain a urine sample via cystocentesis
    - Complete a thorough physical examination
    - Successfully place an IV catheter

Notes

Monitoring

Continuous monitoring of parameters listed below should always be performed; documentation in the medical record should occur at a minimum of every five minutes or more often as indicated for quality patient care and when medically indicated.

Table 2.5

Monitoring

Procedure	Temperature, Pulse, Respiration (TPR) and Pulse Quality	Blood Pressure (BP), Electrocardiogram (ECG) and Pulse Oximetry (SpO_2)	Oxygen (O_2)
Sedation	■ Every 5–10 minutes if not ambulatory	■ Pulse oximetry recommended for all patients if tolerated	■ Flow-by recommended unless causing increased patient stress
Brachycephalic-specific sedation	■ Every 5 minutes if not ambulatory	■ BP, ECG as directed by veterinarian ■ SPO_2 required	■ Flow-by O_2 required unless causing increased patient stress
Immobilization	■ Every 5 minutes along with anesthetic depth until full recovery	■ BP required ■ ECG as directed by veterinarian ■ SPO_2 required	■ Flow-by for all immobilized pets ■ Either flow by or inhaled O2 via endotracheal tube required, depending on depth of sedation/ anesthesia

Oxygen support provided until SpO_2 normalizes. Preoxygenate based on patient status and tolerance.

Monitoring

Procedure	IV catheter and fluids	Sterile eye lubrication	Additional information
Sedation	■ As directed by veterinarian	■ As directed by veterinarian	■ Brachycephalic pets have unique requirements
Brachycephalic specific sedation	■ As directed by veterinarian	■ As directed by veterinarian	■ Minimize physical restraint and maintain sternal positioning whenever possible ■ Minimize hospital time. ■ **NEVER use a muzzle**
Immobilization	■ Recommended for all immobilized pets ■ Catheter required for propofol administration	■ Required and repeated as needed	■ **DO NOT perform on brachycephalic pets**

Protocols

Any hospital associate has the ability to identify a problem and pause the procedure if there are concerns about pet or associate safety. If concerns have not been addressed, then any associate also has the ability to escalate the issue.

In-hospital sedation – to be used on pets amenable to handling and restraint.

Table 2.6

In-hospital sedation protocols

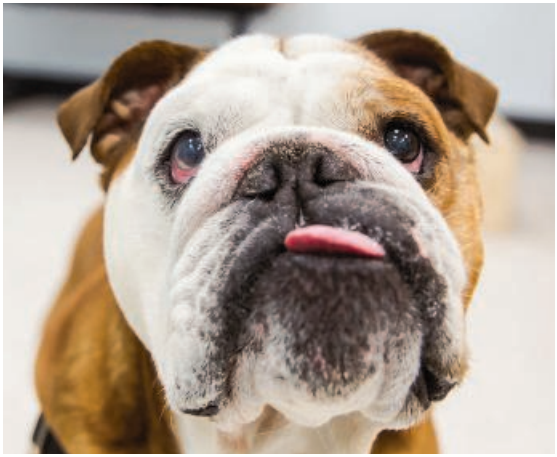
Protocol	Drug(s)	Dosing	Route	Additional information
Single agent Butorphanol	Butorphanol	0.2–0.4 mg/kg	IM, IV or SC	SC administration may provide less predictable activity
Butorphanol and Acepromazine	Butorphanol	0.2–0.4 mg/kg	IM, IV or SC	**DO NOT use Acepromazine on a stressed/ fractious pet** **Maximum Acepromazine dose is 2 mg/ dog and 1 mg/cat** Dilute acepromazine to 1mg/mL prior to use (see *Appendix* chapter for dilution instructions)
	Acepromazine	**Canine:** 0.005–0.05 mg/kg **Feline:** 0.01–0.1 mg/kg		
Butorphanol and Midazolam	Butorphanol	0.2–0.4 mg/kg	IM, IV or SC	Midazolam may be reversed with flumazenil
	Midazolam	0.1–0.3 mg/kg		
Butorphanol and Diazepam	Butorphanol	0.1 mg/kg	IV	Do not mix in same syringe - will precipitate
	Diazepam	0.05 mg/kg		

In-hospital Brachycephalic-specific sedation

- Brachycephalic pet information
  - Defined as pets with relatively broad, short skulls
    - Examples include, but are not limited to, the following breeds:
      - Boston Terrier
      - Boxer
      - English Bulldog
      - French Bulldog
      - Himalayan
      - Lhasa Apso
      - Pekingese
      - Pug
      - Persian cat
      - Shar Pei
      - Shih Tzu (Figure 2.27)
  - Brachycephalic airway syndrome includes one of more of the following components:
    - Elongated soft palate
    - Everted laryngeal saccules
    - Stenotic nares
    - Hypoplastic trachea (Figure 2.28)

Figure 2.27: Brachycephalic Breed (Boxer)

Figure 2.28: Brachycephalic Breed (Bulldog)



Safety concerns with Brachycephalic pets

- A brachycephalic pet is more likely to have chronic hypoxia as evidenced by:
  - Higher packed cell volume (PCV)
  - Higher partial pressure of carbon dioxide in arterial blood ($PaCO_2$)
  - Lower partial pressure of oxygen in arterial blood (PaO_2)
- **This impacts patient safety and increases risk**
- A brachycephalic pet is more likely to be hypertensive.
- Obesity may exacerbate respiratory compromise.
- Points of emphasis:
  - Use the minimum physical restraint necessary.
  - **Never muzzle or restrict the airway of any brachycephalic pet.**
  - Minimize time and stress in the hospital setting.
  - Only use brachycephalic sedation or general anesthesia protocols.
  - Never immobilize a brachycephalic pet.
  - Follow brachycephalic-specific sedation for pets with anatomic or functional abnormalities of any of the following areas:
    - Larynx
    - Pharynx (including excessive pharyngeal folds (*e.g.*, Shar Pei))
    - Trachea
    - Esophagus
  - Due to concerns of respiratory and cardiovascular depression:
    - Acepromazine should be used in brachycephalic pets with extreme caution and avoided if possible.
    - If sedative agents are used for premedication prior to general anesthesia, pets should be induced and intubated as quickly and safely as possible to avoid respiratory compromise.
  - Administration of flow-by O_2 and SpO_2 monitoring is required for sedated brachycephalic pets.

Clinical essential

Keep all pets that have been administered preanesthetic medication under visual observation at all times

- Recognize potential airway issues and compromised respiratory status and be prepared to convert to general anesthesia
  - Have appropriately-sized endotracheal tubes identified and ready for emergency use.
  - Antiemetics (maropitant) are recommended prior to sedation or anesthesia.

Table 2.7

Brachycephalic-specific sedation protocol

Protocol	Drug(s)	Dosing	Route	Additional information
Butorphanol and/or Midazolam	Butorphanol	0.2–0.4 mg/kg	IM or IV	Flow-by O_2 and SpO_2 monitoring required; be prepared to convert to general anesthesia
	Midazolam	0.1–0.3 mg/kg		

If a brachycephalic pet is significantly anxious, consider the addition of low dose (0.01–0.02 mg/kg) Acepromazine as an anxiolytic to help minimize patient stress and further exacerbation of respiratory status.

Use extreme caution with Acepromazine

- Use as low a dose of sedation medications as possible to achieve desired effect.
  - Multiple re-dosings of the same medication are not expected to result in acceptable sedation.
  - In the event of inadequate sedation, another medication should be employed, the procedure aborted and rescheduled, or convert to general anesthesia.
- Additional monitoring is recommended based on pet need and as directed by the veterinarian.
  - BP
  - ECG

- **Brachycephalic pets present a unique challenge for safe sedation. General anesthesia may be a safer option for these pets as it will provide a means to protect the airway.**

- Special notes
  - Other respiratory compromised patients should be handled with the same precautions as brachycephalic pets. Examples include but are not limited to:
    - Laryngeal Paralysis
    - Tracheal Collapse
    - Feline Asthma
  - Refer to the following resources for additional guidelines:
    - *Brachycephalic Pet Restraint Policy*
    - *Brachycephalic Pet Restraint Job Aid*

Notes

Immobilization

Additional information

- **DO NOT USE in brachycephalic pets.**
  - Provide general anesthesia with protected airway for pets with upper airway compromise.
- All immobilized pets receive flow-by or endotracheal tube O2 depending on depth of sedation, SpO2 and BP monitoring.
- Have endotracheal tubes and laryngoscope ready and accessible in case of need.
- Placement of an IV catheter is recommended for all immobilization protocols and required for propofol use.
- Immobilization procedures must be converted to general anesthesia if lasting more than 10 minutes.
- The protocols below are designed for pets that can be safely handled and restrained and require immobilization. If a pet is determined to be too stressed/fractious to safely handle, and the procedure cannot be rescheduled, consider general anesthesia and the use of the *Stressed/Fractious Pet* protocol.

Table 2.8

Canine immobilization protocols*

Protocol	Drug(s)	Dosing	Route	Additional information
Butorphanol, Dexmedetomidine	Butorphanol	0.2 mg/kg	IM or IV	Use with caution in debilitated pets and with lower dose Dexmedetomidine can be reversed with atipamezole
	Dexmedetomidine	2–5 **mcg**/kg		
Butorphanol, Tiletamine, Zolazepam	Butorphanol	0.2 mg/kg	IM	Use with caution in debilitated pets and with lower dose
	Tiletamine, Zolazepam	1–4 mg/kg		
Single Agent Propofol	Propofol	1–8 mg/kg	IV	Administer propofol as previously described Does not provide analgesia

* If immobilization lasts for more than 10 minutes, teams must convert to general anesthesia.

Table 2.9

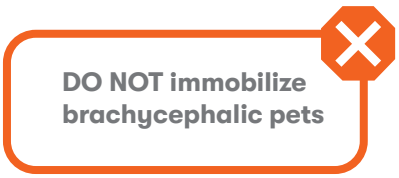
Feline immobilization protocols*

Protocol	Drug(s)	Dosing	Route	Additional information
DKT	Butorphanol, Dexmedetomidine, Ketamine mixture	Compromised cat: 0.035 mL/kg Healthy cat: 0.065 mL/kg	IM	See DKT instructions in the *Appendix* chapter
Single Agent Propofol	Propofol	1–8 mg/kg	IV	Administer propofol as previously described Does not provide analgesia
Dexmedetomidine and Butorphanol	Dexmedetomidine, Butorphanol	Dexmedetomidine 5-10 **mcg**/kg Butorphanol–0.2 mg/kg	IM	Allow 10–15 minutes of quiet before handling. Reversal with Atipamezole may be needed.
Alfaxalone, Butorphanol and Midazolam	Alfaxalone	1–1.5 mg/kg	IM	Alfaxalone is not reversible and can cause twitching upon recovery if sedative not present. Useful in cats with heart disease. Can add dexmedetomidine (2-3 **mcg**/kg) and ketamine 2–3 mg/kg) for highly aggressive cats.
	Butorphanol	0.2 mg/kg		
	Midazolam	0.2–0.3 mg/kg		

* If immobilization lasts for more than 10 minutes, teams must convert to general anesthesia.

Discharge

- Prior to release from the hospital ensure the following:
  - The pet is able to safely walk.
  - Full recovery from sedation or immobilization is achieved (and documented in the medical record):
    - Normotensive (mean arterial pressure (MAP): 80–100 mm Hg)
    - Normothermic (T: 100 –102.5 ° F)
    - Normal oxygenation (SpO_2: 95–100 %) on room air
    - Full neurologic recovery
  - The client is comfortable with the pet's condition



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Induction, monitoring and recovery

Bonnie L. Hay Kraus, DVM, DACVS, DACVAA

Definitions

General anesthesia refers to a procedure that is performed after administration of a medication(s) that results in analgesia, paralysis and unconsciousness. General anesthesia begins with the preanesthetic evaluation and lasts until complete anesthetic recovery is attained.

Induction. The beginning phase of general anesthesia where laryngeal reflexes are lost, allowing intubation. Requires the administration of an induction agent (*e.g.*, propofol).

Intubation. The placement of an endotracheal tube into the patient's trachea, allowing a dedicated and consistent airway.

Anesthetic recovery is defined as that time after anesthesia when a patient is normothermic (temperature greater than 100° F), normotensive (mean arterial pressure (MAP) greater than 80 mm Hg), oxygenating normally (pulse oximetry greater than 95%), mentally appropriate, in sternal recumbency, with pain controlled, after extubation.

Abbreviations

AV	atrioventricular
BER	basal energy requirement
BG	blood glucose
BP	blood pressure
bpm	beats per minute or breaths per minute
CaO_2	blood oxygen content
CNS	central nervous system
CO	cardiac output
CO_2	carbon dioxide
COP	colloid osmotic pressure
CRI	constant rate infusion
CRT	capillary refill time
DAP	diastolic arterial pressure
DO_2	delivery of oxygen to tissues
ECG	electrocardiogram
ENT	ear, nose and throat
ET	endotracheal
$EtCO_2$	end tidal carbon dioxide
f	frequency of respiration
FiO_2	inspired oxygen concentration
GDV	gastric dilatation volvulus
GER	gastroesophageal reflux
HbO_2	oxygen bound to hemoglobin
HR	heart rate
IPPV	intermittent positive pressure ventilation
MAC	minimum alveolar concentration
MAP	mean arterial pressure
MER	maintenance energy requirement
MM	mucous membrane
MV	minute ventilation
NRB	non-rebreathing
O_2	oxygen
OSA	osteosarcoma
$PaCO_2$	partial pressure of arterial carbon dioxide
PaO_2	partial pressure of arterial oxygen
PCV	packed cell volume
PEA	pulseless electrical activity
pH	acidity or alkalinity
PPV	positive pressure ventilation
PRN	as needed
RBC	red blood cell
RR	respiratory rate
SAP	systolic arterial pressure
SpO_2	oxygen saturation
SV	stroke volume
SVR	systemic vascular resistance
TP	total protein
TV	tidal volume
V/Q	ventilation / perfusion
VPC	ventricular premature contraction

Anesthetic induction and intubation

The induction phase of general anesthesia is a critical time and it is imperative that the team member(s) providing anesthesia have all necessary equipment ready and properly checked. The following will help ensure a safe induction phase.

- *Anesthetic Machine Checklist*
- Collection of induction equipment
- Pre-induction patient evaluation

Endotracheal intubation

To be performed in all pets undergoing general anesthesia.

Intubation:

- Allows delivery of oxygen (O_2) and inhalant gas to the pet
- Provides protection of patient airway and prevention of aspiration in the event of vomiting or gastroesophageal regurgitation
- Prevents/decreases waste gas exposure to team members (as would occur with mask administration of inhalant)
- Allows manual or mechanical positive pressure ventilation (PPV) in the event of apnea or hypoventilation
- Provides a patent airway in the event of an emergency

Endotracheal tube selection

See *Equipment* chapter

Endotracheal cuff testing

- Inflate the cuff with a syringe of air until fully inflated.
- Remove the syringe.
- Leave the cuff inflated for at least 10 minutes to check for slow leaks.
  - Apply a thin coat of water soluble lubricant when the cuff is inflated to avoid large amounts of lube in the crevices of the deflated cuff, which could lead to airway obstruction.
  - In urgent situations, if time does not allow, the cuff can be gently squeezed to determine if there are leaks.
- Deflate the cuff with a syringe prior to induction.

Induction equipment

› Supplies for IV catheter placement

- IV catheter (see *Equipment* chapter for size selection), T-port, tape, injection cap, normal **(non-heparinized)** saline for flush
- Local analgesia for IV catheter (if needed for pet comfort and decreased stress):
  - ☐ Liposomal lidocaine cream applied for 30 minutes

OR

  - ☐ Local block using lidocaine and sodium bicarbonate at a 9:1 ratio

› Endotracheal (ET) tubes (see *Equipment* chapter for size selection)

- Three sizes appropriate for pet, cuff leak tested
- Water soluble lubricant
- Tie to secure ET tube

› Laryngoscope

- Small (small dogs and cats) or large blade (medium and large dogs)
- Test light function prior to induction

› Anesthesia machine and checklist (see *Equipment* chapter for breathing circuit selection and proper leak testing)

› Induction agent

› Monitors

Clinical essential

Place an endotracheal tube with every general anesthetic event and/or procedure in which loss of protective airway reflexes occurs

Administration of induction agents

It is important for the anesthesia team to be familiar with the induction agent being used, how to administer, titrate to effect and identify signs of pet readiness for intubation.

- Induction drugs can cause significant cardiopulmonary depression and should be **titrated to effect**.
  - Pets that are moderately-to-profoundly sedated from premedication drugs (such as dexmedetomidine, with or without ketamine or tiletamine/zolazepam) will require significantly **less** induction agent for intubation.
  - The anesthesia team should be familiar with assessing and recognizing pet readiness for ET intubation for the specific agent(s) being used.

Table 2.10

Propofol	
Dosing for healthy pets with premedication	4–6 mg/kg IV
Dosing without premedication	6–8 mg/kg
Optimal dosing to limit cardiopulmonary depression (apnea and hypotension)	■ **Administer 1 mg/kg slowly over 15 seconds** ■ **Continue with increments of approximately 0.5 mg/kg over 15 seconds until intubation can be achieved**

Alfaxalone	
Dosing for healthy pets with premedication	0.5–2 mg/kg IV
Dosing without premedication	1–5 mg/kg IV
Additional Information	■ **Administer slowly to reduce occurrence of apnea** ■ **Rough recovery when used alone, recommend premedication with acepromazine, benzodiazepines or alpha2-agonists.** ■ **Please refer to Anesthesia and Analgesia Book 4 for further information regarding the use of Alfaxalone.**

Signs a pet is ready for ET intubation:

- **Pet relaxation**
- **Eyes roll ventrally**
- **Palpebral reflex weak or absent**
- **Jaw tone relaxes**
- **Loss of swallowing, coughing during intubation attempts**

After induction, keep remaining calculated propofol available in the event the pet rouses or moves during inhalant anesthesia. A small dose (0.5–1.0 mg/kg slowly IV to effect) can be administered to regain unconsciousness. This should only be used when the pet is on a rebreathing system since the time for changing of circuit concentration will be longer than with a non-rebreathing (NRB) circuit.

Anesthetic induction

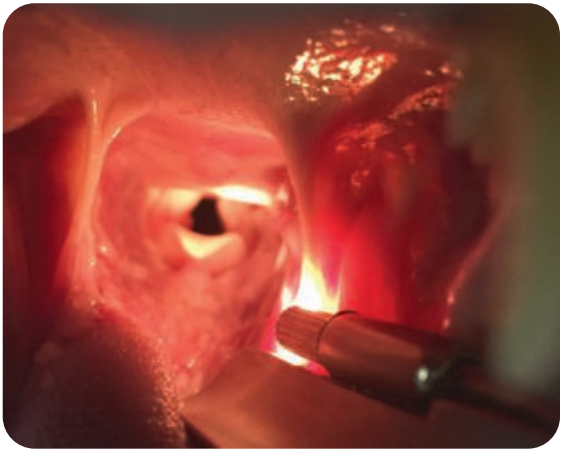
- Check the pet's heart rate (HR) and rhythm, respiratory rate (RR), mucous membrane (MM) color and capillary refill time (CRT).
  - Continuously monitor throughout induction.
- Pre-oxygenate with 50–100 mLs/kg/minute for three to five minutes prior to induction if the pet will tolerate it.
- Ensure completion of *Anesthetic Machine Checklist* .
- Ensure completion of the *Pre-induction Timeout Checklist* (if utilized by hospital teams).
- Confirm the ET tubes are deflated and the cuff is lightly lubricated.
- Place pulse oximeter on the pet's toe, toe web, prepuce or other appropriate site to allow monitoring of pulse and oxygen saturation (SpO_2) during anesthesia induction if tolerated by the pet.

Induction requires a minimum of two team members (additional team members may be needed for large dogs)

Proper pet positioning and restraint for intubation:

- For endotracheal intubation, careful and correct restraint and positioning can make the difference between success and failure, especially in cats.
- The pet is positioned in sternal recumbency.
- The head and neck are extended up and out to promote opening and visualization of the epiglottis and arytenoids.
- The team member holding the pet will place a thumb and forefinger behind the pet's canine teeth.
- The team member performing intubation will gently pull forward on the tongue, straight out of mouth between lower canines. It is very important to **not pull down** on the tongue, as this may cause damage and swelling.
- The blade of the laryngoscope is placed on the tongue, **under the epiglottis** and pressed down to flatten the epiglottis. **Do not touch the epiglottis**. (Figure 2.29)

Figure 2.29: Laryngoscope placement



The blade of the laryngoscope should be placed at the base of the tongue UNDER the epiglottis and pressed down. The epiglottis moves forward and the glottis and arytenoids are visible. Do not touch the epiglottis with the laryngoscope. Feline laryngeal tissues are very delicate and may be damaged or irritated, leading to inflammation or swelling with could result in airway obstruction at recovery.

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Use of a stylet is RARE and should be avoided whenever possible due to the potential for tracheal trauma

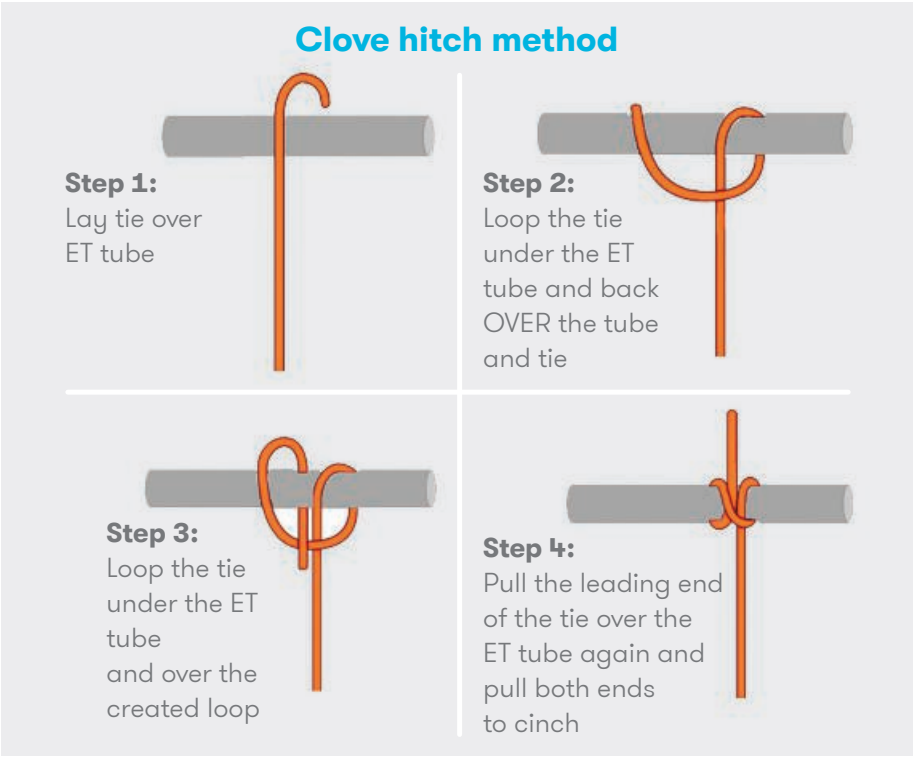
- **FELINE:** A cat's larynx can be easily damaged during forceful intubation and is also prone to laryngospasm if the arytenoids are stimulated during intubation. Therefore, it is recommended that the arytenoids be desensitized with topical lidocaine.
- Using a 1mL syringe, drop <0.1mL of lidociane onto the arytenoids and wait 60–90 seconds. Try to avoid contact with the arytenoid cartilages and vocal folds. Continue oxygen while waiting.
- Alternatively, lidocaine may be gently sprayed on the arytenoids.

Direct the tip of the tube to the ventral aspect of the glottis and into the trachea when the arytenoids open. Rotate the bevel of the tube and advance.

Notes

- **Confirm breathing, HR and rhythm, MM color and CRT**
- Ensure the ET tube is in the trachea via:
  - Pet cough at intubation
  - Fogging of the ET tube
  - Gentle palpation of trachea
  - Capnograph indicating expired carbon dioxide (CO_2) present
  - Movement of the reservoir bag during respiration
- Ensure correct positioning of the ET tube.
  - Gently palpate the tip of the ET tube through the trachea by gripping the trachea with the thumb and forefinger.
  - Gently slide the ET tube in and out a few millimeters.
  - Tip of ET tube should be just cranial to the thoracic inlet.
- Secure the ET tube using recycled IV tubing using the clove hitch method and tie gently around the maxilla for dogs or behind the head for cats and brachycephalic dogs. Do not use rubber bands to secure ET tubes. (Figure 2.30)

Figure 2.30



- Attach to breathing circuit.
  - Turn on O_2 flow.
    - 50–100 mLs/kg/minute for rebreathing system for first 15 minutes after induction
    - 150–300 mLs/kg/minute for NRB circuit (average 200 mL/kg/min)
      - Safe minimum flow rate of 0.5 L/min
- Inflate the ET tube cuff.
  - Attach a syringe filled with air to the end of the pilot line.
  - Close the anesthesia machine pop-off valve.
  - Squeeze the reservoir bag to give the pet a manual positive pressure breath.
  - While observing the pressure manometer, inflate the cuff until there is no leak present at a pressure of 15–20 cm H_2O while squeezing the bag. Once achieved, open the pop-off valve again.
  - Recheck the cuff for leaks at approximately 15–20 minutes as a leak may develop when the pet is more relaxed under anesthesia.

- **CAUTION:** Tracheal damage, including laceration or rupture, can occur with over-inflation of the ET cuff, inappropriate use of stylets or twisting of the ET tube while the cuff is inflated during movement or repositioning of the pet. This can lead to subcutaneous emphysema, pneumomediastinum, pneumothorax and death.

- Turn on vaporizer to 3% sevoflurane.
  - Large dogs may require higher rates (greater than 3%) of sevoflurane.
  - Monitor anesthetic depth closely.
- Lubricate eyes. Repeat approximately every 60 minutes through recovery.
- Apply monitors, including electrocardiogram (ECG), blood pressure (BP), temperature and capnography. Pulse oximeter should already be on the pet. Ensure all are working properly.

Clinical essential

If patient repositioning is necessary, disconnect intubated pets from the breathing circuit prior to movement and reconnect after attaining proper positioning

Figure 2.31

Oxygen flow rates for breathing systems

NON-REBREATHING SYSTEMS (less than 7 kg body weight)	REBREATHING SYSTEMS (greater than 7 kg body weight)
150–300 mL/kg/minute (200 mL/kg/minute average)*	Semi-closed for induction phase (first 15 minutes after induction): 50–100 mL/kg/minute Semi-closed for maintenance: 20–30 mL/kg/minute

Note: Vaporizers are not calibrated for flows less than 200 mL/minute. Therefore, a safe minimum flow rate is 500 mL/minute or 0.5 L/minute.

*These flow rates may result in some partial rebreathing. Monitor CO_2.

Notes

Table 2.11

Oxygen flow rates for anesthesia (l/min)

NRB circuit rates – same throughout procedure (150–300 mLs/kg/minute)

Weight (kg)	Low	High	Average
1.00	0.50	0.50	0.50
2.00	0.50	0.60	0.50
3.00	0.50	0.90	0.60
4.00	0.60	1.20	0.80
5.00	0.75	1.50	1.00
6.00	0.90	1.80	1.20
7.00	1.05	2.10	1.40

Rebreathing Circuit Rates

	50–100 mL/kg/min		20–30 mL/kg/min	
	Transition		Maintenance	
Weight (kg)	Low End	High End	Low End	High End
8.00	0.50	0.80	0.50	0.50
10.00	0.50	1.00	0.50	0.50
12.00	0.60	1.20	0.50	0.50
14.00	0.70	1.40	0.50	0.50
16.00	0.80	1.60	0.50	0.50
18.00	0.90	1.80	0.50	0.54
20.00	1.00	2.00	0.50	0.60
22.00	1.10	2.20	0.50	0.66
24.00	1.20	2.40	0.50	0.72
26.00	1.30	2.60	0.52	0.78
28.00	1.40	2.80	0.56	0.84
30.00	1.50	3.00	0.60	0.90
32.00	1.60	3.20	0.64	0.96
34.00	1.70	3.40	0.68	1.02
36.00	1.80	3.60	0.72	1.08
38.00	1.90	3.80	0.76	1.14
40.00	2.00	4.00	0.80	1.20
42.00	2.10	4.20	0.84	1.26
44.00	2.20	4.40	0.88	1.32
46.00	2.30	4.60	0.92	1.38
48.00	2.40	4.80	0.96	1.44
50.00	2.50	5.00	1.00	1.50

Remember: Minimum oxygen flow rate of 0.5 L/min

Assisted ventilation

Hypoventilation and/or apnea is common during anesthetic induction. All efforts should be made to titrate induction drug doses to the amount needed to achieve endotracheal intubation. Pets that are not breathing spontaneously require manual assisted ventilation. The pop-off valve is closed and the reservoir bag squeezed up to a pressure of approximately 15 cm H_2O (do not exceed 20 cm H_2O) for four to six breaths per minute until spontaneous ventilation resumes. Ventilation should be delivered in a manner similar to normal respiration. To avoid holding positive pressure in the chest with too long of an inspiratory time, it is helpful if the team member providing anesthesia breathes in and out himself or herself along with giving PPV to the pet. The pop-off valve should be opened between administering manual PPV.

The procedure for manual ventilation is the same for rebreathing systems and NRB systems. Careful attention should be paid to ensure that the pop-off valve is opened after each manually assisted breath to avoid dangerously high (>20 cm H_20) pressures developing in the breathing system. This is especially true for NRB systems where O_2 flow rates are high and the circuit volume is low; dangerously high pressures can develop within 30 seconds leading to barotrauma, tracheal tear or rupture, especially in cats.

Indications for manual ventilation may include the following:

- Hypoxemia (SpO_2 <90–93%)
- Hypercarbia (end tidal carbon dioxide ($EtCO_2$) >55%)
- Inability or difficulty in maintaining appropriate anesthetic depth
- Concurrent pulmonary, musculoskeletal or neurologic disease that interferes with normal respiration

Manual ventilation should only be performed by trained associates and only under the supervision and direction of the attending veterinarian.

Anesthetic monitoring

The word **monitor** comes from the Latin word *monere* which means to warn. Since anesthetic drugs alter a pet's normal physiology and the body's ability to maintain homeostasis, the primary purpose of monitoring during anesthesia is to **warn** the team member providing anesthesia of changes in anesthetic depth or physiologic status of the pet to facilitate an early response. The primary cause for crisis during the anesthetic and recovery period is failure to recognize a problem as it occurs. **The highest mortality is within the first three hours of recovery from anesthesia. Therefore, it is imperative that pet monitoring continue into the recovery period.**

The goals of monitoring are to:

- **Anticipate and avoid complications**
- **Identify and correct complications**

Medical record documentation

The anesthetic and medical record provides a legal record of events, prompts the team member providing anesthesia to observe, evaluate and record the pet's status and allows trends to be recognized.

- The following should be included in the anesthetic record:
  - Date
  - Pet identification
  - Physical exam parameters
  - ET tube size
  - Circuit (adult or pediatric rebreathing vs. NRB)
  - Drugs and fluids administered including dose, route and time
  - Oxygen flow rates (recorded at least every five minutes)
  - Anesthetic vaporizer settings (recorded at least every five minutes)
- Follow state practice act requirements for anesthetic record documentation.
- Monitor the following patient parameters continuously and record at least every five minutes and more often when medically indicated:

- HR
- RR
- Body temperature
- CRT/mucous membrane (MM) color
- BP
- SpO_2
- ECG rhythm
- $EtCO_2$ where included on anesthetic cart

Irreversible central nervous system (CNS) and cellular changes occur within three to five minutes of cessation of blood flow. See Table 2.12 for critical values.

Manual assessment: The most important and valuable monitoring tool is an attentive team member providing anesthesia.

Clinical essential

Continuously measure temperature, heart and respiratory rates, blood pressure, ECG, SpO_2 and $EtCO_2$. Document at a minimum of every 5 minutes (or more frequently as clinically indicated) for every general anesthetic event from the time of induction until full recovery.

Notes

Table 2.12

Critical values for anesthetic monitoring

Parameter	Goal	
HR*	>60 Medium - large dogs >80 Small dogs >90 Cats	
BP	Mean (MAP)	60–90 mm Hg
	Systolic (SAP)	90–140 mm Hg
	Diastolic (DAP)	50–60 mm Hg
SpO_2	95–100%	
$EtCO_2$	>35 and <55 mm Hg with normal capnogram	
RR	7–15 bpm	
Temperature	100–102.5° F	
ECG	Normal sinus rhythm	
CRT	<2 seconds	
MM color	Pink	
Pulse quality	Strong, synchronous	

* Without dexmedetomidine. With dexmedetomidine, HR may be 50–60 bpm in dogs but can be as low as 30–40 bpm. HR with dexmedetomidine in cats may be 90–100 bpm but can be as low as 80 bpm.

Notes

Monitoring parameters

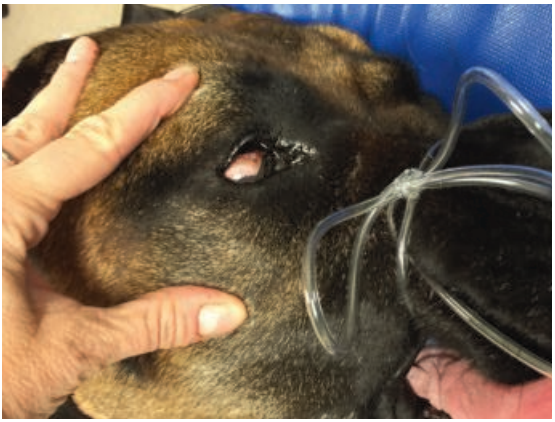
Anesthetic depth

Eye position

May be affected by orbit anatomy in cats and brachycephalic breeds

- Reliable method for monitoring anesthetic depth
- Globe rolls ventrally at a surgical plane of anesthesia. (Figure 2.32) Centered globe and palpebral reflex present indicates a light plane of anesthesia. (Figure 2.33)
- Centered globe without a palpebral reflex indicates a deep plane of anesthesia.
- Dissociative anesthetics such as ketamine and tiletamine alter eye position.
  - Globe may be centered at all planes of anesthesia.

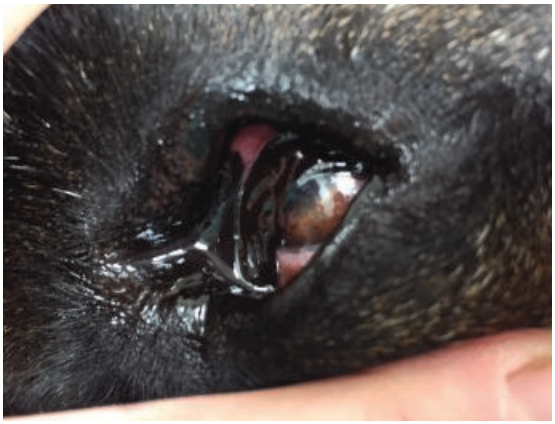
Figure 2.32: Ventral globe position



At a surgical plane of anesthesia the globe is positioned ventrally when the upper eyelid is opened and only the sclera is visible. The palpebral reflex is absent or slight.

Photo used with permission by Dr. Bonnie L. Hay Kraus, DVM, DACVS, DACVAA.

Figure 2.33



Globe is centered at both light and deep planes.

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Palpebral reflex

Elicited by gently tapping on the skin near the medial canthus of the eye

- Absent at a surgical plane of anesthesia
- Utilized to differentiate deep or light plane of anesthesia with central globe positioning
- Can be fatigued with over-stimulation

Figure 2.34: Palpebral reflex

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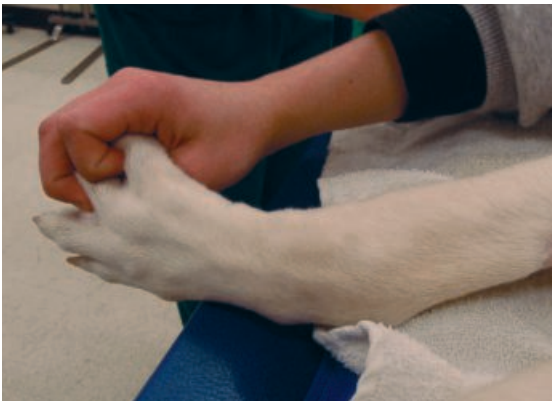
Blood pressure

- Sensitive indicator of anesthetic depth
- Systolic greater than 140 mm Hg and mean greater than 90 mm Hg indicates a light plane of anesthesia
- Systolic less than 80–90 mm Hg and mean less than 60 mm Hg may indicate a deep plane of anesthesia

Withdrawal reflex

- Elicited by pinching the pet's toe or toe web
- Withdrawal of limb indicates a light plane of anesthesia

Figure 2.35: Toe pinch or withdrawl reflex



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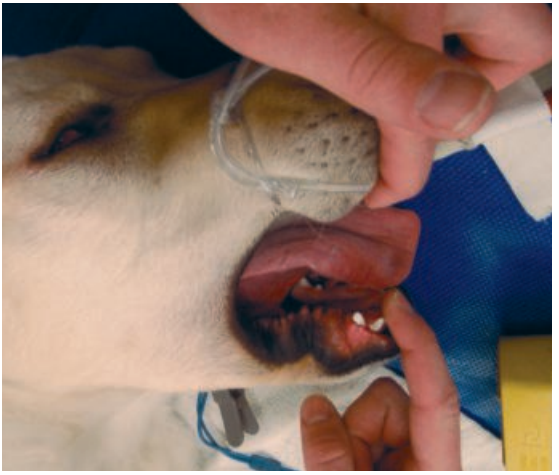
- Perform prior to the start of surgery or while the patient is being draped

Jaw tone

- Very subjective
- Varies with depth
- Tight jaw tone indicates a light plane of anesthesia.
- Relaxed jaw tone indicates a surgical or deep plane of anesthesia.
- Not as reliable with dissociative anesthetics and in well-muscled dogs such as Pit Bulls and Rottweilers

Figure 2.36: Jaw tone



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Pet movement

- Obvious sign of inadequate anesthetic depth
- Beware of other causes which may mimic pet movement such as surgeon manipulation, hyperventilation due to hypercarbia/ hyperthermia and agonal breathing.

Table 2.13: Factors used to assess anesthetic depth

Anesthetic depth

		Light	Optimal/ surgical	Deep
Eye position*		Central	Ventral	Central
Palpebral reflex		Positive	Negative	Negative
BP	SAP	>140	>80 and <140	<80–90
	MAP	>90	>60 and <90	<60
Withdrawal reflex		Positive	Negative	Negative
Jaw tone**		Tight	Relaxed	Relaxed
Patient movement		Yes	No	No

* May be affected by use of dissociatives.
** May be affected by breed.

End tidal CO_2

- Normal respiration is tightly controlled by the chemoreceptor response to arterial carbon dioxide in the respiratory centers in the brain.
- Many anesthetic drugs, especially inhalant anesthetics, are dose-dependent respiratory depressants and suppress the respiratory center response to CO_2.
- Normal $PaCO_2$ while the pet is awake is 35–40 mm Hg.
  - Hypoventilation is defined as a $PaCO_2$ greater than 45 mm Hg.
- Monitoring of the expired or $EtCO_2$ can be used as a non-invasive monitor of $PaCO_2$.
  - May serve as an indirect measure of anesthetic depth by giving a measure of respiratory depression
  - Normal $EtCO_2$ is approximately 40 mm Hg in awake pets.
    - Anesthetized patients' $EtCO_2$ values will be higher depending on their depth and the amount of respiratory depression.
- **$EtCO_2$ should be kept under 55–57 mm Hg.**

Mean alveolar concentration

- The MAC is the inhalant anesthetic concentration in the lungs required to prevent purposeful movement in 50% of pets in response to a noxious stimulus.
  - The MAC of sevoflurane is 2.3% in dogs and 2.6% in cats.
- A surgical plane of anesthesia is approximately 1.3 to 1.5 times MAC and the majority (95%) of pets can be adequately anesthetized at 1.5 MAC.
  - Premedications, intraoperative analgesics and local blocks will all lower the MAC of inhalant anesthesia.
- MAC represents a population of dogs and cats and not the individual pet.
  - **Inhalant gases should be always be titrated to the individual pet and procedure.**

Management of inconsistencies in anesthetic depth

The team member providing anesthesia should evaluate anesthetic depth every three to five minutes. Pay particular attention at key transition times, such as:

- Movement from the gurney to the surgery table
- Draping and towel clamp placement
- Start of the surgical incision

Ensure anesthesia breathing circuit and rebreathing bag (if applicable) is appropriate to patient size and ideal body weight.

Anesthetic depth can be deepened if necessary by increasing the vaporizer setting and the O_2 flow rate until the desired plane of anesthesia is achieved.

If the pet awakens or moves on the surgery table, interventions depend upon the type of breathing circuit used.

Interventions

Rebreathing system

- Increase the vaporizer setting and O_2 to 3–4 L/min.
- It will take time to change the circuit concentration and is dependent on the volume of the breathing circuit and the oxygen flow rate.

Example:

Changing the vaporizer concentration from 1% to 2% in an adult breathing circuit with a 3L bag (total circuit volume of approximately 7L) with a 1 liter O_2 flow will take 35 minutes.

- Circuit volume/O_2 flow = 7L/1L = 7 minutes
  - To determine time to reach new inhaled concentration, multiply time by 5
  - 7 × 5 = 35 = minutes to reach new concentration
- Increasing the O_2 flow to 4L will significantly decrease the time until the pet is breathing the percentage dialed on the vaporizer setting
- Circuit volume/O_2 flow = 7L/4L = 1.75 minutes
  - To determine time to reach new inhaled concentration, multiply time by 5
  - 1.75 × 5 = 8.75 = minutes to reach new concentration

- Manual ventilation of the pet will increase alveolar ventilation and increase anesthetic concentration in the lungs and brain, especially in pets that have a rapid shallow breathing pattern due to a light plane of anesthesia.
- A small bolus of propofol (0.5–1 mg/kg) can be administered IV slowly over approximately 15 seconds, to effect. Remember limb-brain circulation time is approximately six to eight seconds.

Giving additional induction agent may cause hypoventilation or apnea. This results in a vicious cycle, because when the pet is not breathing, there is poor uptake of the inhalant anesthetic. Therefore, once the additional propofol is redistributed from the brain, the pet will again awaken.

After the pet is reanesthetized, the vaporizer should be set approximately 0.5% higher than the previous setting and/or additional analgesics administered if indicated.

Non-rebreathing system

- Increase the vaporizer setting, with or without manual ventilation.
  - The anesthetic concentration changes very rapidly (in less than one minute) due to the low circuit volume of the NRB system and high O_2 flow rate. Therefore, the depth of anesthesia can be increased quickly.

- **Caution: Since the anesthetic concentration changes quickly, the vaporizer setting should not be left too high for very long since the pet may then enter too deep an anesthetic plane**

  - Using inhalant gas (with or without additional analgesics, if indicated) helps avoid the vicious cycle of awakening, administering additional induction agent, pet apnea and reawakening.

Circulation

Monitoring of circulation is focused primarily on the function of the cardiovascular system.

Subjective clinical assessment consists of evaluation of:

- **CRT**
- **Cardiac auscultation**
- **Peripheral pulse palpation**

Capillary refill time

- Normal is less than two seconds.
- CRT greater than two seconds indicates poor tissue perfusion or dehydration.
- Anesthetic drugs may interfere with interpretation due to vasodilation or vasoconstriction.

Cardiac auscultation

- Performed with a stethoscope or esophageal stethoscope.
- HR may change with anesthetic depth.
- Altered by many anesthetic drugs, usually causing bradycardia.
- Audible heart sounds assess presence, absence and regularity of heart beat.

Peripheral pulse palpation

- Use femoral, dorsal pedal or lingual arteries.
- Determine presence or absence, strength or weakness, regularity or irregularity.
- Remember the pulse pressure reflects systolic arterial pressure (SAP) minus diastolic arterial pressure (DAP) and **does not** indicate MAP.
- Pulse pressure is affected by anesthetic drugs.
  - Ketamine and dexmedetomidine cause vasoconstriction, which will decrease pulse pressure while MAP may be normal or high.

Patients with the same pulse pressure may have different MAPs

Example 1:
SAP = 90 mm Hg, DAP = 30 mm Hg → pulse pressure = 90 - 30 = 60 mm Hg
MAP = (SAP + 2 X DAP)/3 = (90 + 2 X 30)/3 = 50 mm Hg

MAP is **insufficient** to maintain tissue and organ perfusion

Example 2:
SAP = 120, DAP = 60 → pulse pressure = 60 mm Hg
MAP = (120 + 2 X 60)/3 = 80 mm Hg

MAP is **sufficient** for adequate tissue and organ perfusion

Do not rely only on pulse pressure to estimate perfusion

Cardiac monitoring equipment

Esophageal stethoscope

- Inserted to the level of the heart
- Inexpensive method of monitoring HR and RR

Disadvantages
■ Only useful when earpieces are being used ■ Difficult to use during certain procedures (ear, nose, throat (ENT) procedures, endoscopy)

- Monitors HR and rhythm
- Used to definitively diagnose arrhythmias and monitor treatment
- Gives an audible beep with each R wave

Limitations
■ Only gives electrical (not mechanical, *i.e.*, cardiac output (CO) or blood flow) information regarding the activity of the heart ■ **Not be used as a sole monitor during anesthesia**

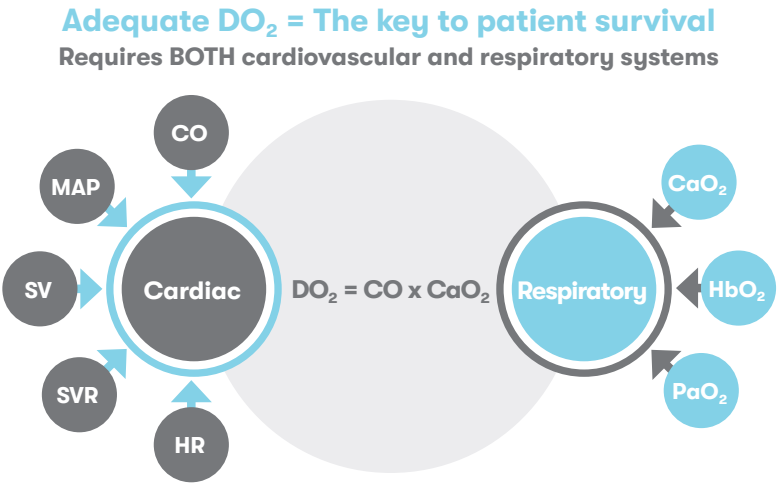
Blood pressure

- Arterial BP provides information regarding the blood flow to tissues.
- CO is a significant determinant of adequate delivery of oxygenated blood to tissues and organs.
- MAP is significantly affected by CO (and systemic vascular resistance) and provides a close measure of clinical CO.
- Anesthetized pets are at risk for hypotension due to depression of CO from injectable and inhalant anesthetics.
- **Untreated hypotension can compromise perfusion of the kidneys, liver, heart and brain, leading to organ dysfunction or even death.**

Adequate delivery of oxygen to tissues (DO_2) is the key to pet survival.

- DO_2 to tissues is dependent on CO and the content of oxygen in the blood (CaO_2). $DO_2 = CO \times CaO_2$
- MAP is the driving force for blood flow through capillaries that supply oxygen to organs and tissues.
  - MAP is dependent on CO and systemic vascular resistance (SVR) (MAP = CO x SVR).
    - In turn, CO is dependent on HR and stroke volume (SV) (CO = HR x SV).
- It is important to remember these relationships when considering the underlying cause(s) of hypotension in order to choose the best treatment.

Figure 2.37



Blood pressure monitoring equipment

Non-invasive blood pressure monitoring:

- Readings are intermittent and can be affected by motion.
- Accuracy is affected by correct cuff size (40–50% of limb circumference) and fit.
  - Too large or loose a cuff will give a falsely low reading.
  - Too small a cuff will give a falsely high reading.

Oscillometric blood pressure:

- Detects the periodic fluctuations in the arterial wall.
  - The cuff is automatically inflated.
  - As it deflates, the oscillations rapidly increase at SAP, reach a maximum at the MAP and then rapidly decrease at the DAP.
- Measures HR, systolic, DAP and MAP
- BP cuff may be placed on a peripheral limb (distal tibia, metatarsus, radial-ulnar region) or tail base.

Advantages	Disadvantages
■ Easy to use ■ Automatic	■ Motion sensitive ■ Decreased accuracy during conditions of low BP, low/high HR or the presence of arrhythmias ■ Accuracy dependent on cuff size and fit

Interpretation of blood pressure values

- **Systolic blood pressure (90–140 mm Hg)**
  - Low SAP (less than 80–90 mm Hg) may indicate a low CO and decreased venous return.
  - High SAP (greater than 140 mm Hg) may indicate a light plane of anesthesia or inadequate analgesia causing high sympathetic tone.
- **Diastolic blood pressure (50–60 mm Hg)**
  - Indicator of systemic vascular resistance
  - Low DAP (less than 50–60 mm Hg) indicates vasodilation or hypovolemia.
  - High DAP (greater than 60 mm Hg) may indicate vasoconstriction and can be seen in pets administered dexmedetomidine.
- **Mean blood pressure (60–90 mm Hg)**
  - Maintains adequate tissue and organ perfusion
  - Low MAP (less than 60 mm Hg) indicates organ hypoperfusion.
  - High MAP (greater than 90 mm Hg) may indicate a light plane of anesthesia or inadequate analgesia.

Hypotension is more common than hypertension during anesthesia (see *Treatment of Hypotension and Hypertension in Perianesthetic Complications*).

Hypotension

Hypotension is defined as MAP lower than 60 mm Hg and SAP below 90 mm Hg.

Causes of hypotension related to bradycardia

Bradycardia is defined as a HR under 60 bpm in medium/large dogs, under 80 bpm in small dogs and under 90 bpm in cats.

- Drugs (opioids cause an increase in vagal tone, especially when used with acepromazine)
- Hypothermia
- Other physiologic conditions (electrolyte abnormalities, cardiac disease, brachycephalic syndrome and neurologic disease)
  - Treat the underlying cause of bradycardia (*e.g.*, hyperkalemia) when possible

Pediatrics

Pediatric pets are more dependent on HR to maintain CO and cannot compensate by increasing SV as well as adults.

- More likely to become hypotensive when bradycardic

Consider including an anticholinergic drug with premedication in brachycephalic breeds, pediatric pets and when using opioids with acepromazine.

- Anticholinergic drugs should be used with caution in geriatric pets and pets with cardiac disease since they can cause sinus tachycardia.
  - Sinus tachycardia increases myocardial work and O_2 consumption while decreasing blood flow to the heart, which may increase the potential for ventricular arrhythmias in pets with less cardiac reserve.

Dexmedetomidine and bradycardia

CAUTION: Dexmedetomidine may cause significant bradycardia (HR below 50 bpm). The severity is related to dose (the higher the dose, the higher the MAP and the lower the HR) and tends to be more severe in dogs than cats.

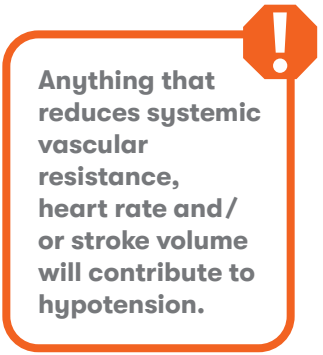
This is a REFLEX bradycardia in response to peripheral vasoconstriction and baroreceptor mediated decrease in HR and SHOULD NOT be treated with an anticholinergic drug. However, at lower doses of dexmedetomidine (less than 5 **mcg**/kg) and also when the vasoconstrictor response starts to diminish (approximately 30 minutes to one hour post-administration), the central sympatholytic effect is in effect, resulting in bradycardia AND HYPOtension.

- When bradycardia is associated with hypotension in pets administered dexmedetomidine, it is appropriate to administer an anticholinergic drug.
- Partial or full reversal with atipamezole may be indicated if the HR is under 30 bpm with or without cardiac dysrhythmia.
- Reversing pets during general anesthesia is generally not recommended and should only be done in an emergency situation and the anesthetic procedure aborted.

Causes of hypotension related to decreased stroke volume.

Stroke volume depends on preload, contractility and afterload (vascular tone). Factors that affect these will impact SV. See *Physiology* chapter for more information.

- Factors that decrease preload include:
  - Decreased blood volume (hemorrhage, dehydration, shock, sepsis)
  - Vasodilation (inhalants, acepromazine, propofol)
  - Intermittent positive pressure ventilation (IPPV)
- Factors that decrease contractility include:
  - Anesthetic drugs (inhalants, acepromazine, propofol)
  - Cardiac disease
- Factors that increase afterload include:
  - Increased arterial tone due to sympathetic nervous system stimulation
  - Hyperthyroidism
  - Pheochromocytoma
  - Ketamine
  - Dexmedetomidine (this results in reflex bradycardia)



Notes

Ventilation

Subjective clinical assessment consists of evaluation of:

- **Chest wall movements**
- **Excursion of the rebreathing/reservoir bag**
- **Lung sounds**

Such evaluation gives information regarding:

- The presence, absence, regularity and frequency of ventilation
- The pattern, effort and depth of respiration

Minute ventilation (MV) is dependent on tidal volume (TV) and frequency of respiration (f). As MV decreases, $PaCO_2$ will increase. Since MV depends on both TV and f, monitoring RR alone is insufficient to identify hypoventilation.

$$MV = TV \times f$$

Qualitative assessment of ventilation requires arterial blood gas analysis and/or capnography.

Blood gas analysis

- Requires collection of an arterial blood sample from a peripheral artery
- Used to evaluate the acid/base status of a pet and $PaCO_2$
  - pH imbalance can indicate acidosis or alkalosis
  - $PaCO_2$ is a measure of the ventilatory status of the pet.
    - Normal awake $PaCO_2$ is 35–45 mm Hg.
    - Anesthetic drugs cause dose-dependent respiratory depression, which will lead to an increase in $PaCO_2$.
    - $PaCO_2$ should be kept under 60 mm Hg.
      - Corresponds to approximately 7.2 pH
      - Cellular enzymes malfunction outside a pH range of 7.2–7.5.

Table 2.14: Evaluation of $PaCO_2$

$PaCO_2$ Trend	$PaCO_2$ Value	Indications
Decreasing/low $PaCO_2$	<40–45 mm Hg	Hyperventilation and respiratory alkalosis
Increasing/ elevated $PaCO_2$	>45 mm Hg	Hypoventilation and respiratory acidosis
Permissive hypercarbia	45–60 mm Hg	Unlikely to have detrimental patient effects May cause increased sympathetic stimulation (tachycardia, ventricular arrhythmias), but these complications are typically seen at levels above the "permissive hypercarbia" range

Notes

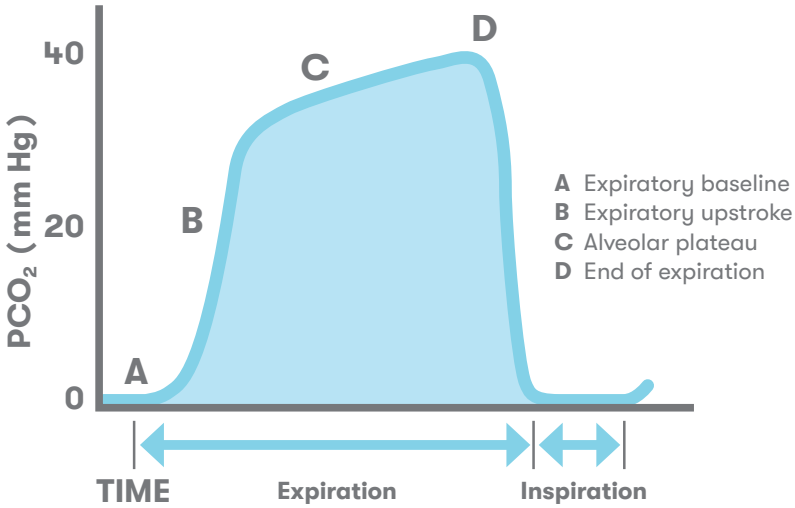
Capnography equipment

Monitoring of $EtCO_2$ (as a non-invasive monitor of $PaCO_2$) is a Clinical Essential where equipment exists. Assuming that ventilation and perfusion are adequately matched in the pet's lungs, $EtCO_2$ is usually 3–5 mm Hg lower than $PaCO_2$.

$EtCO_2$

- Gives numerical $EtCO_2$ value, which is the partial pressure of CO_2 (PCO_2) at the end of exhalation
- Shown as a wave form of the inspired and expired CO_2 during inspiration and expiration
- Provides information about systemic metabolism, CO and pulmonary perfusion in addition to alveolar ventilation

Figure 2.38: Capnogram



Monitoring capnography

The capnogram waveform displays the expired CO_2 over inspiration and expiration of the respiratory cycle and is divided into four phases:

Phase I (A in figure 2.38)

- Expiratory baseline (end of inspiration)
  - Gas typically contains no or an unmeasurable concentration of CO_2
    - Gas is coming from:
      - Dead space in the circuit
      - Large airways (trachea, bronchioles) that do not participate in gas exchange
  - Baseline above zero indicates rebreathing of CO_2, which can be caused by:
    - Low O_2 flow in the NRB circuit
    - Dessicated soda lime in the circle system
    - Malfunctioning one-way valve

Phase II (B in figure 2.38)

- Expiratory upstroke
- Transition between gas from the airway dead space to alveolar gas, which contains CO_2

Phase III (C in figure 2.38)

- Expiratory or alveolar plateau
- Occurs when all the gas is coming from the alveoli
- $EtCO_2$ (D in figure 2.38) occurs at the end of the alveolar plateau
  - Represents the concentration of CO_2 at the end of expiration

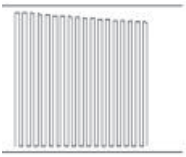
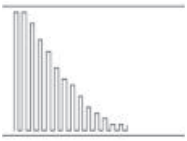
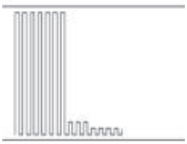
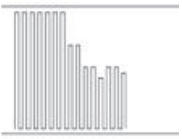
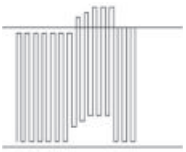
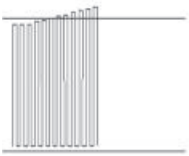
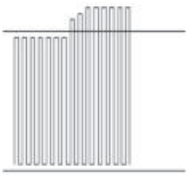
Phase IV

- Inspiratory downstroke
- Occurs at the beginning of the next inspiration
- Characterized by the CO_2 rapidly returning to zero

Deviations in the wave shape represent different clinical situations or conditions and require investigation.

Table 2.15

Abnormal capnography trends

$EtCO_2$ Changes	Etiologies	Image
Gradual decrease	■ Hyperventilation ■ Decreasing body temperature ■ Decreasing perfusion	
Sudden decrease	■ Circulatory arrest ■ Air or clot embolism ■ Sudden, severe hyperventilation	
Sudden drop to zero	■ Kinked/blocked ET tube ■ Extubated patient ■ Disconnected sensor or circuit	
Sudden drop (above zero)	■ Circuit leak ■ Deflated cuff ■ Obstructed ET tube ■ Acute bronchospasm	
Sudden rise in baseline	■ Malfunctioning valve ■ CO_2 absorber problem ■ Calibration error	
Gradual increase	■ Hypoventilation ■ Rapid hyperthermia	
Sudden increase	■ Injection of sodium bicarbonate ■ Tourniquet release ■ Sudden hypertension	

Capnography is most useful for detection of apnea and/or hypoventilation but also can aid in detection of abnormalities in CO, pulmonary perfusion, systemic metabolism and equipment/technical problems. (Table 2.16)

Table 2.16

Causes for abnormal $EtCO_2$

	Increased	Decreased
Metabolism	■ Fever ■ Malignant hyperthermia ■ Sodium bicarbonate administration ■ Tourniquet release ■ Seizures	■ Hypothermia ■ Hypothyroidism ■ Muscle relaxants
Pulmonary perfusion	■ Increased CO or BP	■ Decreased CO* ■ BP ■ Hypovolemia ■ Pulmonary embolism ■ Cardiac arrest*
Alveolar ventilation	■ Hypoventilation* ■ Rebreathing of CO_2	■ Hyperventilation* ■ Apnea* ■ Partial airway obstruction, asthma, pulmonary edema
Technical errors	■ Rebreathing of CO_2* (exhausted soda lime) ■ Inadequate fresh gas flow (NRB system)* ■ Faulty valves* ■ Leaks	■ Pet disconnect* ■ Sampling line leak
Pet factors	■ Obesity ■ CNS disease	

* Most important/most common etiologies

The consequences of hypoventilation

- The most severe form of hypoventilation is apnea or respiratory arrest, which can lead to cardiac arrest and death.
- Hypoventilation and apnea lead to hypoxemia, especially in pets breathing room air.

$EtCO_2$ limitations

- Is typically 3–5 mm Hg **lower** than $PaCO_2$
  - This difference can increase with ventilation-perfusion mismatch caused by lung atelectasis.
- Only arterial blood gas analysis can tell the true $EtCO_2$ to $PaCO_2$ difference.

Oxygenation

Oxygen is inspired and delivered to tissues with adequate CO and BP. Therefore, oxygenation requires appropriate function of both the respiratory and cardiovascular systems.

Subjective clinical assessment can be difficult but consists of evaluation of the MM:

- **Pale MM may be due to vasoconstriction (pain, drugs, blood loss), decreased CO or red blood cells (anemia) or hypoxia (cyanosis greater than 5 g/100 mL reduced hemoglobin)**
- **Dark pink MM may indicate vasodilation, increased CO_2 and/or endotoxemia**
- **MM color is affected by anesthetic drugs**
- **Oxygenation cannot be evaluated using MM color in pets with pigmented MM**

Equipment: pulse oximetry

- Provides pulse rate and noninvasive measurement of the percentage of HbO_2 in the arterial blood.
- The percentage of oxyhemoglobin and reduced hemoglobin present in arterial blood is calculated and converted to a percentage of SpO_2.
- The probe is usually attached to the pet's tongue, lip, ear, interdigital space or prepuce.
  - Reflectance probes are also available where the infrared/red light emitter and the receiver are located on the same side of the probe (rather than on opposite sides as in the "clip" probe). These probes can be placed on a flat anatomic area such as the cheek pouch, palate, base of the tail, dorsal metatarsus or rectally to measure SpO_2.
- Pulse oximeter function may be affected by:
  - Motion artifact (shivering, body movement)
  - Fluorescent light
  - Poor peripheral blood flow (hypotension, vasoconstriction)
  - Increased blood carboxyhemoglobin and methemoglobin levels
  - Dark pigmentation of skin or tongue
  - Poor contact with tissues (minimize by placing wet gauze with the lingual probe)
- Pulse oximetry is most helpful at induction and during the transition from 100% O_2 to room air at recovery.

Interpretation

Normal values for the partial pressure of arterial oxygen (PaO_2) depend on the inspired oxygen concentration (FiO_2).

- PaO_2 can be predicted using the FiO_2 (FiO_2 x 5 = predicted PaO_2)
  - Pets breathing room air (21% O_2) = (21 × 5) = approximately 100 mm Hg
  - Pets breathing 100% O_2 = (100 × 5) = approximately 500 mm Hg
  - Pets in an O_2 cage at 40% O_2 = (40 × 5) = approximately 200 mm Hg
- Pets with a PaO_2 less than 60 - 80 mm Hg are considered hypoxemic.

Patient status	FiO_2	SpO_2	PaO_2
Healthy, awake	Room air (21% O_2)	SpO_2 >95%	100 mm Hg
Healthy, stable, anesthetized	100%	98–100%	>250–650 mm Hg
Hypoxemic	Variable	<90%	~ 60 mm Hg

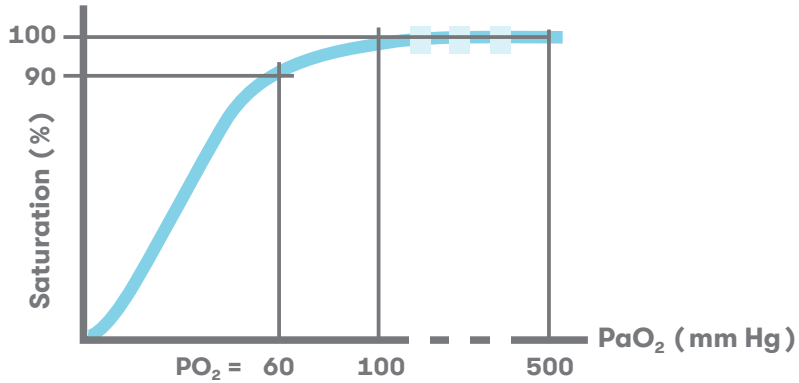
SpO_2 should always be maintained greater than 95%.
See *Assisted Ventilation* section for additional information.

The relationship between SpO_2 and PaO_2 is demonstrated by the oxyhemoglobin dissociation curve.

Figure 2.39

Oxyhemoglobin dissociation curve

Demonstrates relationship between SpO_2 and PaO_2



In the clinical setting, there are several ways to estimate PaO_2 using pulse oximetry, based on the mid-portion of the O_2 dissociation curve.

- $PaO_2 = SpO_2 - 30$
  - The formula only applies to pulse oximeter readings between approximately 75–90%.
  - This is due to the linear relationship between PaO_2 (in mm Hg) and SpO_2 values on the mid portion of the hemoglobin disassociation curve.
  - Outside of these values, this rule cannot be applied.

- 4-5-6-7-8-9 Rule:
  - PaO_2 40 = SpO_2 70%
  - PaO_2 50 = SpO_2 80%
  - PaO_2 60 = SpO_2 90%
- The mnemomic: 30 is 60%, 60 is 90% and 40 is 75%.

The shape of the O_2 dissociation curve impacts the value of the SpO_2 while pets are breathing 100% O_2 during anesthesia.

PaO_2 = 100 mm Hg	→ SpO_2 = 98 - 100%
PaO_2 = 500 mm Hg	→ SpO_2 = 98 - 100%

- **Significant lung dysfunction can be present and not identified while the pet is breathing 100% oxygen.**
  - These abnormalities can be identified with arterial blood gas analysis or they may become apparent when the pet is transitioning from 100% O_2 to room air.

It is IMPERATIVE that SpO_2 be monitored through the recovery period

Physiologic causes of Hypoxemia

- Hypoventilation
- Low FiO_2
- Ventilation/perfusion mismatch or shunting
- Diffusion abnormalities in the lung (e.g., pneumonia, neoplasia)
- Decreased PaO_2 content due to anemia*

*See *Management of Intraoperative Hemorrhage* section.

See Treatment of Respiratory Insufficiency: Hypoventilation and Hypoxemia in Perianesthetic Complications

Body temperature

The goal is to maintain body temperature at 100–102.5° F. **Proactive preservation of body temperature is superior to reactive rewarming techniques.**

Objective clinical assessment:

- **Thermistor probe inserted into the lower third of the esophagus: This technique measures the temperature of aortic blood and correlates well to core body temperature.**
- **Rectal temperature is useful in monitoring relative changes in body temperature but reflects more regional blood flow and other factors and, therefore, may be different from core body temperature**

Hypothermia parameters

Mild hypothermia	98–99° F
Moderate hypothermia	96–98° F
Severe hypothermia	92–96° F
Critical hypothermia	Less than 92° F

Hypothermia

- Body temperature under 100° F
  - Clinical consequences can be seen when a pet's body temperature is below 95° F.
- Anesthesia interferes with the body's ability to maintain body temperature by inhibiting vasoconstriction and shivering.
- Heat loss occurs primarily by redistribution of blood from the core body to the periphery and to some extent by conduction, convection, radiation and evaporation.

The causes of hypothermia include:

- Decreased heat production due to decreased metabolism and muscle movement during anesthesia
- Vasodilation contributing to redistribution of core blood to the periphery
- Heat loss via an open body cavity
- Cold IV fluids or environment

The consequences of hypothermia include:

- Decrease in MAC of inhalant anesthetics
- Decreased metabolic rate and HR
- Prolonged recovery
- Increased blood viscosity
- CNS depression (confusion at approximately 95° F, unconsciousness at approximately 86° F)
- Increased risk of surgical infection
- Increased cancer metastasis
- Impaired coagulation, platelet function and wound healing
- Increased mortality

Myocardial conduction slows, resulting in bradycardia that is non-responsive to anticholinergic drugs. The myocardium becomes irritable, leading to ventricular arrhythmias and fibrillation at approximately 86° F.

Hyperthermia parameters

Hyperthermia	Body temperature greater than 102.5° F

The causes of hyperthermia include:

- Excessive pet warming
- Malignant hyperthermia syndrome
- Thick-coated dogs (Nordic breeds, Newfoundlands)
- Opioid use in cats: typically occurs within five hours postoperatively

Cats receiving opioid analgesics are at increased risk for postoperative hyperthermia if they are hypothermic intraoperatively

The consequences of hyperthermia include:

› Increased metabolic rate and O_2 consumption, leading to increased myocardial work and cellular hypoxia

See treatment of hypothermia and hyperthermia in *Perianesthetic Complications* section for more information.

Blood glucose (BG)

Hypoglycemia or severe hyperglycemia can prolong recovery. Target BG levels are 70–180 mg/dL.

Subjective clinical assessment is difficult to assess in anesthetized pets:

› Objective clinical assessment
- **Monitor BG in pets at-risk for hypoglycemia**

Pets at risk for hypoglycemia include:

- Pediatric pets fasted prior to anesthesia
- Pets with liver dysfunction, portosystemic shunt, insulinoma, septic shock and/or severe emaciation
- Diabetic pets can be at risk for hypo- or hyperglycemia, even if considered to be "well controlled" due to preoperative fasting and the stress of anesthesia/surgery.

Management:

- Limit fasting in pediatric pets (approximately two to three hours in pets under 3–4 months old).
- Monitor BG every 30–60 minutes with a commercial veterinary glucose testing kit.
- If BG drops below 70 mg/dL, administer 2.5–5% dextrose added to balanced electrolyte IV fluids.

For the diabetic pet:

- Check BG the morning of anesthesia and administer half the normal insulin dose
- Monitor BG every 30–60 minutes
- Administer 2.5–5% dextrose if the pet's BG drops below 70 mg/dL
- Administer 0.25–0.5 insulin dose if the pet's BG exceeds 180 mg/dL. Continue to monitor BG every 30 minutes
- Schedule anesthesia for early in the day to limit fasting time and to allow the pet to return to normal feeding as soon as possible
- Maropitant (1 mg/kg subcutaneously (SC)) has been shown to significantly decrease the time to return to feeding post anesthesia and surgery in dogs[11]

Notes

Table 2.17

Summary of anesthetic monitoring assessments

Parameters	Subjective	Objective
Anesthetic depth	Eye position	BP $EtCO_2$ MAC
	Palpebral reflex	
	Withdrawal reflex	
	Jaw tone	
	Movement	
Blood glucose	Difficult to assess in anesthetized pets	Intraoperative monitoring for at-risk pets Target level 70 - 180 mg/dl
Circulation	CRT	ECG BP
	Cardiac auscultation	
	Peripheral pulse palpation	
Oxygenation	Mucous membranes	SpO_2
Temperature	N/A	Rectal temperature (regional blood flow and relative changes) Distal esophagus temperature probe (core temperature)
Ventilation	Chest wall movement	Blood gas analysis $EtCO_2$
	Excursion of reservoir bag	
	Thoracic auscultation	

Perianesthetic complications

Anesthetic drugs can significantly alter a pet's ability to maintain homeostasis; therefore, the team providing anesthesia needs to be aware of the complications that may occur with any pet undergoing heavy sedation, immobilization or general anesthesia and have a plan for intervention. Vigilant monitoring will warn the team member providing anesthesia of changes in the pet's status and allow for early intervention.

Perianesthetic complications include:

- Respiratory insufficiency: hypoventilation and hypoxemia
- BP abnormalities: hypotension and hypertension
- Cardiac dysrhythmias and cardiac arrest
- Hemorrhage
- Hypothermia and hyperthermia
- Gastroesophageal reflux/aspiration pneumonia

Preoperative pet preparation plays a significant role in avoiding perioperative complications

Respiratory insufficiency: hypoventilation and hypoxemia

Hypoventilation occurs in over 60% of anesthetized pets. The incidence of hypoxemia is approximately 16%.[12]

Treatment of hypoxemia (SpO_2 less than 95%) depends on the cause:

- Hypoventilation
- Low inspired oxygen
- Ventilation-perfusion abnormalities
- Diffusion abnormalities

Hypoventilation

- Pre-oxygenate pets prior to anesthetic induction.
- Intubate and provide high FiO_2 (100% O_2) during inhalant anesthesia.
- Monitor $EtCO_2$ during anesthesia and keep within acceptable ranges.
- Provide 5–10 minutes of O_2 after discontinuing inhalant anesthetic.
- Monitor SpO_2 at transition from 100% O_2 to room air.
- Provide flow-by O_2 support until pet is able to maintain SpO_2 greater than 93–95% on room air.

Low inspired oxygen

- Evaluate anesthetic machine for malfunction, such as:
  - Depletion of O_2 supply
  - Broken O_2 flowmeter
  - Flowmeter accidently shut off or not turned on after connecting pet

Ventilation–perfusion abnormalities

- Includes lung atelectasis during inhalant anesthesia
  - This can be severely exacerbated with any intrathoracic fluid, air or abdominal contents.
- Evacuate fluid or air in the chest prior to anesthesia induction (even if the pet is nonclinical while awake).
- Utilize IPPV in obese pets that have an increased pressure on the diaphragm.

Diffusion abnormalities

- Provide higher FiO_2 (such as 100% O_2) unless very severe and resulting in pulmonary shunting (venous blood not able to be oxygenated and going directly into arterial circulation).

Treatment of hypoxemia may also be influenced by phase of anesthesia:

- Induction
- Maintenance
- Recovery

Shivering at recovery will increase metabolic O_2 consumption up to 200–400%. Therefore, it is important to prevent/limit hypothermia during anesthesia by providing active pet warming and O_2 support during recovery and monitoring SpO_2.

During induction:

Hypoventilation (or apnea) and hypoxemia are common at induction with all induction agents. The duration and severity is related to the dose and rate of administration of induction agent.

Prevention

- Pre-oxygenation for at least four minutes prior to induction delays onset of hypoxemia from 30 seconds to up to three to five minutes.[9]
- It is important to recognize the presence of hypoxemia and hypoventilation.
  - A pulse oximeter should be placed on the pet during induction or as soon as the pet is intubated.
- It is also important to recognize hypoventilation and/or apnea.
  - The presence of pet breathing can be identified by observing pet chest wall movements, movement of the reservoir bag and monitoring of $EtCO_2$.
- Intervention for apnea requires quick and efficient pet intubation and O_2 supplementation with low frequency (two to four breaths per minute) manual IPPV.

During maintenance:

Hypoventilation is the primary concern during anesthesia maintenance.

- Anesthetic drugs, especially inhalant anesthetics, cause decreased chemoreceptor responsiveness to $PaCO_2$.
  - This results in decreased RR and TV, leading to increased $PaCO_2$ and increased $EtCO_2$.
- Monitoring $EtCO_2$ allows identification of hypercarbia.
- "Permissive" hypercarbia = $EtCO_2$ allowed up to 55–57 mm Hg.
  - Mild hypercarbia helps increase HR and BP due to mild sympathetic stimulation.
- Treatment of hypercarbia should consist of:
  - Assessing anesthetic depth
  - Lowering the level of inhalant anesthetic
  - IPPV if needed

During recovery:

Hypoventilation and hypoxemia are again a concern as the pet is transitioned from 100% O_2 to room air (21% O_2).

Causes

- Residual respiratory depression from gas anesthetics/opioids
- Ventilation/perfusion mismatch (atelectasis)
- Upper airway obstruction (brachycephalic breeds)

Treatment

- Allow at least 5–10 minutes supplemental O_2 after the vaporizer is turned off.
- Monitor SpO_2 during the transition to room air.
- Provide supplemental O_2 until SpO_2 exceeds 95%.
  - "Flow-by" for the short term
  - Nasal/nasal tracheal O_2 if it is anticipated to be needed longer term than the immediate postoperative period (refer to *Procedure for placement of nasal O_2 tubes* in this chapter)

Partially reverse opioids to alleviate respiratory depression (0.1 mL (1 mg) butorphanol + 0.9 ml NaCl, given in 0.2 mL (0.2 mg) increments)

CAUTION: Brachycephalic breeds are especially prone to upper airway obstruction in the postanesthetic period. They should be recovered slowly in a (preferably) darkened, quiet room. They should be placed in sternal recumbency with their head slightly elevated. Be careful not to compress the jugular veins and allow drainage of gastroesophageal reflux should it occur at recovery. The ET tube should be kept in place as long as the pet will tolerate it. SpO_2 should be monitored at the transition from 100% O_2 and throughout recovery, especially after extubation. Brachycephalic pets need to be carefully observed for evidence of upper airway obstruction after extubation. The team member providing anesthesia should be prepared to reintubate (induction agent, laryngoscope and ET tube) should obstruction occur.

Procedure for placement of nasal oxygen tubes

Note that there are multiple methods described to place nasal O_2 catheters. The medical record should contain accurate documentation of the step-by-step procedure utilized.

1. Instill one to two drops of lidocaine into each nostril if needed based on patient level of consciousness and tolerance.
2. Premeasure and mark a red rubber catheter from the end of the nose to the medial canthus. A tape butterfly may be placed at the mark to assist with securing the tube.
3. Coat the end of the catheter with a small amount of water soluble lubricant.
4. Aiming medially and dorsally, advance the tube into the nose to the level of the mark on the tube.
5. Secure the tube under the alar fold (when possible, based on patient anatomy).
6. Using suture, staple or tissue glue, secure the tube as close as possible to end of nostril.
7. Provide additional attachments on midline of muzzle and at top of head.
8. Attach end of red rubber tube to O_2 line.
9. Administering O_2 at 100 mL/kg/min unilaterally should increase FiO_2 to 37%.
10. If needed, place an Elizabethan collar or similar device to prevent patient dislodgement of tube.

Treatment of abnormal $EtCO_2$

Hypercarbia (increasing EtCO2)

By far, the most common cause in anesthetized pets is hypoventilation. $EtCO_2$ should be kept above 35 mm Hg and below 55–57 mm Hg (permissive hypercarbia).

- Check the pet's anesthetic depth and lower inhalant if indicated
- Check machine and breathing circuit for:
  - Exhausted soda lime
  - Faulty expiratory valve (rebreathing system)
  - Inadequate O_2 flow rate (NRB circuit)
- Provide IPPV (manual or mechanical) if unable to lower inhalant due to inadequate pet depth despite providing additional analgesics.

Hypocarbia (decreasing $EtCO_2$)

Most often seen with over ventilation, usually during IPPV.

- Beware of "panting" pets and low $EtCO_2$.
  - Often, $EtCO_2$ is low due to low TV, resulting in sampling of gases from anatomic dead space (as in *Phase I*), despite $PaCO_2$ actually being higher. (Figure 2.38)
- Pets with this respiratory pattern often have a higher $PaCO_2$ and are difficult to maintain at a steady anesthetic depth with inhalant gas.
- Administering manual PPV, 4 - 6 bpm with a peak inspiratory pressure of 15 - 20 cm H_20, will help stabilize depth of anesthesia and assist in transitioning to a more normal respiratory pattern.
  - Low $EtCO_2$ can also be seen with low CO (and pulmonary perfusion).
  - Pets typically are hypotensive and should be managed accordingly.

Blood pressure abnormalities: hypotension and hypertension

Hypotension is the second most common complication in small pets undergoing anesthesia, occurring in approximately 38% of pets.[12]

Treatment of hypotension:

- Assess anesthetic depth.

- Consider the following interventions:
  - Administer anticholinergic drugs (if bradycardic).
  - Increase vascular volume (considering pet's cardiovascular status).
  - Use positive inotropes or vasopressors.

Assess anesthetic depth:

- Inhalant anesthetics cause dose-dependent myocardial depression and vasodilation.
  - Decrease inhalent percentage if indicated.
  - Additional opioid doses and/or adjunct analgesics will help decrease the MAC of inhalant, allow lower inhalant levels and therefore cause less cardiovascular depression.

Administer anticholinergic drugs:

- If hypotension is associated with bradycardia, treatment with anticholinergic drugs is indicated.

> !
> - Anticholinergic drugs will be less effective or not effective in the face of moderate to severe hypothermia

Increase vascular volume:

- SV can be improved with IV fluids including:
  - Crystalloid bolus of 5–10 mLs/kg
  - Colloid administration at 2–5 mL/kg (up to 20 mL/kg)
  - Hypertonic saline at 2–4 mL/kg
  - Blood products if indicated (blood loss greater than 20–30% of blood volume)
- Caution should be used in pets with cardiac disease
  - Adjust dose for:
    - Patient species (*i.e.* lower dose in cats)
    - Clinical status
  - Administer over 5–15 minutes to effect

Use positive inotropes and vasopressors

- Positive inotropes increase myocardial contractility, increasing CO.
- Vasopressors cause vasoconstriction, increased SVR and BP.

Positive inotropes and vasopressors

Ephedrine

- Acts directly on beta-1 and beta-2 adrenergic receptors to increase myocardial contractility
  - Has greater beta-1 than beta-2 activity
  - Has an indirect effect thorough release of norepinephrine, causing alpha-mediated vasoconstriction
  - Clinically, the HR may decrease as BP increases.

Ephedrine dosing:

- 0.05–0.1 mg/kg IV as a bolus. This dose may be repeated in 15–20 minutes if effective.
- Ephedrine is only available in a 50 mg/mL concentration and, therefore, may need to be diluted for administration to smaller pets
  - Dilute 0.1 mL in 0.9 mL crystalloid fluid to equal 5 mg/mL

Dopamine

- Doses of less than 2.5 **mcg**/kg/minute stimulate DA1 and DA2 dopamine receptors and cause vasodilation, especially in the kidney.
- Doses of 2.5–5 **mcg**/kg/minute stimulate beta-1 receptors, which increase myocardial contractility and positive inotropy.
- Higher doses (greater than 5–10 **mcg**/kg/minute) stimulate alpha-1 and alpha-2 receptors, leading to vasoconstriction and increased afterload.
- As BP increases, so does myocardial work.

Dopamine dosing:

- Low dose: 1–3 **mcg**/kg/minute
- Mid-range dose: 4–6 **mcg**/kg/minute
- High-range dose: 7–10 **mcg**/kg/minute

Dobutamine

- Beta-1 agonist that increases contractility and does not have a significant effect on SVR
- Has some beta-2 and alpha effects

Dobutamine dosing:

- 1–10 **mcg**/kg/minute

Hospitals should recognize the complexities in the correct dosing, administration and monitoring of CRIs and should ensure that anesthesia team members are properly trained to effectively and safely utilize these medications.

Calculate CRI: Intraoperative CRIs are calculated for three hours' duration to include the intraoperative and immediate recovery period. The calculations below are mixed in a syringe and administered with a syringe pump to allow precise dosing.

For patients >10 kg

Dopamine and dobutamine may be administered separately if desired or if medically indicated.

Calculate 10 mcg/kg/min and adjust rate to adjust dose

10 **mcg**/kg/minute
x body weight (kg) ÷ 1,000 **mcg**/mg
x 60 minutes / hour ÷ drug concentration (mg/ml)*

= ☐ mL/hour x 3 (hours)
= ☐ volume of drug for 3 hours of therapy

Subtract the total volume of one or both drugs from 30 mL D5W to get the mL of crystalloid to mix with.

For this method, always calculate for 10 **mcg**/kg/min and then adjust the fluid administration rate to alter the dose.

10 **mcg**/kg/minute = 10 mL/hr
5 **mcg**/kg/minute = 5 mL/hr

Example 1: 20 kg dog needing 10 mcg/kg/min of dopamine

20 kg x 10 **mcg**/kg/min = 200 **mcg**/min
200 **mcg**/min x 60 min/hr = 12000 **mcg**/hr
12000 **mcg**/hr ÷ by 1000 **mcg**/mg = 12 mg/hr
12 mg/hr ÷ by 40 mg/ml = 0.3 mL/hr
0.3 mL/hr x 3 hours = 0.9 mLs for 3 hours of treatment

- Remove 0.9 mLs from 30 mL D5W syringe and replace with 0.9 mLs dopamine
- Syringe should have 0.9 mLs dopamine + 29.1 mLs D5W
- Adjust dose to patient response
  - ❯ Run the infusion at 10 mLs/hr to = 10 **mcg**/kg/min
  - ❯ Run the infusion at 5.0 mLs/hr to = 5.0 **mcg**/kg/min
  - ❯ Run the infusion at 3.0 mLs/hr to = 3.0 **mcg**/kg/min etc.

This method allows easier titration to patient needs

*Dopamine = 40 mg/mL, dobutamine = 12.5 mg/mL. Double-check concentration to ensure accuracy.

For patients <10 kg

Dopamine and dobutamine may be administered separately if desired or if medically indicated.

It is important to be cognizant of the total fluids a small pet is receiving. Therefore, calculate the volume to which the drugs are mixed.

Body weight (kg) x 3 = ☐ total infusion volume for 3 hours

Calculate 10 mcg/kg/min and adjust rate to adjust dose

10 **mcg**/kg/minute
x body weight (kg) ÷ 1,000 **mcg**/mg
x 60 minutes / hour ÷ drug concentration (mg/ml)*

= ☐ mL/hour x 3 (hours)

= ☐ volume of drug for 3 hours of therapy

Subtract the total volume of one or both drugs from the total infusion volume (calculated above) to get the mL of crystalloid to mix with.

Note: The highest volume of infusion is 1 mL/kg/hour, so a normal IV fluid rate can be administered to the pet without risk of overhydration.

Since the volume of infusion is based on a fluid rate, the dose is also based on the rate/kg:

10 **mcg**/kg/minute = 1 mL/kg/hour
5 **mcg**/kg/minute = 0.5 mL/kg/hour

*Dopamine = 40 mg/mL, dobutamine = 12.5 mg/mL
Double check concentration to ensure accuracy

Example 2: 5 kg cat needing 5 mcg/kg/minute of dobutamine:

Calculate total infusion volume:

Body weight (kg) x 3 = 5(3) = 15 mL total infusion volume

5 kg x 10 **mcg**/kg/min = 50 **mcg**/min

50 **mcg**/min x 60 min/hr = 3000 **mcg**/hr

3000 **mcg**/hr ÷ by 1000 **mcg**/mg = 3 mg/hr

3 mg/hr ÷ by 12.5 mg/ml = 0.24 mL/hr

0.24 mL/hr x 3 hours = 0.72 mL for 3 hours of treatment

› Remove 0.72 mL from 15 mL D5W and replace with 0.72 mLs dobutamine

› Adjust dose to patient response

Run the infusion at 0.5 mL/kg/hr = 5.0 **mcg**/kg/min

Run the infusion at 1.0 mL/kg/hr = 10 **mcg**/kg/min

Run the infusion at 0.3 mL/kg/hr = 3.0 **mcg**/kg/min etc.

Note:

- **Blood pressure must be monitored every one to two minutes.**
- Start at the low end of dose, gradually increasing every 3–5 minutes until the desired BP is achieved.
- **Inotropes and vasopressors may cause cardiac arrhythmias. ECG must be monitored.**
- **Stop the CRI** if tachycardia or other arrhythmia (VPC, severe bradycardia) occurs. Arrhythmia is usually short lived and the CRI can be restarted at lower rate once arrhythmia resolves.

Treatment of hypertension

- Evaluate depth of anesthesia.
- Supplement analgesia (re-dosing of opioids or adding an adjunct analgesic).
- Consider increasing the inhalant if indicated.
- BP at the high end of normal limits is an expected effect in pets administered dexmedetomidine, especially at higher doses (greater than 5 **mcg**/kg in dogs, greater than 10 **mcg**/kg in cats).
- Hypertension may also be seen in some pets with comorbidities, such as hyperthyroidism, Cushing's disease or renal disease.

Cardiac dysrhythmias

Evaluation for dysrhythmias

- Perform preoperative cardiac auscultation with simultaneous palpation of peripheral pulses to identify cardiac arrhythmias prior to anesthesia.
- A preoperative lead II ECG allows definitive diagnosis of the arrhythmia and treatment monitoring.
- Further cardiac workup (chest radiographs, echocardiograph) should be offered to the client when medically indicated with a discussion of potential risks prior to the pet undergoing general anesthesia.
- Arrhythmias may be seen in pets with cardiovascular disease, critical/unstable pets and those with moderate-to-severe electrolyte and acid/base abnormalities.

Causes of cardiac dysrhythmias associated with anesthesia:

- Cardiac disease
- Drugs
- Electrolyte and acid/base abnormalities
- Hypercapnia
- Hypotension
- Hypovolemia
- Hypoxemia
- Increased sympathetic tone
- Increased vagal tone
- Pain
- Systemic disease (*e.g.*, gastric dilatation-volvulus (GDV), splenic mass)

Types of dysrhythmias

Being familiar with the common arrhythmias associated with anesthesia and underlying diseases allows the team member providing anesthesia to quickly identify and treat if needed. Common dysrhythmias seen in perioperative pets include:

- Sinus bradycardia
- Sinus tachycardia
- Second degree A-V block
- Ventricular premature contractions

Table 2.18

Causes of specific cardiac arrhythmias

Bradycardia	Tachycardia
Brachycephalic breed*	Anemia*
Hyperkalemia	Anticholinergics
Hypoglycemia	Hypercarbia
Hypothermia	Hyperthyroidism
Opioids	Hypoxia
Propofol	Ketamine
Sedatives	

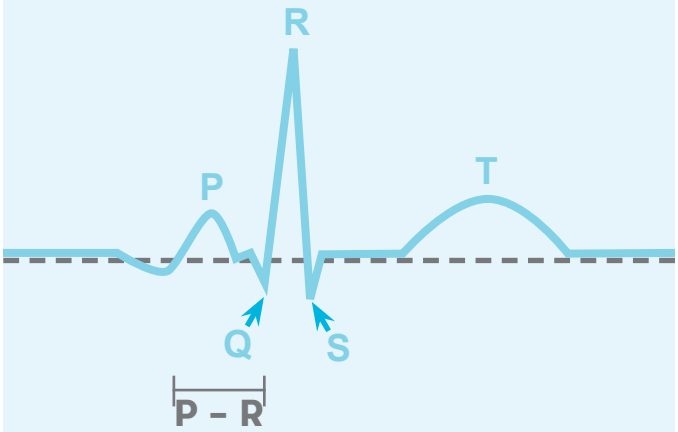
*Not associated with anesthesia.

Notes

A simple systematic approach is helpful when evaluating for cardiac dysrhythmias:

- Identify P, QRS and T waves.
- Is there a P for every QRS?
- Is there a QRST for every P?
- Is the R-R interval constant or varied?
  - Is there a pattern to the variation?

Figure 2.40: Normal sinus rhythm



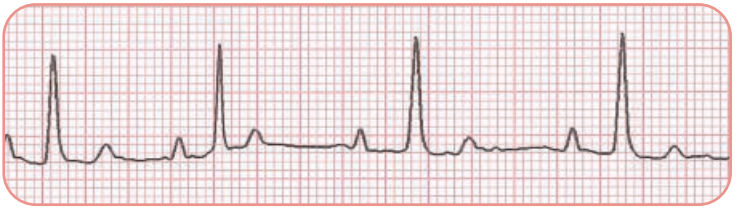
P wave: Atrial depolarization
PR interval: Time from start of atrial depolarization to start of ventricular depolarization
QRS complex: Ventricular depolarization
T wave: Repolarization of the ventricular myocardium

Normal HR ranges:
Canine: 60–150 bpm
Feline: 80–180 bpm

Sinus bradycardia (Figure 2.41)

- CO is directly reliant on HR and MAP is dependent on CO, therefore, low HR can cause decreased CO, leading to decreased MAP.
- **Bradycardia is a common anesthetic complication, occurring in approximately 36% of small pets.**[12]
- Treatment is indicated if bradycardia is resulting in hypotension.
  - Treat the underlying cause if known.
  - Administer anticholinergic drugs (atropine, glycopyrrolate).

Figure 2.41: Sinus Bradycardia, lead 2 tracing



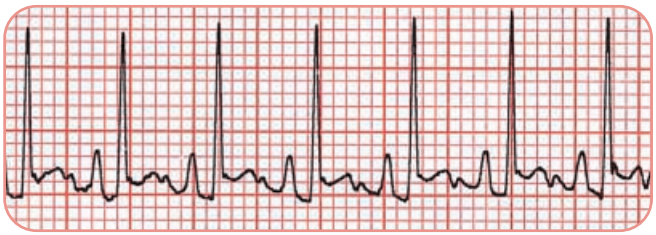
ECG tracing is courtesy of Iowa State University VMC Cardiology.

Notes

Sinus tachycardia (Figure 2.42)

- Severe tachycardia will decrease SV, leading to decreased CO and MAP.
  - It will also increase myocardial work and O_2 consumption while decreasing cardiac perfusion, which can lead to ventricular arrhythmias.
- Investigation into the likely underlying cause is indicated. IV anticholinergic administration causing short term tachycardia can be tolerated in young healthy pets with adequate cardiac reserve as it is usually self-limiting (5–10 minutes duration).
  - Judicious use of anticholinergic drugs (*i.e.*, administration of 0.25–0.5 the calculated dose) is indicated in geriatric pets or pets with cardiac disease.
- Treatment with a beta-blocker may be indicated for sustained tachycardia but hypotension may be a side effect of treatment.

Figure 2.42: Sinus tachycardia, lead 2 tracing



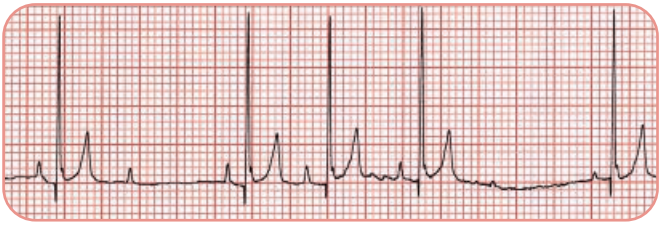
ECG tracing is courtesy of Iowa State University VMC Cardiology.

Notes

Second degree A-V block (Figure 2.43)

- This arrhythmia has many of the same causes as sinus bradycardia since it is also a vagally-induced arrhythmia.
- Treat with anticholinergic drugs (atropine, glycopyrrolate) if clinically indicated.

Figure 2.43: Second degree AV block, lead 2 tracing

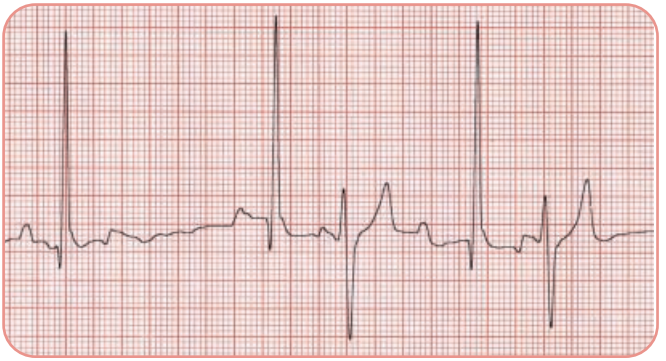


ECG tracing is courtesy of Iowa State University VMC Cardiology.

Ventricular premature contractions (VPC) (Figure 2.44)

- Characterized by:
  - No P wave with QRS
  - Variable R-R interval
  - R wave may be wide and bizarre
  - Compensatory pause after the VPC
  - Premature complex comes **before** a normally expected QRS

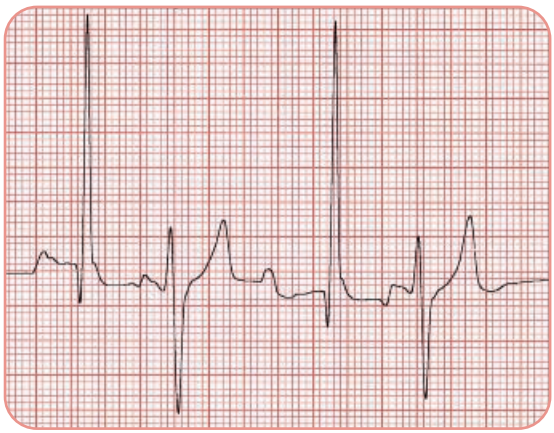
Figure 2.44: VPC, lead 2 tracing



ECG tracing is courtesy of Iowa State University VMC Cardiology.

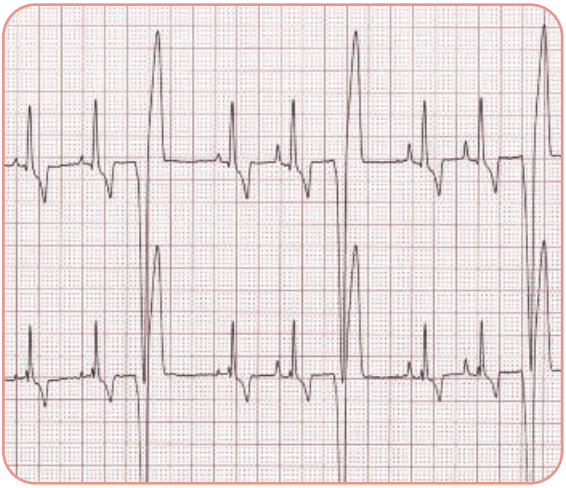
- Causes of VPC's are many and include:
  - Cardiac disease
  - Drugs (thiopental, digitalis)
  - Electrolyte or acid/base abnormalities
  - GDV
  - Hypoxemia
  - Ischemia
  - Osteosarcoma (OSA)
  - Pancreatitis
  - Splenic hemangiosarcoma
  - Traumatic myocarditis
- Indications to treat include:
  - HR above 150–180 bpm
  - Clinical signs (hypotension, "dropped pulses")
  - VPCs occurring greater than 20–30/minute
  - VPCs occurring in runs of more than three in a row
  - Abnormal VPC configuration such as:
    - Multi-focal (compared to uniform) VPCs: complexes vary in morphology
    - R on T phenomenon: VPC occurs during the T wave of the previous beat
    - Bigeminy: Every 2nd beat is a VPC (Figure 2.45)
    - Trigeminy: Every 3rd beat is a VPC (Figure 2.46)

Figure 2.45: Bigeminy, lead 2 tracing



ECG tracing is courtesy of Iowa State University VMC Cardiology.

Figure 2.46: Trigeminy, lead 2 and 3 tracing



ECG tracing is courtesy of Iowa State University VMC Cardiology.

- **The most important of these criteria is the elevated HR (above 150 – 180 bpm) and clinical signs of hypotension as these are indications that this rhythm may progress to pulseless ventricular tachycardia or ventricular fibrillation (which are cardiac arrest rhythms).**
  - Treatment entails finding/treating the underlying cause if possible and administering lidocaine.
    - Canine: 2 mg/kg IV
    - Feline: 0.25–0.5 mg/kg IV
  - Lidocaine dose may be repeated and then administered as a CRI.
    - Canine: 50 **mcg**/kg/minute
    - Feline: 10–20 **mcg**/kg/minute
  - See *Appendix* chapter for CRI dosing instructions.

- In addition, the team member providing anesthesia should be able to identify the four most common arrest rhythms to allow early intervention in the case of cardiac arrest:
  - Pulseless electrical activity (PEA) (Figure 2.47)
  - Asystole (Figure 2.48)
  - Ventricular fibrillation (Figure 2.49)
  - Ventricular tachycardia (pulseless) (Figure 2.50)

Figure 2.47: Pulseless electrical activity

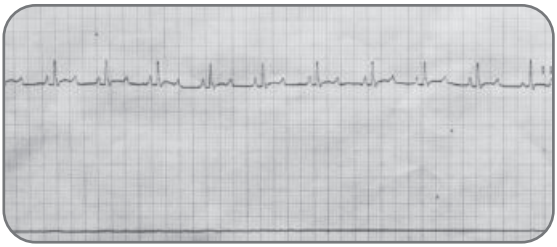


Figure 2.48: Asystole, lead 2 tracing

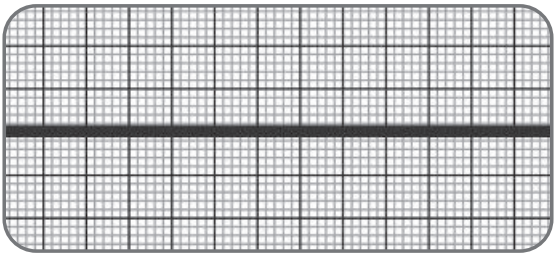


Figure 2.49: Ventricular fibrillation, lead 2 tracing

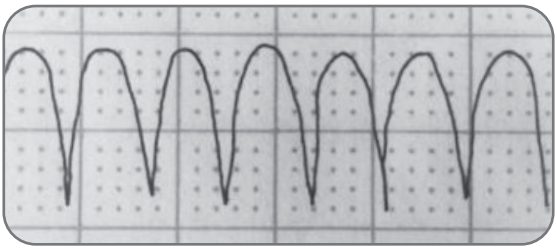
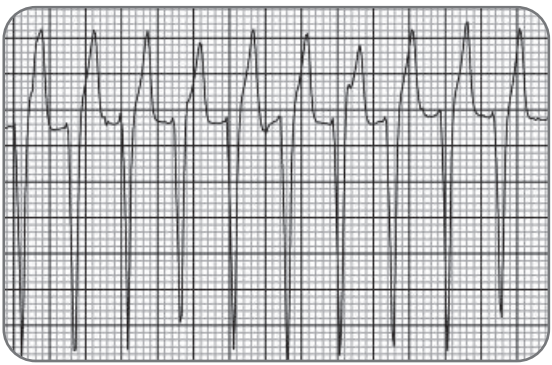


Figure 2.50: Ventricular tachycardia, lead 2 tracing



Hemorrhage

Delivery of oxygen to tissues is essential to pet survival. Normal healthy pets with a packed cell volume (PCV) of 20% can compensate for a decreased O2 content (resulting from anemia) by increasing CO via increasing HR and vasoconstriction. Anesthesia interferes with the ability to compensate by causing vasodilation and many anesthetic drugs also decrease HR.

The following preoperative transfusion triggers are recommended:

PCV	Recommendation
Under 20%	Transfusion recommended
Between 20 and 30%	Transfusion depends on organ reserve, expected blood losses and chronicity/regeneration
Over 30%	No transfusion

Even if a pet has a normal PCV preoperatively, the team member providing anesthesia should be prepared to quantitate and treat intraoperative hemorrhage if it occurs.

Treatment of acute intraoperative hemorrhage

- Induction of general anesthesia decreases PCV, total protein (TP) and colloidal osmotic pressure (COP), even if no crystalloid IV fluids are administered.
  - For procedures where high blood loss may be expected, the PCV, TP and/or COP should be measured after induction to obtain an accurate starting point for these values.
  - The total blood volume can be calculated for the pet and then increments of loss (10%, 20% and 30%) as this corresponds to modalities of treatment.

Table 2.19

Calculate total blood volume

Species	Examples
Canine: 90 mL/kg	20 kg canine x 90 mL/kg = 1800 mL
Feline: 70 mL/kg	2.5 kg feline x 70 mL/kg = 175 mL
Calculate allowable blood loss	
20 kg canine Total blood volume = 1800 mL	10% = 180 mL
	20% = 360 mL
	30% = 540 mL
2.5 kg feline Total blood volume = 175 mL	10% = 17.5 mL
	20% = 35 mL
	30% = 52. 5 mL

During anesthesia, clinical signs may be seen when as little as 10% blood loss has occurred because anesthetic drugs interfere with the pet's ability to compensate. Clinically, the team member providing anesthesia may see hypotension (MAP below 60 mm Hg). Compensatory tachycardia may or may not occur due to drugs, such as opioids, causing increased vagal tone. Blood loss should be replaced as it occurs and, therefore, it must be quantitated.

Quantitating intraoperative blood loss

- Cotton swab: 0.1 mL
- 4" x 4" sponge: 5 - 15 mL
- Lap sponge: 50 mL
- Weight: 1 gm = 1 mL
- Suction canister: mLs blood loss = (PCV of fluid/ PCV of pet) x (volume of fluid in suction canister)

Treatment of blood loss starting with normal PCV

- **10 – 15%: Replace with crystalloid (three to four times the amount of blood lost)**
- **15 – 25%: Add colloid (after crystalloid administration)**
- **Greater than 25–30%: Replace with blood**

Blood Products:

- **Fresh Whole Blood**
  - Includes red blood cells (RBCs), protein, platelets and clotting factors
  - For severe blood loss (over 30–50%)
- **Packed RBC**
  - Includes RBCs
    - PCV may be 80–90%
  - For less severe blood loss, or provide with plasma for severe blood loss

$$\text{MLs blood required} = \text{blood volume} \times \frac{(\text{desired PCV} - \text{recipient PCV})}{\text{donor PCV}}$$

- **Fresh Frozen Plasma**
  - Includes albumin, plasma proteins, clotting factors
  - For hypoalbuminemia (along with colloids), prolonged clotting times
    - High doses are needed (45 mL/kg to raise albumin 1 g/dL)
    - Synthetic colloids may be a more economically-feasible alternative in large dogs

Notes

Temperature abnormalities: hypothermia and hyperthermia

Management of hypothermia

Prevention of heat loss in premedicated pets is important. Ensure the pet is being supported with the appropriate pet warming device, especially in pets premedicated with acepromazine.

Treatment of hypothermia

"Prewarming" of pets prior to anesthesia helps limit the amount of hypothermia caused by redistribution of blood from the periphery to the core.

- Pets should be placed on a warm surface (*e.g.*, cage warmer or clean towels warmed in the dryer) while waiting for their anesthetic premedication to take effect.
- Hypothermia can also be limited by minimizing anesthesia and surgery time and warming of IV fluids and and surgical scrub. Use sterile saline rather than alcohol.
- Warm saline lavage of open body cavities (warm lavage fluid to 104–107° F).
- Body temperature should be monitored with a digital thermometer or thermistor probe. Active pet warming can be supplied by pet warming devices (circulating water blankets, forced warm air blankets and air-free, conductive warming blankets).
  - External heating devices need to be turned down or off as pet temperature reaches 99–99.5° F to prevent over-heating of the pet.

Hyperthermia

Hyperthermia due to over-warming of pets can be prevented by intraoperative monitoring of body temperature and turning down or off warming devices **before** target temperature is reached. Monitoring of body temperature should continue into the postoperative period for up to three hours (five hours in cats), even after the pet reaches normothermia.

- Remove all warming devices
- Active cooling
- Ice packs applied over jugular/carotid vessels and groin area
- Supplemental O_2: 100% O_2 at 50–100 mL/kg/minute
- Acepromazine: causes peripheral vasodilation, which may help lower core body temperature and will decrease excitement and muscle movement in dysphoric pets. Acepromazine (0.005–0.01 mg/kg) can cause peripheral vasodilation and assist in lowering core body temperature by redistribution of blood to the periphery.
- Dexmedetomidine (0.5–1.0 **mcg**/kg) can be helpful in agitated pets, especially cats that have been administered ketamine or Telazol, to decrease heat production from muscle movement.
- Hyperthermia that may be seen with cats administered hydromorphone tends to be self-limiting and may be a result of opioid excitement. If clinically indicated, administration of a reversal agent may be considered. Ensure patient analgesic requirements are met.
- Hyperthermia (T >104⁰ F) may be seen with long acting buprenorphine and cats should be monitored every two hours during onset of action and every 12 hours thereafter. Discontinue use and administer alternative analgesic if T >104⁰ F.

Gastroesophageal reflux (GER)

GER occurs when the gastric contents flow orad into the esophagus due to decreased lower esophageal sphincter tone under anesthesia. The majority of GER is clinically silent. Therefore, the team member providing anesthesia must always ensure the ET cuff is properly inflated to protect the airway.

The consequences of the acidic fluid in the lower esophagus may be esophagitis with subsequent stricture and aspiration pneumonia.

Reflux can be catastrophic in brachycephalic pets. Close monitoring and swift interventions are warranted. Consider pre-emptive use of antiemetics in these pets.

Prevention of aspiration:

- Check the ET cuff for leaks **prior** to induction.
- Intubate all pets undergoing general anesthesia.
- Properly inflate the ET cuff.
- Check cuff inflation periodically during procedure.
- Deflate the cuff during recovery only when the pet has a strong swallow reflex and is ready to be extubated.

Treatment

- Indicated if regurgitation is observed from the mouth or nose during anesthesia.
  - Brownish fluid may be observed from the mouth or nose, especially during or after moving the pet or when removing esophageal monitoring devices.
- Esophagus should be suctioned and lavaged with water until the fluid is clear and sodium bicarbonate instilled into the esophagus.

Equipment list for lavage

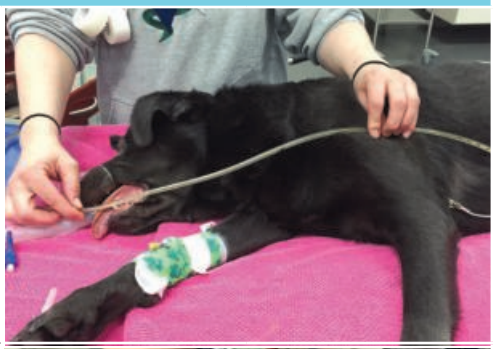
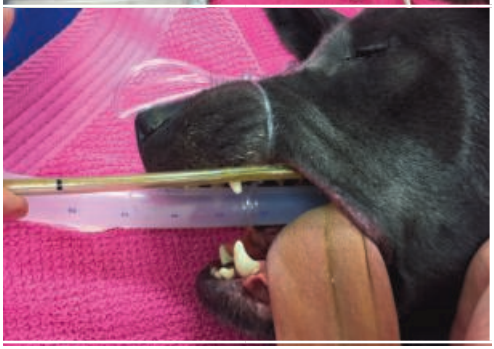
- Double or single lumen gastric tube
- Sodium bicarbonate
- Warm tap water
- 60 mL syringe or vacuum suction

Notes

ALWAYS CHECK FOR PROPER INFLATION OF THE ENDOTRACHEAL CUFF PRIOR TO PASSING THE GASTROESOPHAGEAL TUBING FOR SUCTION AND LAVAGE.

Table 2.20

Gastroesophageal reflux lavage procedure

Step	Description	
1	Measure lavage tubing from tip of nose to approximate level of the lower esophageal sphincter (LES) and mark tubing at tip of nose	
2	Pass tube to measured level	
3	Enlarged view	

Gastroesophageal reflux lavage procedure

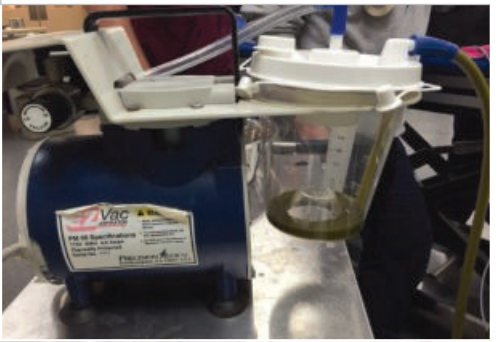
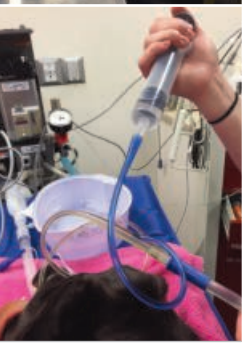
Step	Description	
4	Aspiration of esophageal contents	▪ Gently move the tube slightly inward and outward while suctioning fluid from lower esophagus ▪ Alternate esophageal lavage (using warm tap water) with suction until suctioned fluid is clear
5	Intermittent suction can be applied with a vacuum aspirator **OR** With a 60 cc catheter tip syringe	   
6	Sodium bicarbonate infusion (once suctioned fluid is clear)	▪ Instill 10–20 mLs of dilute (4.2%) sodium bicarbonate into esophagus • Dilute 5–10 mLs 8.4% sodium bicarbonate with 5–10 mLs of warm tap water and leave in (do not suction) ▪ Remove esophageal tube. The lower esophageal pH will be kept greater than 6 for 3–4 hours, decreasing the likelihood of esophagitis[14]

Table 2.21

Interventional modalities for anesthetic monitoring

Parameter	Complication	Techniques to consider
Anesthetic depth	Depth is too light	**Rebreathing** Increase vaporizer and increase O_2 to 3–4 L/min
		Manually ventilate
		Administer propofol 0.5–1 mg/kg IV over 15 seconds
		NRB Increase vaporizer setting
		Consider manual ventilation
Circulation	Bradycardia – AV block	Administer anticholinergic if concurrent hypotension
	Sinus Tachycardia	Investigate underlying cause (pain, hypoxia, etc)
	VPC	If HR >150–180 and hypotense, lidocaine 2 mg/kg IV (canine) or 0.25 mg/kg (feline)
Ventilation	Increased $EtCO_2$ (hypercarbia)	Check anesthetic depth, lower inhalant (remember analgesia)
		Check machine and breathing circuits
		Provide IPPV
	Decreased $EtCO_2$ (hypocarbia)	Provide PPV at 4–6 bpm at peak inspiratory pressure of 15–20 cm H_2O
		Check BP and manage hypotension
Oxygenation	SpO_2 <95 (hypoxemia) depends on cause	Check O_2 supply, flowmeter, machine and breathing circuits Pre-oxygenate with 100% O_2
		Check intubation and provide 100% O_2 with IPPV
		Remove air/fluid from pleural space if present
		Provide 5–10 minutes O_2 after discontinuing inhalant
		Increase FiO_2 to 100%

Interventional modalities for anesthetic monitoring

Parameter	Complication	Techniques to consider		
Temperature	Hypothermia	Prewarm prior to induction		
		Warm IV fluids and patient warming device		
		Warm saline lavage (104–107° F) in body cavity		
		Minimize anesthesia and surgical times		
		Warm scrub; use sterile saline rather than alcohol		
	Hyperthermia	Remove warming devices		
		Actively cool, apply ice packs		
		Administer supplemental O_2 (50–100 mL/kg/min)		
		Consider acepromazine* for vasodilation		
Blood glucose	Hypoglycemia <70 mg/dl	Administer 2.5–5% dextrose in balanced electrolyte IV		
		Continue to monitor		
Blood pressure	Hypertension	Evaluate anesthetic depth		
		Administer supplemental analgesics		
		Consider increasing inhalant		
	Hypotension	Decrease inhalant anesthetic depth (remember analgesia)		
		Administer anticholinergic drugs if bradycardic		
		IV fluids	crystalloids 5–10 mLs/kg	
			colloids 2–5 mL/kg	
			hypertonic saline 2–4 mL/kg	
		Ephedrine	0.05–0.1 mg/kg IV	MUST monitor ECG
		Dopamine	1–10 **mcg**/kg/min CRI	
		Dobutamine	1–10 **mcg**/kg/min CRI	

*Remember maximum acepromazine dosages.

Figure 2.48: Anesthesia monitoring

Blood pressure

Monitor continuously:
Blood pressure
Peripheral pulse, MM/CRT

Hypotension

SAP <90
OR MAP <60 mm Hg

1. **Assess anesthetic depth**
   If too deep:
   - Decrease inhalant
   - Increase O_2 flow to 50 mLs/kg/min (rebreathing)
     - 200–300 mLs/kg/min (NBR)
2. **Assess HR**
   Give anticholinergic if:
   Med - lg canine .....<60 bpm
   Small canine .....<80 bpm
   Feline .....<90 bpm
3. **Asses volume status**
   If hypovolemic:
   Administer IV fluid bolus
   Canines ..... 10 mL/kg
   Felines ..... 5 mL/kg
4. **Assess volume status**
   If still hypovolemic:
   Administer colloid solution
   Canines .....5 mL/kg
   Felines .....2.5 mL/kg
   (max 20–40 mL/kg)
   If normovolemic:
   Administer ephedrine
5. **Assess for hemorrhage**
   Transfuse if indicated
   Administer dopamine + dobutamine (See text for dosing details and instructions)

Oxygenation

Monitor continuously:
SpO_2
Respirations

Hypoxemia

SpO_2 <95%

Assess probe placement

- Use wet gauze with lingual probe

During induction:

- Preoxygenate and monitor
- Intubate quickly
- Provide 100% O2
- IPPV at 2 - 4 bpm

If SpO2 worsens, abort procedure and recover patient

During maintenance:

See text for causes and treatment

During recovery:

Provide O_2 support

If intubated:
50–100 mLs/kg/min via breathing circuit

150–300 mLs/kg/min via NRB circuit

If extubated:
Flow-by/mask/nasopharyngeal – See text for details on partial reversal and brachycephalic recovery

Heart rate

Monitor continuously: heart rate, peripheral pulse

Tachycardia

Large canines ..... >100 bpm
Medium canines .... >120 bpm
Small canines ..... >120 bpm
Felines..... >160 bpm

1. **Confirm manual HR and ECG match**
2. **Assess anesthetic depth**
   If too light:
   - Increase inhalant (and O_2 flow rate)
3. **Administer additional analgesics**
4. **Assess for hemorrhage**
   Transfuse if indicated

End tidal CO_2

Monitor continuously: $EtCO_2$

Hypercarbia

$EtCO_2$ >55 mm Hg

Assess anesthetic depth
If too deep:
- Decrease inhalant

Ventilate patient

Bradycardia

Large canines..... <60 bpm
Medium canines .... <60–80 bpm
Small canines ..... <80 bpm
Felines ..... <90 bpm

NO dexmedetomidine given:

1. **Confirm manual HR and ECG match**
2. **Assess anesthetic depth**
   If too deep:
   - Decrease inhalant
3. **Assess BP** (see *hypotension*) *Administer anticholinergic if indicated:*
   - Bradycardia
   - Heart block
   - HYPOtension
4. **Assess for hemorrhage**
   Transfuse if indicated

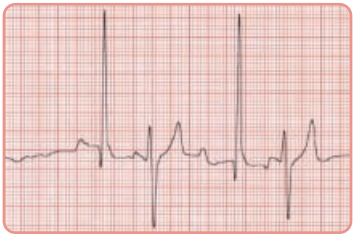
YES dexmedetomidine given:

1. **Confirm manual HR and ECG match**
2. **Assess BP**
   Consider anticholinergic if:
   - Bradycardic
   - HYPOtensive (MAP <60 mm Hg)
   - See text for details
3. ***Consider dexmedetomidine reversal if:***
   - Emergency situation
   - HR <30 bpm
   - Procedure can be aborted

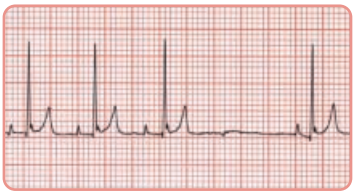
ECG
Monitor continuously

Common deviations from normal sinus rhythm

VPC



Second Degree Heart Block



Check for underlying causes and address:

Causes: Pain, hypercarbia ($EtCO_2$ >60–70), severe hypoxemia, cardiac disease, ischemia, drugs, etc.

Treatment criteria (see text for details):
- HR >150–180 bpm
- Pulse deficits
- Hypotension
- Abnormal VPC configurations
- 3 VPCs in a row, etc.

Consider lidocaine bolus, followed by CRI if indicated

Temperature
Monitor continuously: rectal or esophageal temperature

Hypothermia
T <100 ° F

Mild..... 98–99° F
Moderate..... 96–98° F
Severe..... 92–96° F
Critical..... less than 92° F

Prior to induction:
- Place patient on warm surface
- Abort procedure if T worsens before induction

During maintenance:

1. Utilize pet warming device
- Circulating warm water or forced air patient warming blankets

2. Warm IV fluids
- Place IV fluid warmer as close to patient as possible

3. Warm saline lavage in open body cavity
- Measure fluid T (104–109° F)

4. Assess response

5. Abort procedure and recover patient

Any parameter that is continuing to worsen or is refractory to treatment warrants aborting elective anesthesia procedures and recovering the patient as quickly as possible.

Recovery

Along with induction and intubation, the recovery period is one of the most critical phases of an anesthetic procedure. **The majority of postoperative mortality occurs within the first three hours of recovery from anesthesia. Therefore, continued monitoring will allow for identification of complications and intervention.**[2]

Clinical essential

Assign and document at least one hospital associate with the sole responsibility of dedicated, continuous patient monitoring and dedicated recovery to every immobilization or general anesthetic procedure. If there is not a trained, dedicated associate, the procedure must be rescheduled.

The team member providing anesthesia should prepare for recovery by considering the pet's analgesia and sedation needs to provide adequate analgesia and a smooth transition to wakefulness.

The urinary bladder should be palpated and gently expressed, if noted to be subjectively large, prior to discontinuation of inhalant anesthetic.

- A full urinary bladder may be painful and can be mistaken for surgical pain, resulting in additional doses of analgesic medication.
- Especially true for:
  - Pets receiving dexmedetomidine
  - Pets that have received high volumes of fluids or longer procedure times
  - Pets that have a barrier to normal urination (neurologic disease, large bandage, etc.)

Recovery procedure:

- Consider the pet's analgesia needs and redose if indicated.
- Consider the pet's sedation needs, either pre-emptively or have ready if needed:
  - **Acepromazine:** 0.005 mg/kg
    - Administer at time of discontinuing inhalant.
    - Use is especially indicated if dexmedetomidine was included in premedication and more than an hour has elapsed since administration.
  - **Dexmedetomidine:** 1–2 **mcg**/kg IV
    - Very fast onset of action
    - Provides analgesia and sedation should differentiation between pain and anesthetic emergence not be possible
    - Potent sedative to prevent risk or injury to the the patient or associate
- Turn anesthetic vaporizer off.
- Empty reservoir bag with pop-off valve open and increase O_2 flow rate to three to five liters/minute to eliminate and wash out inhalant anesthetic from the breathing circuit and into the scavenger system.
  - O_2 should be supplied for 5–10 minutes prior to disconnection from the breathing circuit.
  - Continue to monitor $EtCO_2$ while the pet is connected to the breathing circuit.
- **Monitor SpO_2 at transition to room air and provide O_2 support as needed.**
  - Residual respiratory depression may be present at recovery.
  - Even mild hypoventilation ($EtCO_2$ above 45–50 mm Hg) may lead to hypoxemia when the pet is breathing room air.
    - Supply O_2 at 50–100 mL/kg/minute via ET tube or flow-by/mask if SpO_2 is under 93–95% for the short-term postanesthetic period.
    - Consider nasal pharyngeal or nasal tracheal (brachycephalic breeds) O_2 if the pet is anticipated to need longer term O_2 support than the immediate postoperative period.
    - Instructions for placement of nasal O_2 tubes are provided in the *Respiratory Insufficiency: Hypoventilation and Hypoxemia* section.

- Partially reverse opioids to alleviate respiratory depression and sedation due to pure mu-agonist opioids, especially intraoperative fentanyl CRIs.
  - Partial reversal can be considered in pets with prolonged recovery (unarousable, still intubated over 30 minutes after discontinuation of inhalant and/or respiratory depression ($EtCO_2$ above 45–50 mm Hg), leading to prolonged O_2 dependence).
  - Add 0.1mL (1 mg) butorphanol + 0.9 mL NaCl, give in 0.2 mL (0.2 mg) increments.
    - The majority of pets only require one dose.
- Prepare recovery kennel or cage with adequate bedding and additional warming measures as indicated for each patient.
- Ensure adequate numbers of team members are available to safely and gently move pet.
- Deflate the ET cuff when a vigorous swallow reflex is present and extubate (see below for the brachycephalic breed exception).

- Remove ECG leads and BP cuff when values have returned to normal.
- Recheck SpO_2, supply flow-by/mask O_2 if SpO_2 is less than 93–95%.
- Monitor SpO_2, temperature, pulse and RR.
- For cats, monitor body temperature up to five hours post return to normothermia (for possible hyperthermia).
- For cats and dogs, monitor periodically for up to three hours postoperatively, after complete anesthetic recovery has been achieved.

Caution: Brachycephalic breeds are especially prone to upper airway obstruction in the postanesthetic period. They should be recovered slowly in a (preferably) darkened, quiet room. They should be placed in sternal recumbency with their head slightly elevated. Be careful not to compress the jugular veins and allow drainage of gastroesophageal reflux should it occur at recovery. Folded towels or a radiology foam wedge may be used. The ET tube should be kept in place as long as the pet will tolerate it. SpO_2 should be monitored at the transition from 100% O_2 and throughout recovery, especially after extubation. Brachycephalic pets need to be carefully observed for evidence of upper airway obstruction after extubation. The team member providing anesthesia should be prepared to reintubate (induction agent, laryngoscope and ET tube) should obstruction occur.

CLINICAL ESSENTIAL

Endotracheal tubes must remain in place until protective laryngeal reflexes return and are vigorous without the application of noxious stimuli

Factors that may contribute to poor recovery include hypoxemia, pain (surgical, underlying disease, full urinary bladder) and drug side effects. Following the steps in the recovery procedure allows the team member providing anesthesia to prepare for, monitor and prevent many of the causes of poor recovery.

Notes

Prolonged, dysphoric or "rough" recovery

Dysphoria/rough recovery

Emergence delirium is a well-known phenomenon in human medicine, occurring in 5 percent of adults and 12–13 percent of children. It is defined as a dissociated state of consciousness in which the patient is inconsolable, irritable, uncooperative, typically thrashing, crying, moaning or incoherent and does not recognize familiar objects or people.

This condition can also be seen in pets, especially in pets that have a short time to awakening at the end of anesthesia. It is often difficult to discern the exact cause of rough recovery in pets, but some possibilities include:

- Emergence agitation
- Hypoxemia
- Noise sensitivity (due to opioids, dexmedetomidine)
- Pain
- Urinary bladder discomfort

It is important to remember that several life-threatening considerations (*e.g.*, hypoxia, severe hypercarbia, hypotension, hypoglycemia and increased intracranial pressure) may also result in disorientation and agitation. These entities must be monitored for and treated promptly. Bladder distention may also yield a similar clinical picture.

Prevention/preparation

- Anticipate the pet's analgesia and sedation needs for recovery.
- Empty the pet's urinary bladder at the end of surgery/procedure.
- Follow recovery protocol as above to prevent, identify and treat hypoxemia.
- Consider sedation, either pre-emptively or have acepromazine and/or dexmedetomidine ready if needed as described previously.

Postoperative care: pet well-being

Care of the anesthetic/surgical pet does not end with the procedure. Perioperative care can determine pet outcome and even survival, especially in critical pets. Monitoring of vital signs continues until complete anesthetic recovery. Periodically monitor through three hours post-recovery to ensure normalization of homeostasis and continued smooth recovery. Cats may need additional temperature monitoring.

Thereafter, the goals should focus on overall pet well-being:

- Nutrition
- Pain control
- Fluid balance
- Management of stress and anxiety
- Nursing needs such as urination/defecation

A generally accepted approach has been to follow the Five Freedoms, which outline aspects of animal welfare when animals are under human control.

The five freedoms

Freedom from thirst, hunger and malnutrition
Freedom from discomfort
Freedom from pain, injury and disease
Freedom to express normal behavior
Freedom from fear and distress

Nutrition

Surgery and anesthesia lead to a negative energy balance in pets as a result of increased metabolic demand and decreased caloric intake due to:

- Surgery
- Fasting
- Postoperative sedation
- Perioperative nausea/vomiting
- Underlying disease/condition

Healthy pets undergoing elective anesthetic procedures should have minimal difficulty with caloric intake and maintenance of body condition. Pets that are debilitated, acutely ill or injured may develop a negative energy balance. This negative energy balance can increase the basal energy requirement (BER) by a factor of 1.25–1.5.

It is important that the veterinarian calculate the pet's maintenance energy requirement (MER) (BER X MER factor) and monitor caloric intake.

Interested readers are directed to outside resources for detailed information.

Other considerations

There are several other factors that should be considered to ensure pet well-being and comfort.

Pain assessment and management

See *The Individualized Anesthesia and Analgesia Plan* chapter for the basic tenets of pain management, classification of types of pain, review of pain pathway, multimodal approach to pain management, review of analgesia drugs and administration modalities, local anesthesia/analgesia, post-op analgesics and pain assessment tools.

As needed (PRN) analgesia

- Administration of analgesic drugs should be based on the pet's underlying disease or surgical procedure, pre-emptive and pain scale assessment and the dosing requirements for the specific drug(s) that were given.

- **Veterinarians should operate under the assumption that certain conditions and procedures are painful and should be treated with analgesics without the pet having to "prove" she/he is in pain.**
- Surgical procedures, trauma and painful medical conditions, such as gastroenteritis, pancreatitis, neoplasia etc., require pain management in their treatment plans.

Analgesics for sleeping or resting pets

- Pets are more likely to be comfortable and resting when they have adequate pain control.
  - Continue analgesic therapy according to the pharmacokinetic/dynamic dosing recommendations for the specific drug and species.
- Pets should be assessed for pain using the pain scale assessment tool after the expected onset of analgesic drugs.
- Pets should be allowed to sleep following analgesic treatment and assessment for pain and level of sedation.

"Unarousable" pets

- Pets do need to be periodically assessed for their level of consciousness.
  - Best to be completed after the onset of analgesic activity.
- Overmedicating puts pets at risk for regurgitation/aspiration and hypoventilation/hypoxemia.
  - Pets should be able to respond to their name, lift their head and have adequate swallowing reflexes.

Fear/anxiety/stress

- The physiologic consequences of stress are the same as pain and have negative sequelae for most bodily systems:
  - Increased sympathetic tone:
    - Causes increased vasoconstriction and BP, resulting in an increase in myocardial work
  - Decreased pulmonary function due to increased muscular tension and decreased lung compliance:
    - Exacerbates postanesthetic atelectasis and increases postoperative lung complications such as pneumonia
  - Decreased gastrointestinal tone and motility

- Endocrine responses:
  - Cause an increase in stress hormones, resulting in increased catecholamines, cortisol, antidiuretic hormone, angiotensin II, aldosterone, glucagon and interleukin-1 and decreased insulin
- Decreased immune function due to decreased lymphocytes, killer T cells and decreased marginating white blood cells
- Increased platelet adhesion, decreased fibrinolysis and activation of the coagulation cascade

- Pathologic pain and stress can ultimately lead to:
  - Catabolic state (protein catabolism, lipolysis, hyperglycemia and inappetence)
  - Insomnia/sleep deprivation
  - Fatigue
  - Exhaustion
  - Immobility
  - Decreased glomerular filtration rate (water, sodium, and potassium imbalances)
  - Decreased tissue O_2
  - Delayed wound healing
- Stress/anxiety can be difficult to differentiate from pain as pets exhibit many of the same behaviors, including cowering, shaking, aggression, escape behaviors, "vigilance" and refusal to rest.
  - Pets may score high on pain assessment evaluations, indicating the need for adjustment of analgesic protocols, when there is a significant stress/anxiety component.

Management:

- Treat for pain first.
  - Consider additional opioid doses and/or adding a nonsteroidal anti-inflammatory drug (NSAID) or other adjunct analgesic.
- Pay attention to nursing needs.
  - Ensure pet is clean and dry, comfortable bedding is provided, elimination needs are met, etc.
- If little to no improvement is seen, consider sedative/anti-anxiety treatment.
  - Acepromazine: 0.005 mg/kg IV.

- Acepromazine does not have analgesia properties but has synergistic effects with opioids, presumably by decreasing anxiety level and increasing pain threshold.
- Dexmedetomidine CRI
  - See *Appendix* chapter for details
- Alprazolam
  - A benzodiazepine
  - Canine: 0.02–0.1 mg/kg by mouth every 12 hours
  - Feline: 0.125–0.25 mg/cat by mouth as needed up to every 12 hours
- Trazadone
  - A serotonin antagonist/re-uptake inhibitor
  - 3.5 mg/kg by mouth twice a day, up to 7–10 mg/kg twice a day
  - Onset of action: 30–45 minutes
  - Duration of action: approximately four hours

Dysphoria

- Vocalization and lack of response to interaction with people are clinical signs which can be seen in dogs with opioid dysphoria.
- These pets may display many signs interpreted as pain, however, when treated with opioid analgesics they do not improve or the behaviors may worsen.
  - This may lead to aggression.

Management:

- Opioid dysphoria is a diagnosis of elimination.
- After the pet is treated for pain, anxiety/stress and checked for elimination/nursing needs, **then** treatment for dysphoria can include:
  - Sedation
    - Mild dysphoria can be treated with mild sedation.
      - Acepromazine: 0.005–0.1 mg/kg IV
      - Dexmedetomidine: CRI: see Appendix chapter for details
  - Partial reversal with butorphanol
    - 0.1 mL (1 mg) diluted in 0.9 mL saline, given in 0.2 mL increments at three to five minute intervals
  - Full reversal with naloxone
    - Results in rapid resolution of vocalization and opioid-induced dysphoria
    - **Analgesia will also be reversed.**

Elimination needs

- Dogs can have increased sympathetic stimulation, leading to tachycardia, panting and behavioral changes such as vocalization.
- Many dogs become very agitated when they need to eliminate and are not taken out.
  - A dog that is showing distress and vocalizing may need to go outside.
  - Dogs that have eliminated in their kennel or on their bedding may also become agitated.
- Medical conditions, surgery and drugs may alter their elimination patterns and thus pets may be out of sync with the routine "walking" times.

Management:

- Routine emptying/expressing of the pet's urinary bladder postoperatively before the pet awakens from anesthesia
  - May prevent discomfort from a distended bladder and help to decrease confusion between needing additional analgesics and the need to alleviate a distended bladder (also painful)
- Dexmedetomidine will increase urine production and opioids will decrease urine production and increase sphincter tone. It is important to be aware of these drug side effects in pets.
- Assess bladder size every six hours postoperatively.
  - If the pet is not urinating and the bladder is distended:
    - Walk the pet outside with assistance (sling).
    - Attempt to gently express the pet's bladder.
    - Consider intermittent sterile urinary catheterization.
  - Consider partial/full opioid reversal for enlarged bladders that cannot be expressed.

Appetite

- Inappetence may be due to a variety of factors.
  - Nausea caused by opioid drugs
  - Pain, etc.

Management

- Perform proper pain evaluation and address as needed.
- Adjust analgesic plan and/or treat side effects of nausea.
- Ensure that palatable foods with the appropriate caloric needs are offered.

Resentment at being kenneled

- Dogs that are either housed outside or have never been kenneled may vocalize and experience severe anxiety.
  - May lead to self-injury when kenneled in the hospital.

Management

- Rule out all other causes.
- Treat for pain and anxiety.
- Address elimination and feeding needs.
- Attempt alternate housing or early discharge.

Separation issues or loneliness

- Many pets are considered members of their families and, as such, are given status and attention afforded to human family members.
  - Alone in the hospital, they may whine or vocalize for attention and affection and may benefit from one on one attention.
- This can be considered when all other possibilities have been addressed (analgesia, elimination/nursing needs fulfilled, etc.).

Management

- Pet may settle and quiet down with simple attention and comfort and this may take the place of chemical anxiety relief.
- Administer chemical anxiety relief (discussed above) only as needed.

Conclusions

The time starting with anesthetic induction, lasting throughout full anesthetic recovery can be dangerous and life-threatening. Minimize risk and maximize patient safety with a well-trained team, paying careful attention to all patient parameters, anticipating potential complications. Familiarity with anesthetic and analgesic medications, along with diligent monitoring, facilitate success and safety.

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Notes

Definitions

The following definitions are provided to ensure clarity and facilitate communication among hospital teams.

General anesthesia refers to a procedure that is performed after administration of a medication(s) that results in analgesia, paralysis and unconsciousness. General anesthesia begins with the preanesthetic evaluation and lasts until complete anesthetic recovery is attained.

Sedation involves the administration of a pharmaceutical to facilitate the performance of non-painful procedures and to reduce pet anxiety. The patient may be ambulatory and all reflexes are intact. The pet cannot be intubated.

Immobilization is defined as a nonsurgical plane of anesthesia. The pet is non-ambulatory but can be roused with minimal effort. Laryngeal and withdrawal reflexes are intact. Immobilization may be used for non-painful procedures that are expected to last <10 minutes and cannot be used for brachycephalic pets.

An **anesthetic procedure** may refer to and is inclusive of sedation, immobilization and general anesthesia.

Anesthetic recovery is defined as that time when a patient is normothermic (T 100- 102.5 F), normotensive (MAP 80-100 mm Hg), oxygenating normally (SpO2 >95-100%), mentally appropriate, in sternal recumbency, with pain controlled, after extubation.

Direct supervision is defined as the physical presence of a licensed veterinarian with visual contact of the procedure.

Notes

Notes