Anesthesia and Analgesia

for the Veterinary Practitioner: Canine and Feline

Banfield PET HOSPITAL

Book 1 | 2nd Edition

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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.

Original contributing authors

Karen Faunt, DVM, MS, DACVIM
VP Global Quality Design
Mars Veterinary Health

Lorna Lambert, MS, CPHQ, CPMSM, HACP
Corporate Quality Risk Manager,
Mars Inc.

Jo Ann Morrison, DVM, MS, DACVIM
Director, Veterinary Science
Banfield Pet Hospital

Major editorial authors

Morgan Taylor–Rakocevic, VMD, MBA
Dr. Taylor-Rakocevic has been part of the Banfield Pet Hospital team since 2017, and is currently program manager on the Veterinary Affairs team at central support. Throughout her career, Morgan has been driven by a passion for building meaningful relationships, developing and supporting veterinary teams, and advocating for the highest standards of patient care. She is committed to fostering a collaborative, positive workplace culture where associates can thrive, while empowering teams through education, mentorship, and shared learning.

Kristi Grace, MS
Kristi received her Master of Science degree in health systems management from Rush University in 2010, and completed her veterinary technology education from Penn Foster College in 2026. Before joining Banfield's Veterinary Affairs team in 2015, Kristi spent a decade working in quality and process improvement and care management in "human healthcare" in various academic medical centers. She currently manages Banfield's patient safety program, where she drives quality and patient safety improvement actions for the practice. She also represents Banfield as part of a global quality team for Mars Veterinary Health.

Shana Savikko, DVM
Dr. Savikko joined Banfield Pet Hospital in 2015 and has advanced through roles including associate veterinarian, chief of staff, and area chief of staff. She now serves as Program Manager for Veterinary Field Programs.

A 2005 graduate of the Oregon State University College of Veterinary Medicine, Dr. Savikko is passionate about preventive care and strengthening the human–animal bond through collaborative relationships with clients and teams. She is driven by a commitment to medical quality and the spectrum of care, ensuring every patient receives evidence-based care aligned with their family's needs. She is also dedicated to developing others, teaching new skills, and supporting team growth.

Megan Youngs, MBA, MS, LVT
Megan Youngs joined Banfield Pet Hospital in 2016 and is now a Program Manager with the Veterinary Affairs team, focusing on medical quality related to equipment and formulary offerings. Megan is committed to providing hospitals with the needed resources to allow teams to practice medicine to the best of their ability.

Contents

Anesthesia quality

Our commitment to quality	1
What is quality in healthcare?	1
Culture of safety	2
Medical quality standards	4
Conclusion	4

Medical quality standards

Introduction and definitions	7
Clinical essentials and best practices	8
Preanesthetic physical examination	10
Signalment	11
Cardiopulmonary parameters	13
Physical examination for stressed pets	17
Preanesthetic clinical pathology evaluation	19
American Society of Anesthesiologists status	26
Sedation, immobilization, general anesthesia	29
Monitoring and supportive equipment	34
Perioperative antibiotics	37
Checklists	39
Anesthetic machine checklist	41
Pre-induction timeout checklist	43
Conclusions and references	44

Equipment

Ancillary equipment 47
- Intravenous (IV) catheter 47
- Laryngoscope 47
- Endotracheal tube 48
- Breathing circuits 49
- Rebreathing bags 52
- Oxygen masks and diaphragms 52

Oxygen and carbon dioxide 54
- Oxygen cylinders 54
- Carbon dioxide absorbent and canister 56

Anesthesia machine and administration 59
- Evacuation and scavenging 59
- Vaporizer and oxygen regulator 60
- Manometer 61
- Oxygen flush valve 62
- Safety pressure relief valve 63

Anesthesia machine updates 69

Anesthesia breathing circuit standardized color-coding 69
- Procedure 69
- Considerations for procedures 70
- Overview of breathing circuits by type 71
- Overview of anesthesia machine connections by type 71
- Scavenger manifold 72

Anesthesia Y-adapter setup 72
- Setup instructions 72
- Update: Bain non-rebreathing circuit setup 73
- Update: Rebreathing system 76
- Important notes regarding anesthesia 76
- Update: Anesthesia machine and vaporizer leak test 77

Maintenance 79

Troubleshooting and leak test 82

Physiology

Introduction	**88**
Perfusion	**88**
Pharmacologic influence on the nervous system	**91**
Divisions	**91**
Sympathetic system	**93**
Alpha-2 agonist medications	**95**
Parasympathetic system	**97**
Anticholinergic medications	**98**
Stressed/fractious pet physiology	**100**
Stressed versus fractious	**100**
Anesthetic implications	**102**

Anesthesia quality

Our commitment to quality

Banfield Pet Hospital is focused on creating a practice that places the delivery of quality veterinary care at the heart of everything we do. We strive to understand the needs of pets and clients to deliver safe, high-quality healthcare to every pet, every time. The quality of our anesthesia practices is built on a solid foundation of evidence-based standards and protocols, sound operational practices, a focus on patient safety and robust team member training and development programs. Our commitment to the continuous improvement of our anesthesia standards and protocols supports our belief that we can create a better world for pets through the delivery of high-quality veterinary care.

What is quality in healthcare?

Quality in healthcare is defined as the degree to which an organization's processes and results meet or exceed the needs of its patients. Banfield endeavors to meet this definition in part through our continued study and improvement of our anesthetic protocols and processes.

Culture of safety

The concept of a "Culture of Safety" comes from research in industries that involve complicated, high-risk work while still preventing most accidents. A Culture of Safety is the shared result of our environment, tools, training, standards, and –most importantly—the attitudes and behaviors of our teams. It reflects how we work together to keep Associates, clients, and patients safe every day. A Strong Culture of Safety is supported by:

- Facilities that meet or exceed veterinary industry requirements
- The right equipment and medications to help us care for patients
- Policies and procedures that improve patient outcomes and client experience while reducing the risk of harm
- Ongoing training that builds the skills and confidence needed to work safely, efficiently, and effectively

Patient safety

Patient safety means preventing mistakes and harmful events during veterinary care. It's a core part of our Culture of Safety. Our goals is to build processes that reduce the chance of harm reaching a patient. We are committed to making sure the care we provide is safe every time.

When something goes wrong in healthcare, it's often not because of one person's mistake. Instead, it's usually a chain of system or process issues that eventually lead to an error that harms a patient. That is why safety must be built into every part of how we work. Our systems and processes must be intentionally designed to prevent harm.

To do this well, every hospital team member plays a role. We all need to speak up when we see opportunities to make care safer. This can involve real-time conversations, holding huddles with the hospital team, reporting patient safety events. We also need to stay engaged in learnings from errors and "near misses" so we can continuously improve and prevent future harm.

Culture of safety: essential components of patient safety

A strong Culture of Safety is essential for preventing medical errors, protecting patients from harm, and improving the quality of care. We build this culture through the following behaviors and values:

- Team members who practice transparency, take responsibility, and treat one another with respect
- A collaborative environment where everyone shares a commitment to making patient safety a top priority

- Leaders who support teamwork and create psychological safety, so associates feel comfortable speaking up about concerns without fear of blame or retaliation
- A mindset of collective awareness, where associates understand that systems can fail and view near misses as signs that the system needs improvement
- Hospital team members who report errors and near misses instead of ignoring or hiding them, helping the team learn from these events and strengthen the systems that contribute to them.

Never events

A "never event" is a serious, preventable incident that causes unexpected death or major harm to a patient and is not related to their illness or underlying clinical condition. In anesthesia, the clearest example is the unexpected loss of a pet during or after anesthesia because of a medical or procedural mistake.

Events like these have a profound impact on clients, pets, and hospital teams. That is why we must work hard to fully understand what happened, learn from it, and continually improve our systems and processes. Every pet, every client, and every team member matters, and our goal is to try to prevent these tragedies from happening again.

Medical quality standards

Having clear standards is key to ensuring that we deliver safe care and that we are able to continuously improve our processes and systems. In *Anesthesia and Analgesia for the Veterinary Practitioner: Canine and Feline*, we will introduce a tiered standards classification system, consisting of Clinical Essentials and Best Practices. Clinical Essentials are standards of practice that constitute the minimum acceptable level of care required for every Banfield hospital. Best Practices are standards of practice that meet or exceed an expected level of care. It should be noted that individual state practice act requirements must be met or exceeded in all instances.

To improve the quality of anesthesia we deliver, we must shift our focus from only being concerned with outcomes (the *results* of the care we provide) to also being concerned with how we deliver care (the *process* we use to deliver care). The basis of continuous improvement and providing consistency of care is in understanding and standardizing processes. Our anesthesia standards and protocols define processes of care and the requirements – based on current scientific knowledge – that help us ensure that the care we provide is safe, reliable, effective and results in the best possible outcomes for pets every time.

Conclusion

The main goal of Anesthesia and Analgesia for the Veterinary Practitioner: Canine and Feline is to provide all associates with standards and protocols based on proven fundamentals of quality and medical best practices that will lead to sustainable outcomes for our practice and the best results for each pet. To achieve these goals, we will need to ensure that we:

- Build a culture of quality and safety
- Embrace protocols
- Meet all Clinical Essentails
- Learn from our successes and failures

In this way, we will lead care forward and create a better world for pets.

Further reading for anesthesia quality:

Institute for Healthcare Improvement (IHI) resources:
www.ihi.org/resources/Pages/default.aspx

Agency for Healthcare Research and Quality (AHRQ) resources:
www.ahrq.gov/professionals/quality-patient-safety/index.html

Notes

Medical quality standards

Abbreviations

ABCB	updated name for the MDR gene
ALP	alkaline phosphatase
ALT	alanine aminotransferase
ASA	American Society of Anesthesiologists
BG	blood glucose
BNP	brain natriuretic peptide
BP	blood pressure
BUN	blood urea nitrogen
CBC	complete blood count
CPR	cardiopulmonary resuscitation
CRT	capillary refill time
DO_2	delivery of oxygen to tissues
ECG	electrocardiogram
$EtCO_2$	end tidal carbon dioxide
HCT	hematocrit
MAP	mean arterial pressure
MDR	multidrug resistant
OVH	ovariohysterectomy
PCV	packed cell volume
SpO_2	peripheral capillary oxygen saturation
TP	total protein
USG	urine specific gravity
vWf	von Willebrand factor
WBC	white blood cell

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 the post anesthetic evaluation when 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.

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. A veterinarian must examine the patient after recovery.

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

Clinical essentials and best practices

Medical Quality Standards, or clinical essentials and best practices, for anesthetic procedures in Banfield hospitals have been identified. These standards represent the level to which all anesthetic procedures will be provided by Banfield hospitals.

Medical quality standards

Clinical essentials are standards of practice that constitute the minimum acceptable level of care. Practice below this level of care is below expectations. Failure to provide at least this level of care, or clearly document sound reasons for not providing this care, can result in disciplinary consequences.

Best practices are standards of practice that meet or exceed an expected level of care and encompass a scale of care from "desirable" to "aspirational."

Clinical essentials are requirements for every anesthetic procedure and are highlighted throughout the text within a orange box.



Clinical essentials are standards of practice that constitute the minimum acceptable level of care

Through analysis of professional resources, peer-reviewed publications and Banfield data, several key areas have been found to be especially tied to patient safety and anesthetic quality. These areas are emphasized in the anesthesia clinical essentials and additional information is provided in this chapter. These key areas are:

- Performance of a preanesthetic physical examination
  - Signalment
  - Cardiovascular parameters
  - Stressed or fractious pet
- Review of preanesthetic clinical pathology testing
- Determination of American Society of Anesthesiologists (ASA) status

Notes

Preanesthetic physical examination

A complete preanesthetic physical examination includes a review of the patient's medical history. A thorough history is critical to give an accurate evaluation and timeline of any underlying disease processes and allow identification of other abnormalities or comorbidities that may affect anesthetic or surgical outcome.

Prior to any anesthetic procedure, the patient should be systematically examined during the physical examination, and all body systems should be evaluated. Findings should be documented in the patient medical record and discussed with the client. Underlying issues should be resolved prior to anesthesia, if possible, especially if procedures are elective.

The goals of the preanesthetic assessment are to:

- Determine the health status of a pet to minimize the risk of adverse events
- Identify and prepare for anticipated complications
- Promote a problem-oriented approach to pet management, including drug choices
- Decrease perioperative morbidity and mortality and improve pet care



Clinical essential

Perform a thorough physical examination prior to any anesthetic event and obtain a current and accurate weight. Verify, document and address all clinical abnormalities prior to premedication, communicate to the team, and discuss with the client. Dismissal of abnormal findings is not permitted.

Signalment

In some instances, particular breeds of dogs or cats may be predisposed to conditions that may impact drug metabolism, distribution, anesthesia and surgery. Due to wide individual variations within a breed, specific anesthetic protocols for each breed are not possible. The following (Table 1.1) lists a few examples of different breeds, genetic conditions and subsequent clinical considerations for each. Individual pet decisions remain the responsibility of the attending veterinarian.

This is not a comprehensive list of breeds, conditions or clinical considerations.

Table 1.1

Breed	Condition	Clinical consideration
Boxer	Cardiac disease	Cardiac evaluation*
Doberman Pinscher	Von Willebrand's factor (vWF) deficiency**/ cardiac disease	vWF factor analysis or buccal mucosal bleeding time, cardiac evaluation*
German Shepherd	Congenital cardiac disease	Cardiac evaluation*
King Charles Cavalier Spaniel	Myxomatous mitral valve disease, macrothrombocytosis	Cardiac evaluation*, platelet inspection
Soft Coated Wheaten Terrier	Protein-losing enteropathy and nephropathy	Evaluate blood albumin and urine protein levels
Maine Coon	Cardiac disease	Cardiac evaluation*, blood pressure

Table 1.1 (cont.)

Breed	Condition	Clinical consideration
Persian	Polycystic kidney disease	Urinalysis, renal imaging, blood pressure
Brachycephalic breeds: Boston Terrier, Boxer, Bulldog, Himalayan, Lhasa Apso, Pekingese, Persian, Pug, Shar Pei, Shih Tzu	Brachycephalic airway syndrome	Pre-oxygenation, NEVER immobilize these pets, use brachycephalic-specific protocols
Giant breeds: Great Dane, Newfoundland	Cardiac disease, acepromazine sensitivity	Cardiac evaluation*, decrease acepromazine dose
Herding breeds: Australian Shepherd Collie, Shetland Sheepdog	ABCB1 mutations	Decrease doses of acepromazine and opioids
Sighthounds: Afghan Hound, Greyhound, Irish Wolfhound	Cardiac disease, acepromazine sensitivity, slower recovery from propofol, propensity for hypothermia due to low body fat	Cardiac evaluation*, decrease acepromazine dose, perioperative warming
Toy breeds: Chihuahua, Toy Poodle	Propensity for hypoglycemia and hypothermia	Monitor blood glucose levels, perioperative warming

* Cardiac evaluation may include, but is not limited to, ECG, blood pressure, thoracic radiographs, echocardiogram or clinical pathology testing (Brain Natriuretic Peptide (BNP), cardiac troponin I)

** Many breeds may be affected by vWF deficiency

Cardiopulmonary parameters

Temperature, pulse and respiration (TPR) parameters and cardiovascular status are of great importance as they can be the root cause of a life-threatening problem throughout anesthesia. **The key to pet survival is adequate delivery of oxygen to tissues (DO_2).** Therefore, a detailed evaluation of the cardiovascular, respiratory and central nervous systems should occur before any anesthetic procedure. Cardiovascular parameters are evaluated again after premedications have taken effect, prior to induction.

Notify veterinarian of any abnormalities at the time they are noticed.

Postpone procedures if possible, especially elective procedures, if abnormalities are noted.

Figure 1.1

Temperature

Normal range:
99.5–102.5 °F

If elevated:

- If T >102.5°F = hyperthermia or fever
- If fever, perform appropriate diagnostics
- If hyperthermic, institute clinically indicated cooling measures and postpone anesthesia

If hypothermic:

- Institute appropriate patient warming methods
- If temperature decreases, postpone/stop procedure and recover patient as quickly and safely as possible

Figure 1.2

Heart rate/pulse

Normal range:

Awake and non-stressed pets:

Large dogs: 60–100 bpm

Medium dogs: 80–140 bpm

Small dogs: 100–140 bpm

Cats: 120–180 bpm

IF bradycardic or tachycardic:

- Perform ECG and assess

IF persistently tachycardic after premedication:

- Postpone elective procedure
- Evaluate for underlying cardiac disease
- Use *Cardiac* protocol if emergency

IF cardiac murmur is ausculted:

- Determine if acute (new) or chronic (known)
- Consider cardiac evaluation, especially in cats or in juvenile pets where murmurs may indicate congenital disease
- Use *Cardiac* protocol if emergency

Figure 1.3

Pulse quality

Normal:
Strong, synchronous, no pulse deficits

If abnormal:
- Postpone elective procedure
- Evaluate for underlying disease
- Use *Cardiac* protocol if emergency

Figure 1.4

Respiratory

Normal:
Ranges highly variable

If abnormal:
- Postpone elective procedure
- Evaluate for underlying disease
- Use *Respiratory Compromise* protocol if emergency

Figure 1.5

Blood pressure

Normal range (MAP):
80–120 mm Hg

If hypertensive:
- Assess pain and volume status
- Consider cardiac disease. Postpone elective procedure if possible.
- Use appropriate protocol if emergency

If hypotensive:
- Institute appropriate measures
- If BP refractory or worsens, stop procedure and recover patient as quickly and safely as possible

Figure 1.6

Mucous membranes

Normal:
Pink–red, capillary refill time (CRT) <2 sec

If abnormal or changing:
- Perform appropriate diagnostics

Physical examination for stressed pets

If pets are too stressed or fractious to examine, the physical examination must be performed as soon as safely possible or the procedure postponed. Ensure pet weight is current and accurate. Reweigh if necessary to ensure accurate drug dosing for anesthetic and cardiopulmonary resuscitation (CPR) drugs. See the *Physiology* chapter for more details on stressed/fractious pet physiology.

Remember that the best and safest decision may be to stop the procedure, recover the pet and reschedule.

For pets that appear stressed or fractious, remember that most aggressive behavior is a result of underlying fear or pain.

Consider use of the following techniques:

- If present, address pain with analgesics. Allow time for onset of action and reassess pet.
- Administer pheromone therapy (both dogs and cats). Options include towels, blankets and bandanas for larger dogs.
- Environmental manipulation:
  - Move the pet to a quiet area/room, away from other patients
  - Provide soft, clean bedding
  - Reduce lighting
  - Consider classical music
  - Be aware of smells: alcohols, disinfectants, cleaning solutions. **Canines:** Use non-skid surfaces, handle big dogs on the floor. **Felines:** Have cats wait separately from dogs, use cage door covers or provide a hiding option (*e.g.*, patient-sized box).
- If the procedure can be postponed, and is in the best interest of the pet, postpone and reschedule. Consider instituting a counter-conditioning plan.

- If none of the above are successful, consider the Stressed/Fractious Pet protocol.

The stressed/fractious, brachycephalic pet presents a unique safety challenge for both hospital associates and pets.

- If it is determined that the procedure cannot be completed safely, abort the procedure.
- Stabilize and recover the pet.
- Reschedule the procedure.
- Implement a counter-conditioning program.
- **The key point with any brachycephalic pet is oxygenation and a protected airway.**
  - Provision of oxygen and tracheal intubation should be provided as quickly as possible and whenever medically indicated.

If the brachycephalic pet is overweight/obese, and the procedure can be postponed, institute a weight loss program and schedule procedures when an ideal body condition has been attained.

Notes

Preanesthetic clinical pathology evaluation

There are multiple clinical essentials focused on the preanesthetic clinical pathology evaluation and assessment. **The importance of this step in the preanesthetic examination cannot be overemphasized.**



Clinical essential

Obtain and review clinical pathology data prior to general anesthesia. Verify, document and address all clinical abnormalities prior to premedication, communicate to the team, and discuss all abnormalities with the client. Dismissal of abnormal results is not permitted.

Notes



Stop

- Perform further diagnostics to look for underlying causes
- Postpone elective procedures if possible



Critical stop

- DO NOT PROCEED WITH GENERAL ANESTHESIA
- Institute medical management of underlying disorder or consider referral

Table 1.2

Parameter	Stop	Critical stop
Blood Glucose (BG) (mg/dL)	**Canine: >175** OR **Feline: >250** ■ Repeat in several hours with the pet in as minimally stressed environment as possible ■ If no change, or worsening, consider evaluation for hyperglycemia ■ If nonelective, proceed with most appropriate protocol	**<50** OR **>600**
	<70 ■ Recheck to ensure accuracy ■ If nonelective procedure, proceed with appropriate IV dextrose supplementation and recheck BG frequently	

Parameter	Stop	Critical stop
Total Protein (TP) (g/dL)	**<4.5** ■ If nonelective procedure, provide colloid support	**<3**
Albumin (g/dL)	**<2** ■ If nonelective procedure, provide colloid support	**<1**
Calcium (Ca^{2+}) (mg/dL)	**<8** **OR** **>12** ■ Check albumin levels ■ If nonelective procedure, proceed with *Cardiac* protocol	**<7** OR **>16**
Sodium (Na^{+}) (mEq/L)	**<135** OR **>170** ■ Recheck to ensure accuracy, assess hydration and neurologic status	**<125** OR **>180**
Chloride (Cl^{-}) (mEq/L)	**<100** OR **>135** ■ If hyperchloremic, ensure pet is not receiving potassium bromide ■ Recheck to ensure accuracy, assess hydration and neurologic status ■ Recommend put anemia mitigations together	**<90** OR **>145**

Parameter	Stop	Critical stop
Potassium (K^+) (mEq/L)	**<3.5** OR **>6** ■ Obtain ECG tracing ■ If nonelective procedure, provide appropriate fluid support and **recheck K^+ before proceeding to anesthesia** ■ If K^+ improves, recheck frequently ■ If nonelective procedure, use appropriate protocol	**<2.5** OR **>6**
Hematocrit % (HCT) Packed Cell Volume % (PCV)	**Canine: <25 or >55** OR **Feline: <20 or >45** If nonelective procedure: ■ Assess volume status for hemoconcentration ■ Transfusion support for anemia needed	**Feline: <15** **Canine: <20** OR **>60%**
Platelets (/ul)	**<200,000** ■ Confirm with peripheral blood smear and manual count	**<60,000**
	<125,000 ■ Confirm as above and perform appropriate diagnostic testing for thrombocytopenia	

Parameter	Stop	Critical stop
White Blood Cells (WBC) (/ul) Neutrophils (/ul)	**WBC <4000** OR **Neutrophils <2000** ■ Confirm with blood smear and manual differential count	**WBC <2000** OR **Neutrophils <1000**
	WBC >30,000 ■ Perform manual differential to assess for stress leukogram ■ Perform appropriate diagnostics to determine most likely etiology of leukocytosis ■ If nonelective procedure, use disease appropriate protocol	
Blood Urea Nitrogen (BUN) (mg/dL)	**<normal range** ■ Perform appropriate diagnostics OR **Canine: >27** **Feline: >35** Check urine specific gravity (USG) ■ If USG >1.030 (canine) OR >1.035 (feline) • Rehydrate as appropriate and recheck values prior to using Renal/Post-renal protocol ■ If USG <1.030 (canine) OR <1.035 (feline) • If nonelective procedure, use *Renal/Post-renal* protocol	N/A

Parameter	Stop	Critical stop
Creatinine (mg/dL)	**<normal range** ■ Perform appropriate diagnostics OR **Canine: >1.4** **Feline: >1.6** Check urine specific gravity (USG) ■ If USG >1.030 (canine) OR >1.035 (feline) • Rehydrate as appropriate and recheck values prior to using *Renal/Post-renal* protocol ■ If USG <1.030 (canine) OR <1.035 (feline) • If nonelective procedure, use *Renal/Post-renal* protocol	N/A
Alanine Aminotransferase (ALT) (U/L) Alkaline Phosphatase (ALP) (U/L)	■ Consider performing SDMA **Canine: >2 x upper limit of normal range** OR **Feline: >normal range** ■ Postpone procedure if appropriate ■ Hepatic evaluation if medically indicated ■ If nonelective procedure, use *Abdominal/Hepatic* protocol ■ If SDMA>14 ■ If nonelective procedure, use Renal/Post-renal protocol	N/A

Despite the new reference ranges displaying normal for values within the range of a stop or critical stop, it is the veterinarian's responsibility to still follow the stop and critical stop guidelines.

Parameter	Stop	Critical stop
Bilirubin (mg/dL)	**>2.0** ■ Pet should be clinically icteric ■ Recheck to assess for iatrogenic hemolysis ■ Check PCV/HCT/blood smear/slide autoagglutination to evaluate for hemolysis ■ If nonelective procedure, use *Abdominal/Hepatic* protocol	N/A
Lipemia	■ Collect another blood sample in several hours and check to see if lipemia has resolved ■ If nonelective procedure, proceed with most appropriate protocol ■ Idiopathic hyperlipidemia of Schnauzers ■ Other breeds also affected	N/A

ASA status

The ASA has established guidelines for the health status in human patients and has devised a Physical Status Classification System for patients undergoing anesthesia. This is a quick and effective tool designed to standardize assessment of patient physical status and to assess anesthetic risk.

In veterinary medicine, it has been shown that a pet's ASA status is directly related to the risk of perianesthetic death; the perianesthetic death rate in dogs and cats for status I and II was 0.12 percent whereas it increased to 4.8 percent for patients status III - V (a fortyfold increase).[16]

Determine patient ASA status and document status in the medical record for every anesthetic event. Pets scoring I or II have little to no significant increase in anesthetic risk.

Pets with an ASA status of III–V have a significant increase in anesthetic risk

Clinical essential

Assign and document an ASA status to each pet undergoing general anesthesia and address status appropriately as part of the preanesthetic evaluation. Document discussion of increased risks of anesthesia for pets with an ASA status of ≥III with owner and postpone, cancel or refer anesthetic procedures when indicated.

Table 1. 3

Status	ASA Classification	Examples
I	Healthy pet, no disease	Elective OVH or castration
II	Mild systemic disease or localized disease	Healthy geriatric pet, mild anemia or obesity
III (fair)	Moderate systemic disease limiting activity but not life-threatening	Mitral valve insufficiency, collapsing trachea, poorly controlled diabetes
IV (poor)	Severe systemic disease; incapacitating; life-threatening; not expected to live without surgery	Hemoabdomen from splenic rupture, severe traumatic pneumothorax, organ failure
V (grave)	Moribund; not expected to live >24 hours, with or without surgery	Multi-organ failure, severe shock, terminal malignancy

FIgure 1.7

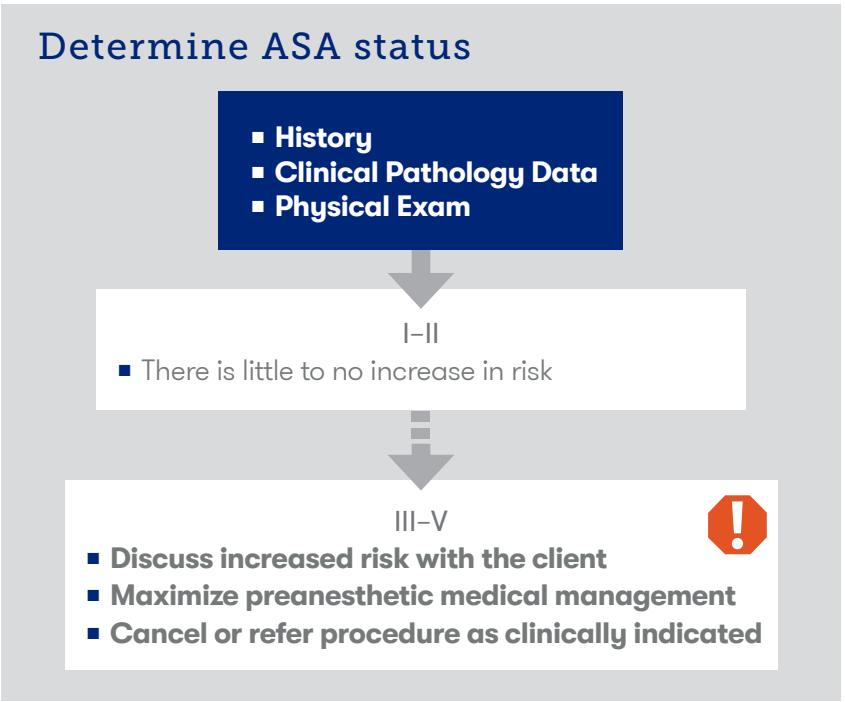
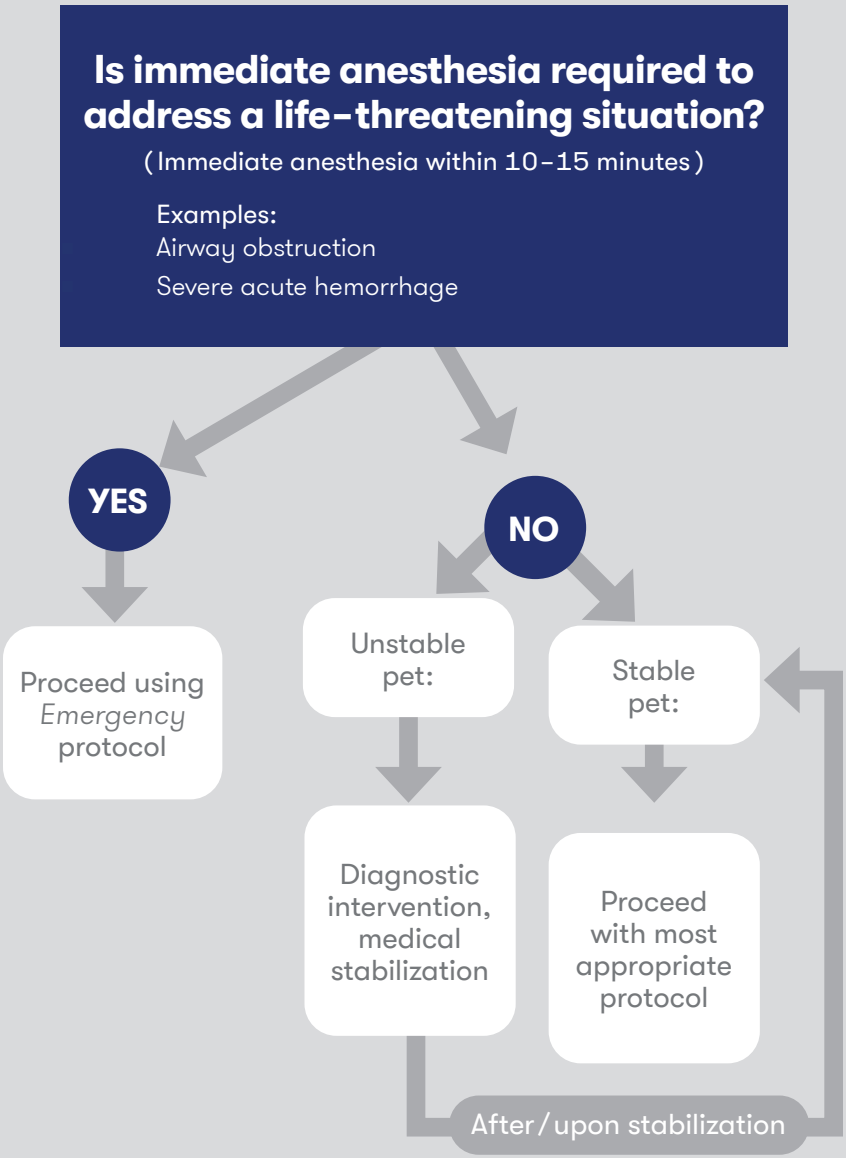


Figure 1.8

General anesthesia: Patient stability and timing



Sedation, immobilization, general anesthesia

Multiple factors influence the decision to sedate, immobilize or anesthetize a patient, including: patient ASA status, diagnostic or therapeutic needs and patient tolerance to manipulation. The anesthetic team must be prepared to adjust plans and not compromise patient safety.

Sedation may need to advance to immobilization and immobilization may need to convert to general anesthesia.

Monitor the following when deciding to convert to a different procedure:

- Time
- Patient physiologic parameters
- Analgesic needs
- Patient stress

Table 1.4

Considerations for procedures

Factor	Example
Invasiveness	■ Small superficial wound ■ Large abscess
Expected pain	■ Mild soft tissue injury ■ Open fracture
Patient drug metabolism abilities	■ Chronic renal disease ■ ABCB1 (MDR1) mutation
Patient requirements	■ Brachycephalic pet

The following charts list the definitions and monitoring requirements for sedation, immobilization and general anesthesia, including those for brachycephalic pets. Consider the unique situation of each pet when choosing which procedure is most appropriate.

Table 1.5

Examples

Procedure	Uses	Pet status	Reflexes
Sedation	■ Nonpainful procedures ■ Decrease anxiety	■ Ambulatory	■ All intact
Immobilization Not for brachycephalic pets	■ Nonsurgical plane of anesthesia	■ Non-ambulatory	■ Laryngeal and withdrawal reflexes intact ■ Pet roused with minimal effort
General Anesthesia	■ Surgery ■ Invasive or painful diagnostic or therapeutic procedures	■ Non-ambulatory	■ Lack of laryngeal, withdrawal or blink reflexes

Examples

Procedure	Examples	Additional information
Sedation	■ Otoscopic examination ■ Blood collection	■ Pet CANNOT be intubated
Immobilization	■ Clipping matted hair ■ Radiographic positioning ■ Pedicure in aggressive pets	■ Procedure is not painful and lasts <10 minutes ■ **Do not use in brachycephalic pets**
General Anesthesia	■ Castration ■ OVH ■ Dental prophylaxis	■ Pet MUST be intubated

Table 1.6

Monitoring

Procedure	TPR, CRT, MM color and pulse quality	BP, ECG, pulse oximetry	Oxygen
Sedation	■ Required if not ambulatory	■ Pulse oximetry recommended for all patients if tolerated ■ BP, ECG as directed by veterinarian	■ Flow by recommended unless causing increased patient stress
Brachycephalic-specific sedation	■ Required if not ambulatory	■ Pulse oximetry required ■ BP and ECG as directed by veterinarian	■ Flow by required unless causing increased patient stress
Immobilization	■ Required along with anesthetic depth until full recovery	■ BP and pulse oximetry required ■ ECG as directed by veterinarian	■ Either flow by or inhaled via endotracheal tube required, depending on depth of sedation/ anesthesia ■ Appropriate- sized endotracheal tubes and laryngoscope ready
General anesthesia	■ Required until full recovery	■ All required with TPR, capnography ($EtCO_2$) as able per hospital	■ Inhaled oxygen via endotracheal tube

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

Monitoring

Procedure	IV catheter and fluids	Sterile eye lubrication	Additional requirements
Sedation	■ As directed by veterinarian	■ As directed by veterinarian	■ Visual observation at all times ■ Brachycephalic pets have unique requirements
Brachycephalic-specific sedation	■ As directed by veterinarian	■ As directed by veterinarian	■ Visual observation at all times ■ Minimize hospital time, minimal physical restraint, maintain sternal positioning if possible, no muzzle use
Immobilization	■ Recommended for all immobilized pets ■ Catheter required for propofol	■ Required and repeated as needed	■ Visual observation at all times ■ **DO NOT perform on brachycephalic pets**
General anesthesia	■ Required	■ Required and repeated as needed	■ Preanesthetic clinical pathology data ■ Food (2 - 12 hours) and water (0 - 2 hours) withheld based on veterinarian decision ■ ASA status determined

Monitoring and supportive equipment

Safe and successful patient care (whether via sedation, immobilization or general anesthesia) depends upon:

- Functional equipment in good working order
- Appropriate pet monitoring devices
- Emergency preparedness

Appropriate use by trained associates of the items on the following lists helps to minimize pet risk and avoid anesthetic complications.

Equipment and medical supply requirements

- Sterile IV catheters (male adapter plugs and tape)
- Dedicated surgical scrub
- Clean and disinfected clippers
- Permanent surgical lighting with additional supplemental lighting available (*e.g.*, head lamp)
- Endotracheal tubes in multiple sizes, adequate for each-sized pet
- Laryngoscope (long and short blades) with functional light
- Portable pulse oximeter
- Equipment sufficient to provide monitoring for pet parameters:
  - Temperature
  - Systolic/diastolic/mean arterial blood pressure
  - SpO2
  - Heart and respiratory rates
  - ECG
  - EtCO2 – if hospital is equipped with multi-parameter monitor
- Anesthesia machine with *Anesthesia Machine Checklist*
- Resuscitation bag sufficient for pet size or other means to assist ventilation
- Breathing circuit appropriately sized for the pet based on ideal body weight
- Approved pet warming device for use with anesthetized or unconscious patients (circulating warm water blanket or forced air)
- Stethoscope

Emergency drug items

The following labeled and non-expired items for providing emergency care and intervention are required should an adverse event occur. These items are to be maintained and accessible at all times when providing anesthesia to any pet (examples of emergency crash kits are shown in figures 1.9, 1.10):

Table 1.7

Atipamezole	Furosemide
Atropine	Glycopyrrolate
Calcium chloride 10% (or calcium gluconate)	Lidocaine 2%
Colloid fluid solution	Mannitol 20%
Dextrose 50%	Naloxone
Diphenhydramine injection	Nitroglycerin paste
Dopamine	Sodium bicarbonate
Epinephrine	Sterile water for injection
Flumazenil	

Note:

- Certain items may periodically be unavailable or on backorder. Suitable replacements may be found if possible.
- Multi-dose vial usage must follow the clinical essentials for fluid administration and intravenous access requirements.

Clinical essential

Crash cart containing emergency drugs and equipment is readily available, in a designated place, portable, clearly labeled and appropriately stocked at all times

Figure 1.9



Example 1: Emergency Crash Kit

Figure 1.10



Example 2: Emergency Crash Kit

Perioperative antibiotics

Numerous studies have evaluated the use of prophylactic, perioperative antibiotics in elective surgical procedures (e.g., OVH and castration). Results of those studies and concerns about antibiotic usage, nosocomial infections and the development of multidrug resistant organisms have led to a reduction in the routine administration of prophylactic antibiotics. The ultimate decision to administer antibiotics lies with the veterinarian.

Adhere to the following for every surgical procedure:

- Vigorously promote aseptic technique.
- Minimize surgical time.
- Minimize tissue manipulation.

The following should be considered when determining if antibiotic use is indicated:

- Factors that increase post-operative wound infection rates:
  - Increased surgical time
  - Decreased veterinarian experience
  - Increased wound contamination level
  - Pet obesity
  - Increased number of associates in surgery room
  - Higher pet debilitation (need for intensive care)
  - Presence of foreign material (e.g., drain)
- Type of procedure being performed:
  - Sterile, elective procedures lasting <90 minutes (for example, OVH and castration)
    - Prophylactic antibiotics not indicated unless directed by the veterinarian
  - Dental prophylaxis
    - Prophylactic antibiotics used at the discretion of the veterinarian
    - Indications may include pets with a history of infectious valvular endocarditis, pets with implanted hardware or congenital cardiac disease.

- The American Veterinary Dental College (AVDC) has developed a position statement on the use of antibiotics in veterinary dentistry (www.avdc.org/statements.html).
  - Oral clindamycin: 5.5–11 mg/kg PO q 12h
    - Started two to three days prior to dental

      OR
    - Administered at minimum of two hours prior to anesthesia
    - Extend therapy as indicated by pet condition
  - Oral chlorhexidine rinse
    - Apply to teeth and gingiva immediately after intubation
    - Allow to stay in place 10 minutes before proceeding with dental

- Pets with pyoderma or requiring orthopedic procedures
  - Cefazolin: 22 mg/kg IV (unless contraindicated in patient)
    - Reschedule surgery if possible to allow treatment of pyoderma
  - Administer as slow IV injection
    - Most effective when given just prior to skin incision
    - Repeat in 90 minutes if surgery not completed

Notes

Checklists

In human medicine, patient morbidity, mortality and complication rates have been significantly reduced with the introduction and usage of checklists. To best support a culture of safety, two checklists have been developed: the *Anesthesia Machine Checklist* and the *Pre-Induction Timeout Checklist*.

Anesthesia machine checklist (clinical essential)

The *Anesthesia Machine Checklist* is designed to accomplish the following:

- Facilitate communication among anesthetic team members
- Help ensure critical components of anesthesia are verified
- Verify anesthetic equipment is functioning properly
- Allow an objective evaluation of machinery and equipment
- Help minimize patient and associate risk

Directions for correct usage of the checklist are as follows:

- Complete entire checklist prior to each general anesthetic event, ideally prior to premedication administration.
- Address and correct any machine problems or abnormalities prior to premedication.
- If any item on the checklist cannot be completed or verified, **do not proceed** to general anesthesia.
- Start with the first item and complete each item in order.
- Mark each item box on the checklist once completed.
- For items with a 'Record' box, write the value for each item in the corresponding box.
- Document successful completion of the checklist in the anesthesia medical notes.

Options for completing the checklist:

- Checklist may be completed by the veterinarian or dedicated monitoring associate.
- Checklist may be completed collaboratively by the anesthesia team or individually.
- The veterinarian ensures completion of the checklist prior to induction.

A laminated reusable checklist should be maintained with every anesthesia machine in the hospital.

Clinical essential

Utilize the Anesthesia Machine Checklist for every general anesthetic event and have the checklist verified by the attending veterinarian prior to induction.

Notes

Figure 1.11

Anesthesia machine checklist

Follow and complete prior to every general anesthesia procedure

	Mark	Record
Check **Anesthesia Cart Preventive Maintenance Sticker** to ensure all maintenance has been performed (record date)	☐	
Verify **Primary Oxygen** source (record volume)	☐	
Verify available **Back-Up Oxygen**	☐	
Verify **O_2 Flowmeters** working	☐	
Verify **Vaporizer** full and port tightly closed (record volume)	☐	
Perform Anesthetic Machine **Leak Test** (If leak is present, DO NOT proceed. See troubleshooting guide.)	☐	
Verify **Scavenging** on and functional	☐	
Verify **CO_2 absorbent** fresh or newly replaced (record date replaced)	☐	
Verify **Monitoring** equipment functional	☐	
Verify **Emergency Medication** available and expiration dates checked	☐	
Verify **Y-adapter** is correctly attached	☐	
Verify appropriate **breathing circuit** is correctly attached	☐	
Verify correct size **rebreathing bag** is attached to the system	☐	

Pre-induction timeout checklist (best practice)

Purpose

- The *Pre-Induction Timeout Checklist* is provided as a tool to assist anesthesia teams in ensuring that all preanesthetic clinical essentials have been met.
    - **Use of the *Pre-Induction Timeout Checklist* is considered an anesthetic best practice.**

The *Pre-Induction Timeout Checklist* provides a method to:

- Verify completion of key components of the preanesthetic evaluation prior to induction
- Maximize anesthetic safety and minimize preventable errors
- Facilitate communication among the anesthesia team

Some of the key components of this checklist include:

- Confirmation of patient name and surgical procedure and site
- Identification and discussion of unique patient risks
- Verification of patient ASA status and completion of *Anesthesia Machine Checklist*

For those teams using the *Pre-Induction Timeout Checklist*, directions for correct usage of the checklist are as follows:

- The veterinarian and dedicated monitoring associate should complete entire checklist prior to each general anesthetic event.
- Complete checklist prior to administration of medications if pet is tractable OR as soon as possible if the pet is stressed or fractious.
- Complete checklist prior to anesthetic induction.
- If any item on the checklist cannot be completed or verified, DO NOT PROCEED to general anesthesia.
- Start with the first item and complete each item in order.
- Mark each item box on the checklist once completed.
- It is the responsibility of the attending veterinarian to ensure completion of the checklist.
- Document successful completion of the checklist in the anesthesia medical notes.

Figure 1.12

Pre-induction timeout checklist

Each task to be completed and checked off by the attending veterinarian or dedicated monitoring associate prior to induction for each general anesthetic procedure

	Mark
Complete **physical examination** performed	☐
Verify *Anesthetic Machine Checklist* completed	☐
Dedicated monitoring associate assigned	☐
Patient name confirmed	☐
Owner **permission** confirmed	☐
Complete **patient history** obtained and reviewed	☐
Clinical pathology data reviewed and addressed	☐
Patient ASA status determined	☐
Procedure, site, positioning and **location** confirmed	☐
Endotracheal tube cuffs checked and laryngoscope available	☐
Breathing system connected, leak free and pop-off valve open and in bag position	☐
Complete **physical examination** performed after premedications have taken effect	☐
Patient risks identified and discussed among anesthetic team	☐
Emergency doses precalculated, within reach	☐
Antibiotics available (if indicated)	☐

* Resources are available to help support responsible antimicrobial use such the American Veterinary Medial Association, AAHA/AAFP Antimicrobial Stewardship Guidelines, and the International Society for Companion Animal Infectious Disease

Conclusions

Safe and successful anesthesia requires a well-trained team working together on behalf of the pet and can be characterized, in part, by the following statements:

- Places the pet in the best condition possible prior to an anesthetic procedure
- Recognizes those times when an anesthetic procedure is not in the pet's best interests and intercedes on behalf of the pet
- Meets or exceeds all clinical essentials, federal regulations and state practice acts

Remember that the pet's condition on recovery should be as good, or better, than before an anesthetic procedure.

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.

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Equipment

Abbreviations

BCS	body condition score	**IV**	intravenous
CO_2	carbon dioxide	**NRB**	non-rebreathing
ET	endotracheal	**psi**	pounds per square inch

A comprehensive review of all anesthetic equipment and supplies is beyond the scope of this chapter. The following information is meant to provide a summary of important points regarding selection and use of various anesthetic-related items. While other members of the hospital team can select and prepare equipment, it is the responsibility of the attending veterinarian to ensure that the proper anesthetic equipment is chosen for each pet and that the equipment is in good working order prior to induction.



Clinical essential

The attending veterinarian ensures all equipment is working correctly prior to proceeding with premedication and anesthesia

Ancillary equipment

IV catheters

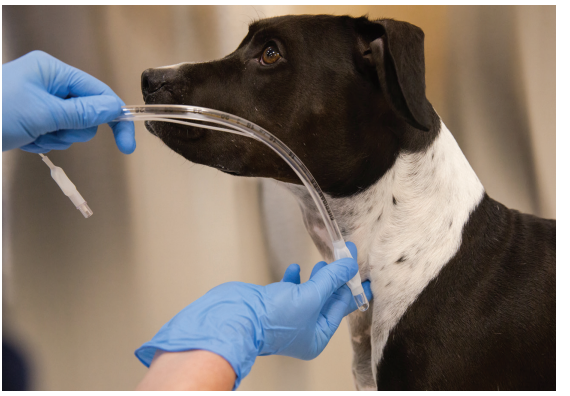
- When selecting catheter sizes, the largest catheter that will not traumatize the vein should be used.
- The size recommendations (Table 1.8) can be used as a guideline to aid in selecting catheters, and should be used in conjunction with evaluating the patient's body condition score (BCS), physical condition and vascular status.
- Normal (non-heparinized) saline should be used to flush catheters, T-ports and extension sets prior to use.
- IV fluids are administered via extension sets and T-ports and are not to be delivered via needle through a catheter cap.

Laryngoscopes

- A laryngoscope should always be used to aid intubation.
  - This is especially important when intubating cats and brachycephalic dogs.
- Using a laryngoscope to visualize the trachea reduces the risks of complications during intubation.
- The small blade is typically used for cats and small dogs, and the large blade is typically used for medium and large dogs.
- See Induction, Monitoring and Recovery chapter for details regarding intubation.
- Test the laryngoscope and light prior to inducing anesthesia.
- Replace worn or damaged laryngoscopes as needed to ensure proper use and function.
- Evaluation of the larynx should be performed during intubation through use of the laryngoscope

Endotracheal tubes

Figure 1.13: Estimating ET tube length

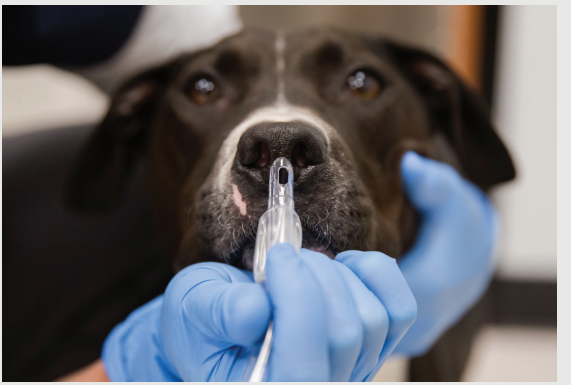


Selection:

- Correct endotracheal (ET) tube size will depend on the breed and body condition of the patient.
- The ET tube must be an appropriate diameter and length for each pet.
- The largest tube that will fit easily and not irritate or traumatize the trachea is recommended.
- The length of the ET tube should be measured from the nose to the point of the shoulder (thoracic inlet). The distal end of the tube is appropriately positioned when it is located at the point of the shoulder (just cranial to the thoracic inlet). (Figure 1.13)

Two methods to determine ET tube diameter:

Figure 1.14: Estimating ET tube diameter



The distal end of the ET tube can be measured against the width of the patient's nasal septum.

1. Palpating the patient's trachea will often help indicate optimal tube size.
2. The distal end of the endotracheal tube can be measured against the width of the patient's nasal septum (Figure 1.14). While this method is effective, there is the possibility of selecting an improper size.

- Have at least three ET tubes ready prior to intubation—the tube intended for use, along with one larger and one smaller in diameter.
- This will ensure that additional tubes are at hand if the tracheal diameter is over- or underestimated.

Leak testing:

- Cuffs should be tested for integrity before each use.
- Replace damaged or leaking ET tubes.
- When checking the cuff for leaks, do not overinflate as this will destroy the cuff. (See Induction, Monitoring and Recovery chapter for additional details)

Breathing circuits

Selection:

- There are two types of breathing circuits available:
  - Non-rebreathing circuit (NRB)
  - Rebreathing circuit
- Breathing circuit selection should be based on the patient's **ideal** body weight.
  - **Lung size and breathing capacity do not change with weight gain.**
  - Use patient history, breed standards and previous BCSs to estimate ideal body weight.
    - See table 1.8 for recommendations on selecting breathing circuit sizes.

Leak testing:

- Breathing circuits are leak tested before each use per the *Anesthesia Machine Checklist*.
  - At least two of each type of breathing circuit should be in the hospital in case a leak develops in a circuit.

Clinical essential
Assisted ventilation is available for every anesthetic procedure

Non-rebreathing circuit

- The NRB (e.g., Bain, Jackson-Rees) circuit should be utilized on pets that are 7 kgs or less.
- It is important to remember that a NRB circuit does not utilize the CO2 absorbent.
  - In order to prevent rebreathing of CO2, the flow rate of oxygen must be higher than the patient's respiratory volume.
    - Therefore, the oxygen flow rate should be 150–300 mLs/kg/minute when using a NRB system.
- The NRB circuits are consumable items.
  - Replace annually or more frequently as needed.

Directions for connecting the NRB circuit:

- The patient end is the portion of the breathing circuit connected to the endotracheal tube
- The inhalation limb attaches to the anesthesia machine by inserting into the female end of the tubing that comes out of the vaporizer
- The exhalation limb on the NRB circuit should be inserted into the scavenger hose that is a part of the hospital's anesthesia scavenger system. Always verify that the pop-off valves on the NRB circuit are open before connecting to the scavenger system.
- **Always trace the flow of gas and oxygen through the anesthesia machine to ensure that the NRB circuit has been set up properly. (see Figure 1.21)**

Rebreathing circuit

- The rebreathing circuits (pediatric or adult) should be utilized on pets that are greater than 7 kgs.
- It is important to remember that the rebreathing circuit utilizes the CO_2 absorbent.
  - CO_2 absorbent must be monitored closely and changed regularly.
    - See CO_2 absorbent section for more details.
- Both sizes of rebreathing circuits are consumable items.
  - Replace every three months or more frequently as needed.

Directions for connecting the pediatric (7 - 10 kg) and adult (>10 kg) rebreathing circuit:

- The patient end is the portion of the breathing circuit connected to the endotracheal tube
- The inhalation limb attaches to the anesthesia machine at the designated port
- The exhalation limb on the rebreathing circuit should be inserted into the anesthesia machine at the rebreathing bag. Always verify that the pop-off valves are open before connecting the patient.
- **Always trace the flow of gas and oxygen through the anesthesia machine to ensure that the rebreathing circuit has been set up properly. (see Figure 1.22)**

Anesthetic rebreathing bags

Selection:

- When selecting which size bag to use for rebreathing systems, the decision should be based on the patient's **ideal** body weight. (See Table 1.8)
  - **Lung size and breathing capacity do not change with weight gain.**
  - Use patient history, breed standards and previous BCSs to estimate ideal body weight.
  - Rebreathing bag size should be three to five times tidal volume.
    - Tidal volume is estimated to be 10–15 mL/kg.

Leak testing:

- Anesthetic rebreathing bags should be leak tested before each use.
- Keep at least two of each bag size on hand in case a leak develops in a bag.
  - Bags are consumable items.
    - Replace every six months or more frequently as needed with the exception of the 5L bag, which is replaced annually or more frequently as needed.

Oxygen masks and diaphragms

Mask inductions can cause patient stress, delayed airway control, and associate safety concerns due to environmental contamination. Masks should only be used for oxygen delivery.

Selection:

- Masks should fit snugly over pet's muzzle without causing undue stress or anxiety.
  - Rubber diaphragm can be used to minimize gaps around pet muzzle.
  - Beware of potential ocular trauma in brachycephalic pets.
    - Consider use of ophthalmic lubricating ointment if prolonged usage is anticipated.
- If pet resents use of oxygen mask, do not use excessive physical restraint.
- Ensure masks and diaphragms are clean, dry and free of visible debris prior to use.
- Inspect for signs of wear or damage and replace as needed.

Table 1.8

Personal anesthesia equipment sizing chart

IV Catheter Sizes	**Wt. (kg)**	**Catheter Size**
	<2 kg	22–24 gauge
	2 - 8.9 kg	20–22 gauge
	9 - 16 kg	18–20 gauge
	>16 kg	18 gauge
Breathing Circuit	**Less than 7 kg = Non-rebreathing circuit (NRB)**	
	Bain	Jackson-Rees
	Greater than 7 kg = Rebreathing Circuit	
	7 to 10 kg: Pediatric (pink)	Greater than 10 kg: Adult (blue)
Rebreathing Bag Sizes	**Wt. (kg)**	**Bag Size**
	0–7 kg	Use NRB system
	7–13 kg	0.5-L bag
	13–26 kg	1-L bag
	26–40 kg	2-L bag
	40–66 kg	3-L bag
	66 kg and above	5-L bag

Oxygen and carbon dioxide

Oxygen cylinders

There are various sizes of oxygen cylinders available.

The approximate minutes of oxygen remaining in a partial tank can be calculated based on the oxygen tank's capacity and the oxygen flow rate (L/min).

- **Full tanks, regardless of size, are pressurized to approximately 2,000 psi (pounds per square inch).**
  - This pressure decreases proportionally as the tank empties.

Table 1.9

Oxygen Volumes

	Small E Tank	Large H Tank
Full Tank Volume	600 L	7,000 L
Full Tank Pressure	2,000 psi	2,000 psi

Notes

The volume of oxygen remaining in the tank can be calculated from the tank capacity and the psi

$$\text{Current oxygen volume (L)} = \frac{\text{(current psi)} \times \text{(oxygen tank capacity in L)}}{\text{2,000 (psi of the full tank)}}$$

$$\text{Minutes of anesthesia time left} = \frac{\text{current oxygen volume (L)}}{\text{oxygen flow rate (L/min)}}$$

Example 1:

600 L tank at a pressure of 500 psi

$$\text{Current } O_2 \text{ volume} = \frac{(500 \text{ psi})\,(600 \text{ L})}{2000 \text{ psi}} = 150 \text{ L}$$

$$\text{Minutes of anesthesia time left at 1 L/min} = \frac{150 \text{ L}}{1 \text{ L/min}} = 150 \text{ minutes}$$

Example 2:

7000 L tank at a pressure of 1200 psi

$$\text{Current } O_2 \text{ volume} = \frac{(1200 \text{ psi})\,(7000 \text{ L})}{2000 \text{ psi}} = 4200 \text{ L}$$

$$\text{Minutes of anesthesia time left at 0.5 L/min} = \frac{4200 \text{ L}}{0.5 \text{ L/min}} = 8400 \text{ minutes}$$

Oxygen Concentrator

Oxygen concentrators provide a sustainable alternative to compressed oxygen by generating oxygen on-site, reducing energy use and environmental impact. This supports both sustainability goals and veterinary quality.

Once turned on and warmed up, the concentrator will continuously provide medical grade oxygen while the machine is powered on. The machine can be turned on in the morning and off in the evening, which will allow it to supply oxygen throughout the day. This can be fed into the anesthesia system either directly through the cart or through the centrally plumbed lines. Remember that oxygen is always being produced with these units so flow meters on the anesthesia carts MUST remain open at a level of ~2L/min.

It is recommended that an e-tank remain attached to the anesthesia cart in case of an emergency failure of the oxygen concentrator.

Carbon dioxide absorbent and canister

One of the most important maintenance items on the anesthesia machine is the absorber assembly, which contains the canister for the CO_2 absorbent (*e.g.*, soda lime, Carbolime®, Amsorb®, etc.). This removes carbon dioxide from the rebreathing circuit. (Figure 1.15)

Figure 1.15: Carbon dioxide absorbent canister



The canister and absorbent are common areas for malfunctions in the anesthetic system.

- When filling, be aware that the CO2 absorbent canisters hold approximately one, full 3-pound bag of absorbent.
  - Specific volumes are dependent on the type of canister.

Gloves are recommended when handling carbon dioxide absorbent. When large amounts of dust are present, consider the use of a mask.

When pouring the absorbent into the canister, use care and do not allow granules to fall into the center tube of the canister.

- There may be granules left over in the bag when the canister is full.
- Always discard absorbent left in the bag after filling the canister. Absorbent is not safe for use after storage.

The absorbent has an expected life span based on anesthesia time, or a maximum of four weeks with exposure to room air.

Leaks can result from failure to create a tight seal when replacing the canister.

- This can be caused by misalignment of the canister threads to the monometer threads or by absorbent granules becoming lodged in the threads.
  - Gently shake the canister while filling it with absorbent.
    - This helps prevent loose packing (increased amounts of air between granules) and channeling (development of specific, dedicated pathways through the absorbent within the canister, which minimizes exposure of gasses to absorbent).
    - Packing tightly causes dust formation and increases resistance to ventilation.
  - If granules enter the center tube while filling, empty the canister, clear the center tube of granules and reattempt.
  - Granules in the center tube are a safety hazard that have the potential to enter the breathing circuit and the pet's airway.

CO_2 absorbents will become exhausted or desiccated when used beyond their capacity to hold carbon dioxide.

Dangerous levels of carbon monoxide and compound A may be generated within the anesthesia system if granules are not replaced regularly.

Absorbent desiccation occurs from:

- Utilization within the breathing circuit during anesthesia
- Unused absorbent in the canister
- Exposure to room air once bag is opened

Indications of desiccation are:

- Fresh granules: soft enough to crush
- Exhausted granules: chemically altered and hard

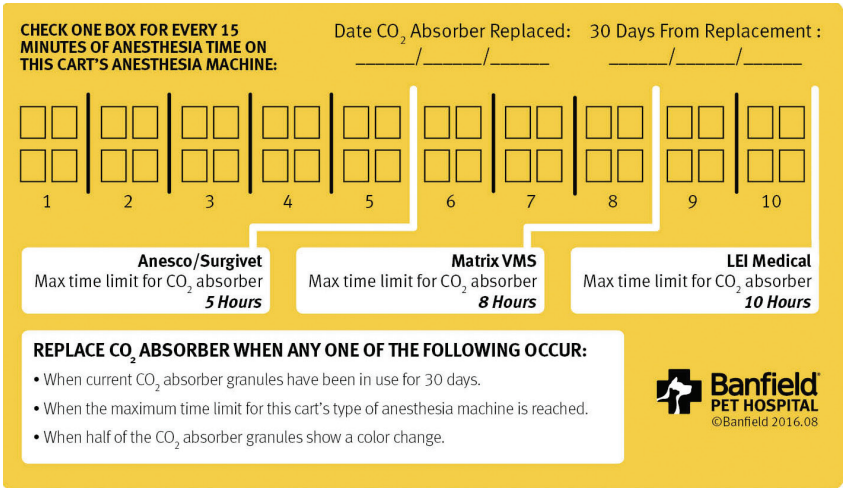
Once the granules become hardened, they will no longer absorb CO_2 and should be thrown away and replaced immediately.

- Many CO_2 absorbents will turn from white to violet as the granules become exhausted.
  - **Granules may revert back to white after a period of time; this does not indicate that the granules are safe to continue using.**

Dangerous levels of carbon monoxide and compound A may be generated within the anesthesia system if granules are not replaced regularly.

Required schedule:

Figure 1.16: CO_2 absorbent sticker



- Change the CO2 absorbent based on anesthesia time or every 30 days, whichever comes first.
  - Absorbent MUST be changed every 30 days, even if maximum anesthesia time has not been reached.
- Mark every 15 minutes of anesthesia time on the canister sticker.
  - When the anesthesia time is reached for the specific type of canister on the machine, change the CO_2 absorbent.
- Remove the old sticker and replace with new every time the absorbent is changed. (Figure 1.16)

- **CO_2 absorbents are changed based on specific schedules**
- **Follow the schedule listed on the canister sticker (Figure 1.16)**
- **Exact times are based on the type of absorbent canister on the anesthesia machine**
- **DO NOT wait for color change to replace absorbent**
- **If unsure of canister type, default to 5-hour change time**

Anesthesia machine and anesthetic administration

Evacuation system

The evacuation system must be hooked up and adjusted correctly to ensure that inhalant anesthesia is delivered properly to the pet.

Set-up

- Connect one end of the evacuation tubing to scavenger output and the other end to the waste gas interface valve on the machine.
  - **Do not connect tubing from output directly to the pop-off valve (rebreathing system) or bag bleed valve (NRB system).**
- Connect one end of the scavenging tubing to either the pop-off valve on the rebreathing head or the bag bleed valve on the NRB system; the other end attaches to the waste gas interface valve on the machine.

Use

All Banfield hospitals should have a scavenger system.

- This system has been installed for the safe removal of waste anesthesia generated during anesthesia.
- It is imperative for associate safety and quality anesthesia that this system is functioning.
- This unit is turned on and off by a lighted wall switch commonly located inside or directly outside the surgery suite.
  - □ The switch should be clearly labeled as the scavenger system.
- It is the doctor's responsibility to ensure each veterinary technician/assistant understands how the scavenger system works and why it is important to utilize it correctly.

Vaporizer

The vaporizer holds and administers the sevoflurane anesthetic gas.

- Fill new/empty vaporizers with sevoflurane 45 minutes prior to use to saturate the wick.
- Level of sevoflurane within the vaporizer can be determined by visualization of the liquid sevoflurane in the fill chamber.
- Refill vaporizer when the level drops below 50%.

Oxygen Regulator

Figure 1.17: Oxygen regulator



The oxygen regulator is a medical grade, preset, nonadjustable regulator designed to reduce oxygen tank pressure from approximately 2,000 psi, when full, to approximately 50 psi. The oxygen regulator can fail, resulting in pressure being too high or too low. (Figure 1.17)

Results of high-pressure failure include:

- Failure of the oxygen quick-disconnects
- Failure of the oxygen check valves in dual gas supply
- Failure of tubing
- Failure of oxygen flush
- Oxygen leak from regulator

Results of low-pressure failure include:

- Improper or insufficient oxygen flush
- Improper or insufficient oxygen delivered to patient
- Failure of oxygen to pass through the regulator

Manometer

Figure 1.18: Manometer



The manometer indicates the pressure (in cm H_2O) of the gasses (anesthetic gas and oxygen) in the pet's airways and lungs. Reading the manometer provides a safety measure to ensure that maximum pressures are not exceeded during anesthesia when performing manual ventilation. (Figure 1.18)

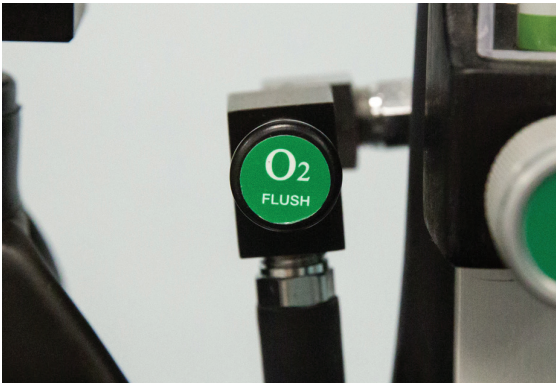
- **Damage, including fatal pneumothorax, can result if maximum pressures are exceeded**
- **Pressures should not exceed 20 cm H_2O in dogs or 15 cm H_2O in cats**
- **Puppies and kittens have even lower maximum pressures, as do some adult animals with respiratory disease. See *Protocols* for details.**

Calibration

- When not in use, the needle on the manometer gauge should be at zero.
  - The re-zero screw is located at the 12 o'clock position under the crystal manometer cover.
  - Remove the cover by turning counterclockwise.
  - Adjust the screw mechanism until the needle is zeroed.
  - Replace manometer cover.
- If the manometer will not re-zero it should be replaced.
- If the manometer cover is cracked, broken or missing, it should be replaced.

Oxygen flush valve

Figure 1.19: Oxygen flush valve



The oxygen flush valve allows the delivery of a high flow rate of oxygen (35 to 75 L/min), while bypassing the vaporizer, quickly filling the breathing system with pure oxygen. (Figure 1.19)

- Can produce a rapid decrease in anesthetic depth!
- Do not use the flush valve when a patient is attached to the anesthesia machine.

Use **only** for leak testing procedure.

The flush valve is only used when performing a leak test on the anesthesia machine, prior to attaching the pet to the machine. Do not use the flush valve to inflate the rebreathing bag during an anesthetic procedure. Instead, turn up the oxygen flow rate until the bag fills.

Notes

Safety pressure relief valve

Figure 1.20: Safety pressure relief valve



Comprised of a "screw-down" portion and the push button (also described as the "pop-off") valve. (Figure 1.20)

- High pressure can only be maintained in the system when BOTH the screw portion and the pop-off valve are completely depressed.
- The pressure relief valve is designed to stay open to help avoid dangerously increased pressures and resultant trauma to the pet.

When the pop-off valve is forcefully depressed, anesthesia gas and oxygen cannot leave the system.

- Depressing the pop-off valve should only be performed in conjunction with manual ventilation.
- Valve must stay open at all other times to prevent gasses from building to a dangerous pressure within the system and the pet's airways.

Notes

Table 1.10

Safety pressure relief valve settings and functions

Screw-down valve	Pop-off valve	Manometer reading ($cm\ H_2O$)	Function	Additional comments	
Open	Up	0 - 1 May have slight fluctuations with pet respiration	Normal operation Default position on machine	Squeezing rebreathing bag does not create pressure within system	
Open	Down	20 - 25	Manual ventilation	Allows pressure to build to perform manual ventilation Leak will occur at higher pressure	

Safety pressure relief valve settings and functions

Screw-down valve	Pop-off valve	Manometer reading (cm H_2O)	Function	Additional comments	
Closed	Up	0.5	Pet safety	System will leak to avoid increasing pressure if screw-down valve is accidentally left closed	
Closed	Down	>25 - 30	High pressure leak check Leak check performed before each anesthetic procedure	Do not perform with pet connected to system Open screw-down valve after leak check is completed	

Figure 1.21

Non-rebreathing system

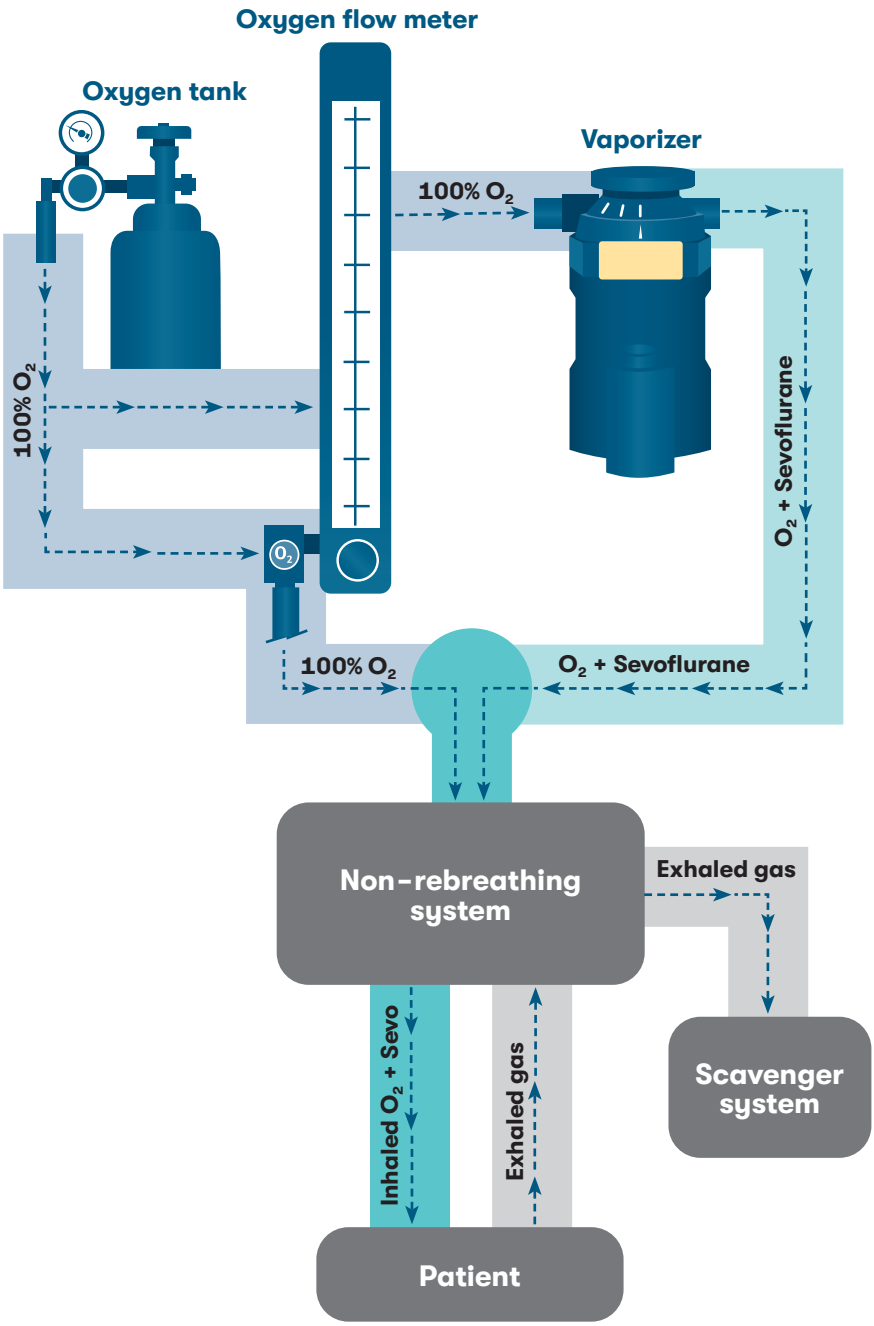
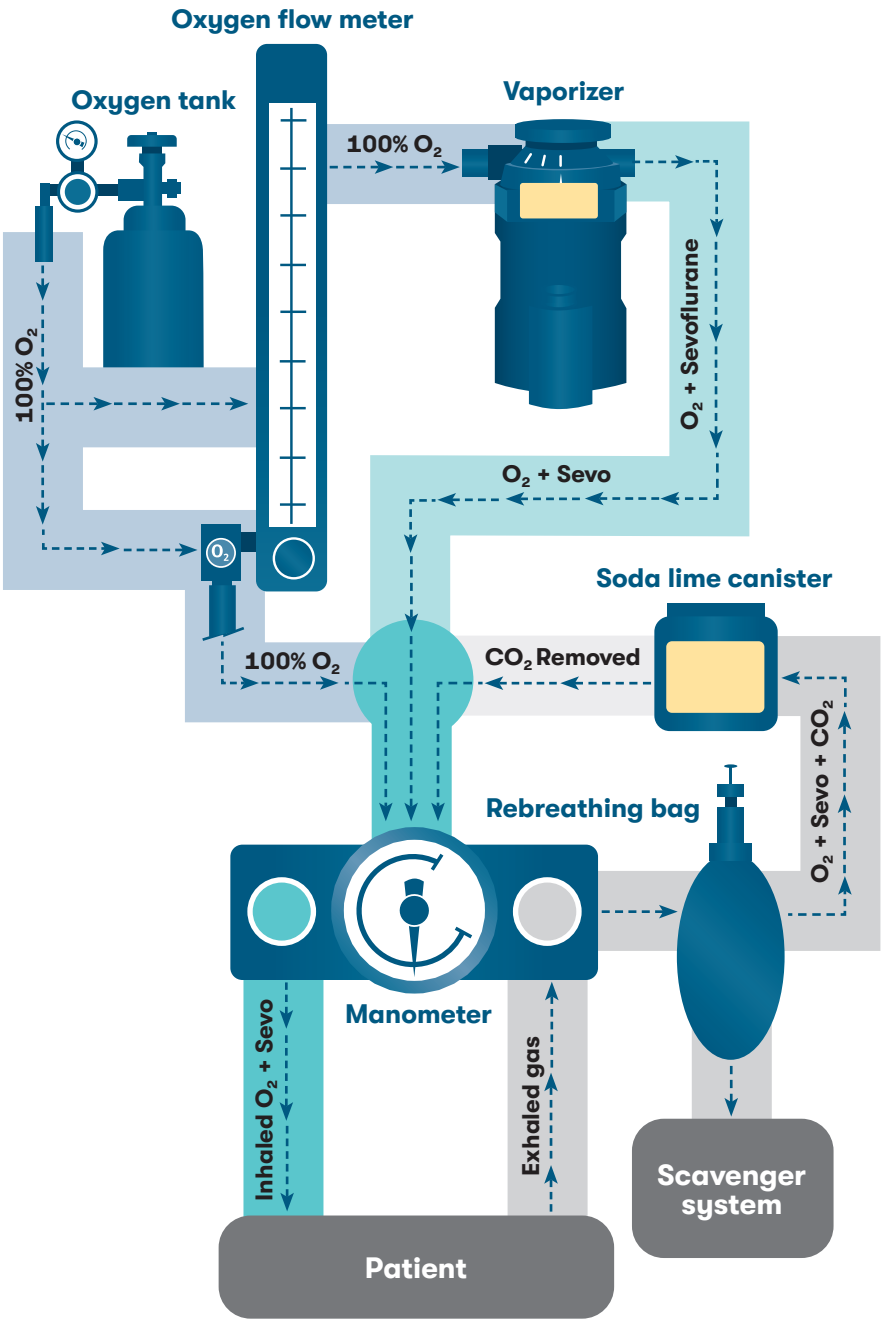


Figure 1.22

Rebreathing system



Ordering and maintenance

Please refer to the Ordering and Maintenance Guides per individual piece of equipment.

Notes

Anesthesia machine updates

The following information is to be used in conjunction with the standards already noted regarding anesthesia equipment. If instructions are labeled as an UPDATE, the information supersedes any previous information printed in the book.

Many of these updates are specific to Banfield Pet Hospital but can be adapted for other veterinary clinics. While any trained member of the hospital team can select and prepare equipment, it is the responsibility of the attending veterinarian to ensure that proper anesthetic equipment is chosen for each pet, equipment is used correctly, and is in good working order prior to induction.

Anesthesia breathing circuit standardized color-coding

Having a standardized color-coding process provides visual cues for the primary connections for anesthesia machines. By adopting these standardizations, it reduces the risk of misconnections during set up of the machine. It is important to utilize the anesthetic machine checklist to ensure proper connection.

Procedure

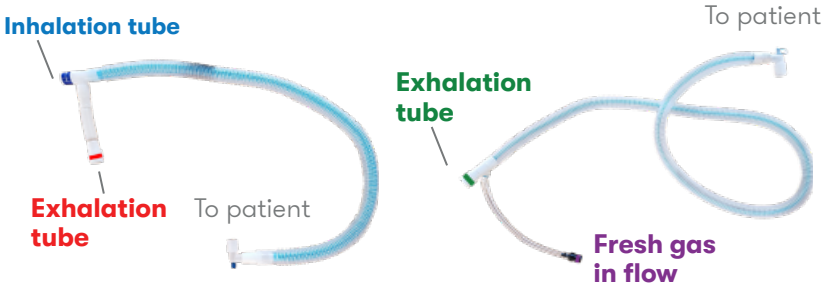
1. Identify the various connection points on each anesthesia cart (see diagram below)
2. Follow the chart below to place the correct color on each connection limb. Ensure the tape placement does not interfere with the connection
3. Use the corresponding color for the rebreathing and non-rebreathing tubes
4. Replace tape quarterly or any time new tubes are needed, based on wear and tear
5. Review the color-coding system and the importance of verifying prior to each anesthetic event with your team

Table 1.4

Considerations for procedures

Connection point	Designated tape color
Fresh gas–flow tube	■ Purple
Rebreather inhalation limb	■ Blue
Rebreather exhalation limb	■ Red
Bain exhalation limb	■ Green
Scavenging in limb (bain & rebreather)	■ Orange
Scavenging tube to outflow manifold	■ Yellow
Outflow manifold to scavenger system	■ Brown

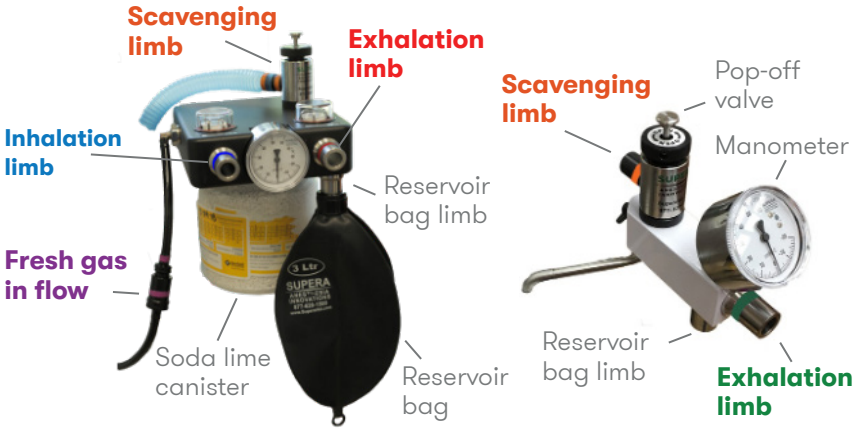
Overview of breathing circuits by type*



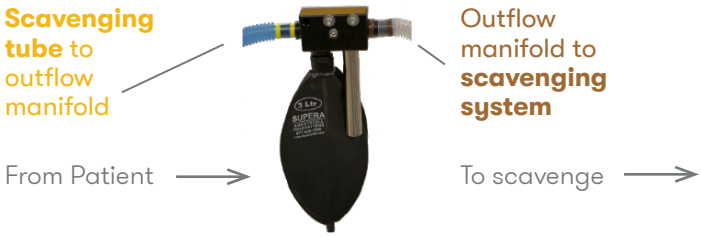
Rebreathing Circut **Bain circut**

*breathing circuit colors may vary based on individual hospital's equipment availability and patient size.

Overview of anesthesia machine connections by type



Scavenger manifold



Anesthesia Y-adapter setup

Misconnection of the anesthetic machine scavenging system increases the risk of patient trauma due to hyperinflation. The anesthesia Y-adapter is designed to reduce the need to change the scavenging connection from the rebreathing to the non-rebreathing anesthetic circuit. Proper setup of the anesthesia Y-adapter is vital to safe use. Please use these instructions for setup and training purposes.

Setup instructions

1. Identify and remove existing blue exhaust tubing from your anesthesia cart

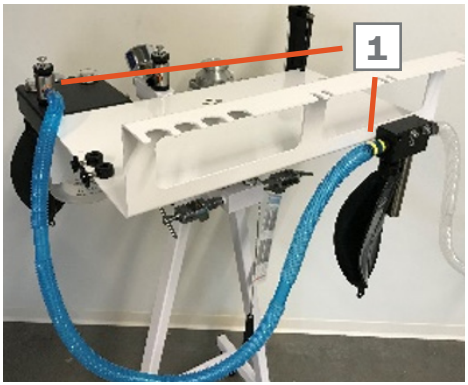


Figure 1
(New style anesthesia cart)

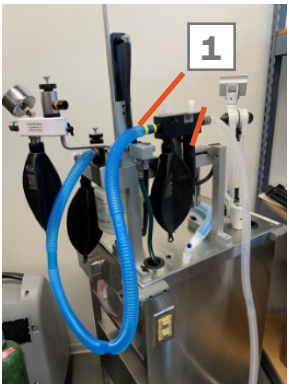


Figure 2
(Old style anesthesia cart)

2. Your Y-adapter should come with blue exhaust tubing attached. Attach the two longest arms of the blue Y-adapter tubing to the two scavenging limbs on the anesthesia cart – one to the rebreathing system limb and one to the non-rebreathing system (Bain) limb. These will correspond with **orange** tape that will need to be added to the blue tubing.
3. Attach the shorter arm of the blue Y-adapter tubing to the anesthesia cart's exhaust manifold. This corresponds with the **yellow** tape, which should be added to this end of the blue tubing (see photos below).

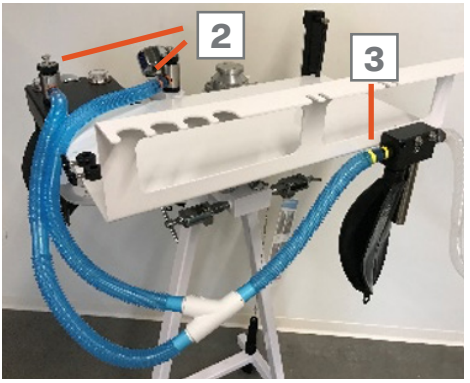


Figure 1
(New style anesthesia cart)

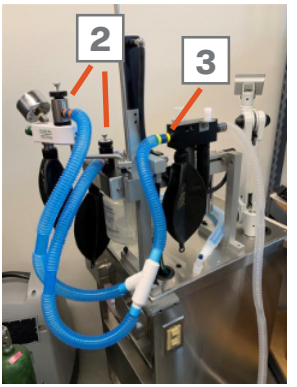


Figure 2
(Old style anesthesia cart)

4. Ensure that all connections are properly in place and snug before beginning each anesthetic procedure according to the Anesthetic Machine Checklist.

When completing the anesthesia machine checklist, it is important to understand and ensure correct attachment of the Y-adapter.

Update: Bain non-rebreathing circuit setup

1



Attach a 1-liter reservoir bag to the limb under the Bain control arm.

2



Connect the **exhalation tube** of the Bain circuit to the **exhalation tube** on the Bain control arm.

3

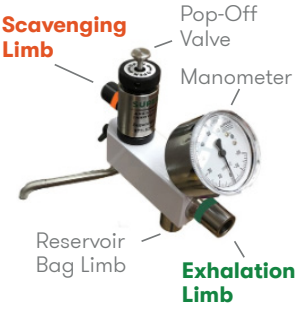


Connect the **clear, smooth inhalation tube** of the Bain circuit to the **fresh gas out-flow tube** on the anesthesia cart..

4



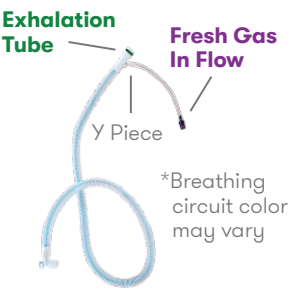
Connect the **blue, corrugated scavenger tube** to the **scavenging limb** on the Bain control arm.



Bain Control Arm



Reservoir Bag



Bain Circut



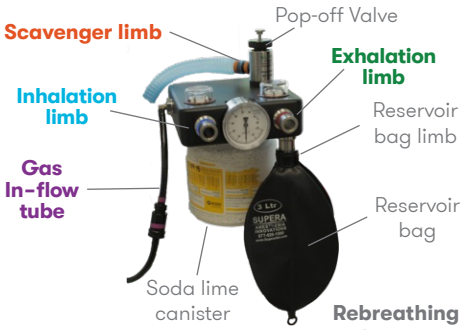
Ensure that a Y-adapter is in place and that the blue, corrugated scavenger tube is connected FROM the scavenging limbs on the Bain control arm to the cart's outflow manifold

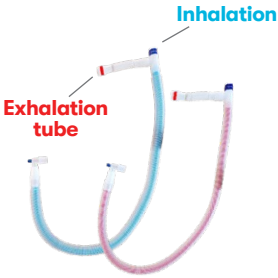
Ensure the clear, corrugated scavenger tube is connected **FROM** the **cart's outflow manifold TO hospital's scavenger system.**

Update: Rebreathing system

For pets weighing more than 7.0kg, use one of the following circuits:

Pediatric circuit = weight between 7.1–10kg | Adult circuit = weight greater than 10 kg





Adult circuit (blue)
Pediatric circuit (pink)



Ensure that a Y adapter is in place and that theblue, corrugated scavenger tube is connected FROM scavenging limb on rebreathing system TO cart's outflow manifold.

Ensure clear, corrugated scavenger tube is connected FROM cart's outflow manifold TO hospital's scavenger system.

Important notes regarding anesthesia

DO NOT allow the manometer to exceed the following pressures, it may result in a patient safety event:

Adult Dogs: 20cm H

Adult Cats: 15cm H

Juveniles: 15cm H



Clinical essential

Utilize the Anesthesia Machine Checklist for every general anesthetic event and have the checklist verified by the attending veterinarian prior to induction

Do not use the oxygen flush valve when a patient is attached to the anesthesia machine.

Update: Anesthesia machine and vaporizer leak test

1. Prepare anesthesia cart for use by following the connection job aid for the intended breathing circuit (you will need to repeat for each system)
2. Cover the patient end of breathing circuit, using your thumb or white post (older carts only)
3. Close pop-off screw valve by turning clockwise
4. Turn on oxygen via flowmeter until pressure gauge reads 20cmH2O
    a. Once pressure reaches 20cm H2O, with system still closed, turn off oxygen and depress valve button





5. **If pressure holds or leaks less than 1cm H2O/sec**, no significant leaks present
    a. While continuing to hold pressure with your thumb, open the pop-off screw valve by turning it counterclockwise
    b. Squeeze the reservoir bag and evacuate oxygen to ensure that there is no obstruction in the evacuation system

DO NOT release pressure by removing your thumb from the breathing tube during this step

If gauge drops more than 1cm H2O/sec, there is a significant leak. Proceed to following steps to correct: Refer to troubleshooting tables.

6. Ensure that all connections are secure
    a. Check hoses and reservoir bag, vaporizer inlet and outlet connectors
    b. Soda lime canister (properly seated and no granules are present on seal)
    c. Replace any failed parts
7. If leaking, spray window cleaner on fittings
    a. Look for cleaner bubbling which indicates a leak
    b. If no leaks, open valve fully, squeeze reservoir bag
    c. If leak present, repeat step 6

Safety Pressure Relief Valve Setting

Open

Screw Valve Open, Button Up.

Normal operation/default position. No pressure created in system.

Screw Valve Open, Button Depressed.

Manual ventilation position. Pressure is able to build, leak will occur at >25cm H2O.

Closed

Screw Valve Closed, Button Up.

Pressure will build, however system leaks at 25cm H2O if left closed

Screw Valve Closed, Button Depressed.

Completely closed system, pressure will build. Used for pressure checking the anesthesia system

Manual ventilation

Pets that are not breathing spontaneously require manual assisted ventilation. Follow the steps below to safely provide manual ventilations:

1. With pop-off screw valve open, depress valve button.
2. Squeeze the reservoir bag up to a pressure of 15cm H2O (do not exceed 20cm H2O) and release to allow for exhale.
3. Continue for four to six breaths per minute until spontaneous breathing resumes.
4. Pop-off valve button should be released between manual ventilations to allow for exhalation.

Do not use the oxygen flush valve when a patient is attached to the anesthesia machine.

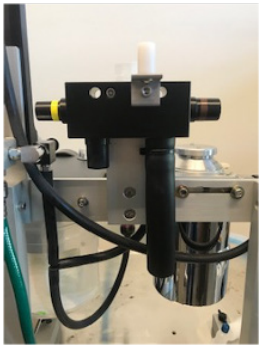
Anesthesia exhaust manifold cleaning

The anesthesia exhaust manifold is a black box on the back of the anesthesia cart that connects the anesthesia exhaust tubing to the scavenging system. Its purpose is to prevent the waste gas system from creating negative pressure in the anesthetic machine.

Over time, the exhaust manifold tubing and intake ports can build up dust, pet hair and debris. A clogged manifold can cause rebreather bags to inflate or deflate improperly. If the bag is overinflating, increased back pressure to the patient can develop resulting in barotrauma. If the bag is being deflated, you may see increased respirations and light patients with increased CO2 and decreased SpO2 values. Anesthetic machines will still pass a leak test, even with a dirty exhaust manifold. The exhaust manifold should be cleaned quarterly.

How to clean the exhaust manifold

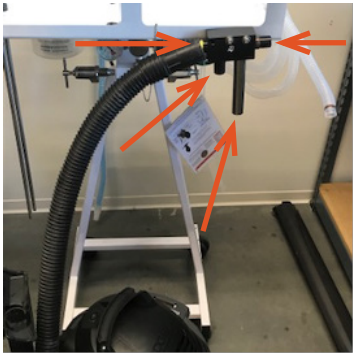
1 Remove all tubing and 3L bag (if present) attached to the exhaust manifold.

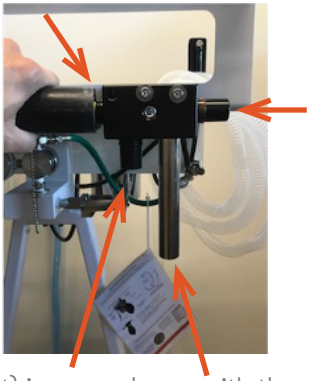


***Do NOT remove or loosen any screws attached to the manifold.**

2 Use a vacuum (Shop-Vac® or similar) to suction each entry point to the exhaust manifold (4 total)

Current style anesthesia cart





3 Replace tubing and 3L bag (if present) in accordance with the Anesthesia Breathing Circuit Standardized Color-Coding.

Current style anesthesia cart



Troubleshooting

When performing any troubleshooting on the anesthesia machine, it is imperative to consider how each part works together and to check each part to accurately identify any leaks or broken equipment.

If patients are not staying anesthetized even with the vaporizer set to 4% or higher, complete the steps below using the information outlined in the following pages:

1. Ensure the appropriately sized breathing apparatus/circuits/ ET tubes/etc. are used, and that cuffs are working properly.
2. Check for single bronchus intubation. If the endotracheal tube is accidentally placed down a single bronchus, anesthetic gas is only being administered to one lung and anesthesia will be difficult to maintain. Check for the distal end of the ET tube and back out if necessary.
3. Check the system for any leaks — check the entire system as there may be more than one leak.
4. Check that the vaporizer is filled and working correctly.
5. Check the evacuation system for the appropriate balance of positive and negative pressure.
6. Check the oxygen flowmeter and regulator.
7. Check the breathing circuit and ET tube for physical obstructions — if found, remove.

Anesthesia leak test process

Table 1.11

Anesthesia cart

Test procedure	Leaks
Perform prior to each anesthesia procedure. **DO NOT PERFORM with pet attached to machine.** 1. Close pop-off valve 2. Occlude end of anesthesia tube 3. Push oxygen flush valve until: a. Manometer reads 20 cm H_2O **OR** b. Rebreathing bag is filled 4. If manometer stays constant with oxygen off = no leaks 5. Reopen pop-off valve to normal position 6. Squeeze rebreathing bag to evacuate gas 7. Remove occlusion from anesthesia tube	If: ■ Manometer drops ■ Bag deflates ■ Audible hissing noise = System Leak **Sources of Leaks** ■ All hoses ■ Rebreathing bags ■ Pressure relief valve ■ Vaporizer ■ Any mechanical fittings ■ CO2 absorbent canister **Next Steps for Leaks** ■ Repair or replace leaking equipment ■ Repeat leak test. May have more than one source for leaks. ■ Ensure proper function prior to anesthesia

Table 1.12

Oxygen flow meter and regulator

Test procedure	Leaks
DO NOT PERFORM THIS TESTING WITH PET ATTACHED TO ANESTHESIA MACHINE 1. Turn off oxygen flowmeter 2. Turn on oxygen tank 3. Watch oxygen tank pressure gauge 4. When needle is stable, turn off oxygen tank	■ If needle is stable = no leak ■ If needle drops = leak ■ The faster the drop, the bigger the leak
Sources of Leaks	**Solutions**
Oxygen regulator or hose nut is loose	■ Tighten nuts
Oxygen flowmeter is stuck in open position (float ball in tube does not go to zero)	■ Replace flowmeter
Oxygen flush valve seal is defective	■ Replace flowmeter and flush systems
Fitting on back of flowmeter is loose	■ Tighten fitting
Faulty check valve in dual gas supply	■ Replace check valve

Additional Checks

Check oxygen flowmeter knob for correct function

Check oxygen tank is on

If oxygen flush and flowmeter do not work with tank turned on:

- Oxygen tank or regulator needs to be replaced
- Replace with new oxygen tank or change regulator

Table 1.13

Endotracheal tube

Test procedure	Leaks
Perform with pet anesthetized, intubated and attached to machine. 1. Close pop-off valve 2. Gently squeeze rebreathing bag to pressure of 15–20 cm H_20 ■ Do not hold breath for more than 2–3 seconds 3. Listen for hissing or leaking around tube	■ Hissing or sound of airflow around tube ■ Unable to maintain pressure **Sources of Leaks** ■ May occur around ET tube with pet relaxation ■ Inadequate inflation of ET tube cuff ■ Defective ET tube cuff **Next Steps for Leaks** ■ If leaking, add small increments of air to cuff, only until leak stops ■ If unable to resolve leak, extubate and place alternate ET tube

Table 1.14

Evacuation system

Test procedure	Next steps for leaks
1. Gently squeeze rebreathing bag to pressure of 18–20 cm H_20. a. Hold a tissue to the opening of the scavenger tube b. Tissue should be gently pulled to the tube 2. Do not allow tissue to be pulled into the tube 3. Ensure adjustment handle is set to approximately 45 degrees (if applicable)	■ Contact CTS Facilities team for pressure imbalance assistance

Table 1.15

Vaporizer

Ensure the following:	Additional considerations
■ Appropriately filled ■ Cap and drain are both tightly closed ■ Inlet and outlet adaptors fit snugly	■ System is self-contained ■ Do not attempt to adjust or tighten other parts of vaporizer



Clinical essential

Anesthetic machines and equipment are maintained and a permanent log of maintenance is kept

Physiology

Abbreviations

ANS	autonomic nervous system
ASA	American Society of Anesthesiologists
BP	blood pressure
BPM	beats per minute
CNS	central nervous system
CO	cardiac output
CRI	constant rate infusion
HCM	hypertrophic cardiomyopathy
HR	heart rate
MAP	mean arterial pressure
PNS	peripheral nervous system
SNS	somatic nervous system
SV	stroke volume

Definitions

Adrenergic: Related or responsive to epinephrine and/or norepinephrine

Agonist: Substance that combines with a receptor and initiates a physiologic response

Antagonist: Substance that blocks a receptor or blocks/reverses a physiologic response

Cholinergic: Related or responsive to acetylcholine

Introduction

A comprehensive review of physiology is beyond the scope of this update. The following information is meant to provide a summary of important points regarding:

Neurologic and cardiovascular physiology

- Resultant effects of anesthetic and analgesic agents on canine and feline physiology
- Physiology of stressed or fractious pets

Perfusion

Defining good perfusion

- Good perfusion is the state of blood flow and blood volume adequate to push red blood cells to the lungs, carry oxygen and deliver it to the tissues.
- A pet with good perfusion can be described as having adequate circulating blood volume, blood pressure, oncotic pressure and cardiac output (CO) to maintain normal physiology and function.

Perfusion and anesthesia maintenance

All anesthetic drugs affect perfusion to some extent.

- **The vast majority of anesthetic and preanesthetic agents will decrease cardiac output and decrease perfusion.**
- Most drug effects are dose dependent.
- Understanding the mechanisms of how drugs alter perfusion during anesthesia is critical to be able to maintain a pet's perfusion when placing them under anesthesia.

Cardiac Output (CO) = Heart Rate (HR) x Stroke Volume (SV)

- CO is defined as the volume of blood pumped by the heart.
- SV is defined as the amount of blood pumped with each contraction.
- SV is dependent on venous return to the heart (preload), total peripheral resistance (afterload) and cardiac contractility.

- It is important to note that preload and afterload affect cardiac output.
  - Pets with systemic hypertension have a higher afterload which can decrease cardiac output, due to the heart pumping against higher pressure.
    - Control hypertension prior to anesthesia.
  - Pets with hypotension often have reduced preload and, therefore, decreased cardiac output.
    - Assess hydration status and administer fluids as medically indicated.

- **Pets with abnormal blood pressures must be stabilized prior to anesthesia. Postpone/reschedule anesthesia if cardiac output cannot be stabilized.**

- Cardiac output is fundamental to perfusion.
  - Pets with diseased heart muscles, excessively high heart rates or excessively small cardiac chamber sizes, as in feline hypertrophic cardiomyopathy (HCM), may have stroke volumes so small that cardiac output is severely compromised.
    - These pets are often subclinical upon presentation and decompensate rapidly under anesthesia.
  - **Heart rate reduction is expected after administration of preanesthetic medications.**
    - **Re-evaluation of vital signs impacting cardiac output is important to ensure adequate perfusion in the post-premedication, pre-induction phase of anesthesia.**
    - If the heart rate does not decrease after premedications are administered and allowed to take effect, or if heart rate is increased, the hospital team should stop and re-evaluate whether anesthesia is appropriate. (Table 1.16)



Clinical essential

Perform a physical examination (including all cardiovascular parameters) post-premedication and pre-induction for every general anesthetic event

Table 1.16

Examples of heart rates and premedication effects (feline)

Prior to premedication	Post premedication	Action
HR = 200 beats per minute (BPM)	HR = 140 BPM	Proceed with procedure if all other physical parameters normal.
HR = 230 BPM	HR = 220 BPM	**Reassess the patient and reevaluate the pre-medication protocol and administration.** **Evaluate for underlying cardiac disease** **Reschedule anesthesia when medically indicated**

- Circulating blood volume is critical to maintaining blood flow.
  - Protocols include IV fluids (colloids and crystalloids) to help maintain cardiovascular volume and tissue perfusion that could be compromised during anesthesia.
- Oncotic pressure also affects perfusion.
  - If albumin and total protein levels are significantly below normal, pulmonary edema can result from fluid movement into the interstitium.
  - Ensure total protein and albumin concentrations are within normal limits prior to anesthesia.

Clinical essential
Obtain and review clinical pathology data prior to general anesthesia

Pharmacologic influence on the nervous system

Divisions

The nervous system can be divided into two broad anatomic categories:

Central Nervous System (CNS)	Peripheral Nervous System (PNS)
Brain and spinal cord	Nerves located outside the CNS extending into the "periphery"

Anesthesia will affect both of these systems in different ways, depending on the specific subset of receptors associated with the nervous tissue in these different regions.

Central Nervous System

- Various sections of the brain are associated with different clusters of nervous tissue with unique functions.
- Anesthetic induction and maintenance agents affect these areas to cause the unconsciousness, immobilization and amnesis associated with anesthesia.
  - Some agents also modulate the centrally mediated perception of pain.

Peripheral Nervous System

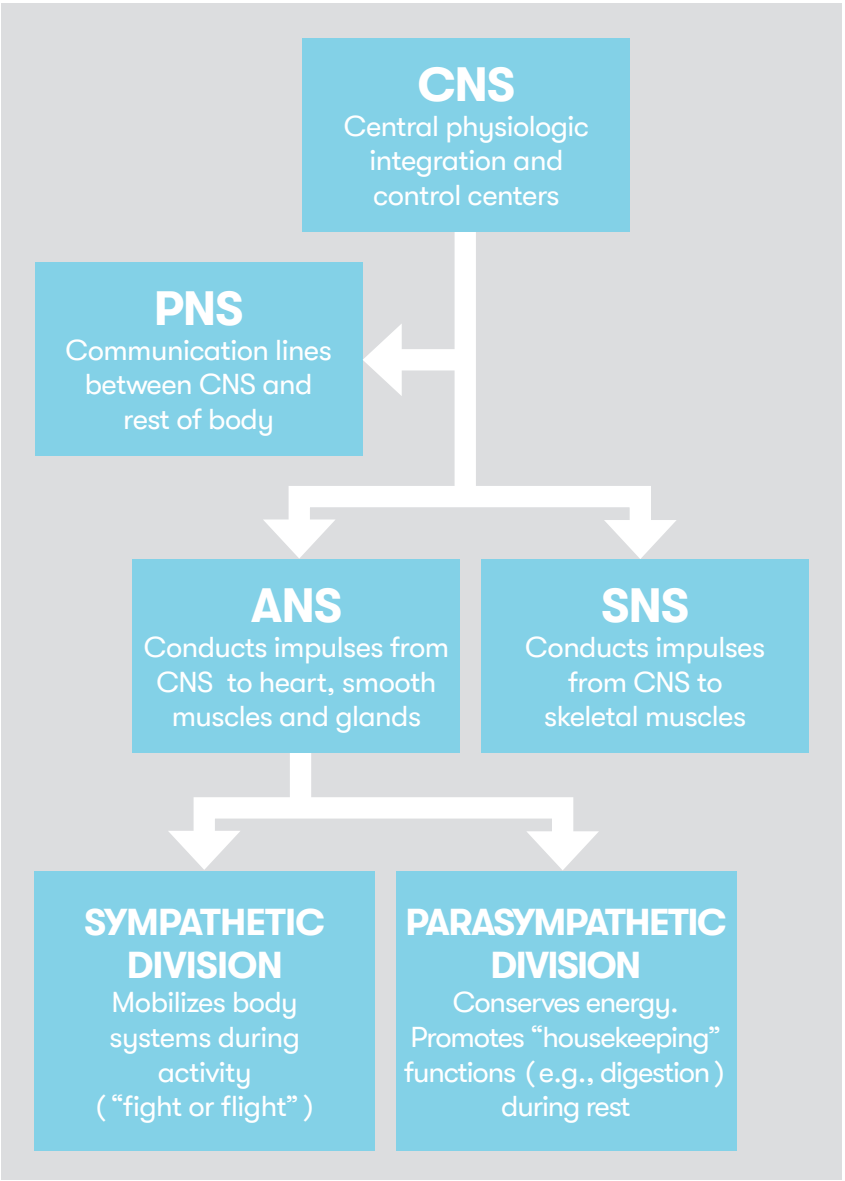
Comprised of the following:

Cranial Nerves	Spinal Nerves
Originate from the brain stem	Arise from the spinal cord

- Involved with the control and sensation of the various effector sites (muscles, sensory systems and glandular tissue)
- Includes both autonomic nervous (ANS) and somatic nervous (SNS) subsystems (also called involuntary and voluntary, respectively)
  - The autonomic subsystem is further divided into the parasympathetic and sympathetic nervous system.
  - Understanding these functional systems of the ANS is important for the safe use of anesthesia and the drugs that modulate anesthesia.

Figure 1.23

The nervous system



Sympathetic (Adrenergic) Nervous System – "Fight or Flight" (Figure 1.24)

- Acute stimulation of this system causes rapid release of epinephrine, as well as acetylcholine and norepinephrine.
- Effects of stimulation are mediated through the alpha and beta receptors. (Table 1.17)

Figure 1.24

Sympathetic responses mediated by alpha and beta receptors

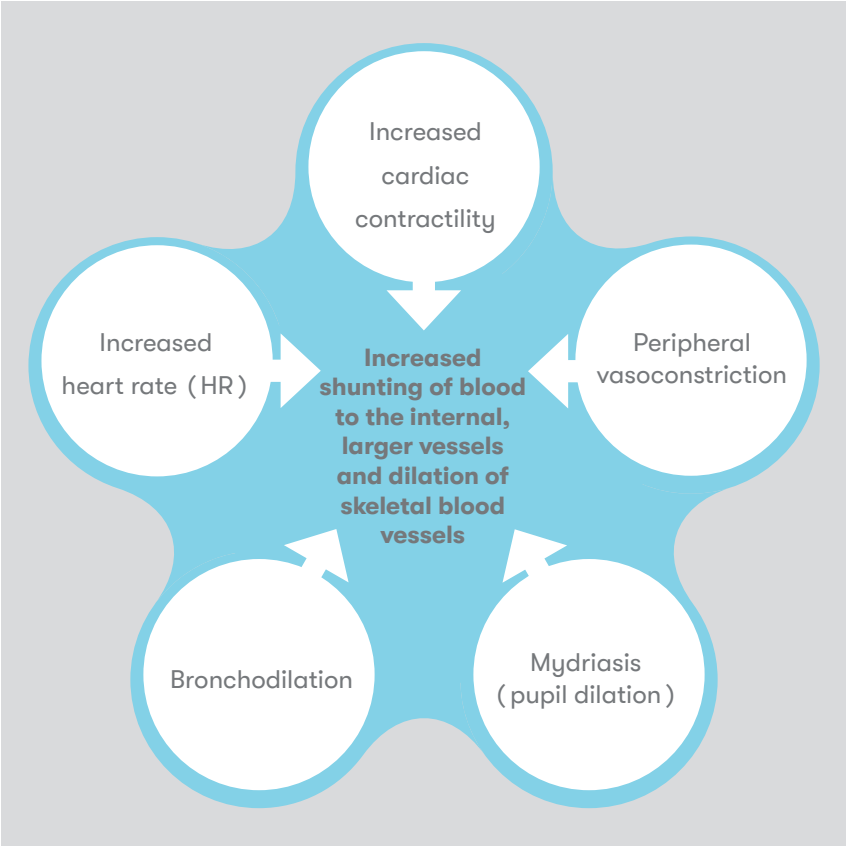


Table 1.17

Alpha and beta adrenergic receptors

Receptor Type	Alpha-1	Alpha-2	Beta-1	Beta-2
Main Site of receptors	Blood vessels	Neural tissue and blood vessels	Cardiac tissue	Respiratory tract
Stimulation results in	Peripheral vasoconstriction leading to increased blood pressure (BP) Use of antagonist will result in decreased BP	CNS: sedation and mild analgesia PNS: peripheral vasoconstriction, transient hypertension, reflex bradycardia	Cardiac effects predominate: Increased HR and contractility resulting in increased CO	Respiratory effects predominate: Bronchodilation due to relaxation of bronchiolar smooth muscle
Agonists	Epinephrine, ephedrine	Dexmedetomidine	Epinephrine, ephedrine, dobutamine	Epinephrine, albuterol, terbutaline
Antagonists	Acepromazine	Atipamezole	Beta blockers	
			Atenolol, propranolol	Propranolol
Additional information	See stressed/ fractious pet physiology for discussion of "epinephrine-reversal"	Powerful sedatives with the potential for significant side effects Must be used with caution (ASA I - II)	Beta-1 effects are typically cardiac in nature. Atenolol is a relatively specific beta-1 antagonist.	Albuterol is a relatively specific beta-2 agonist

Utilizing alpha-2 agonists

Caution:

- Pets can still be roused while under the influence of an alpha-2 agonist.
  - Immobilized pets may still pose an associate safety risk.
  - Utilize extreme caution, especially when handling a stressed/ fractious pet.
- Alpha-2 agonists significantly lower or eliminate the need for induction agents.
  - Induction doses of propofol may be as low as 1 mg/kg.
    - Titrate propofol carefully and follow administration instructions closely.
- Use of alpha-2 agonists may reduce the minimum alveolar concentration of sevoflurane.
  - Maintenance under general anesthesia may require significantly less inhalant anesthetic gas.
- May cause vomiting, especially in cats.
  - Fasting is recommended to reduce stomach contents.

- **Recommended that only clinically healthy dogs and cats (ASA status I or II) be treated with alpha-2 agonists due to the cardiovascular effects**

Clinical use:

- Powerful sedative and analgesic effects utilized for:
  - A preanesthetic sedative-analgesic agent

A constant rate infusion (CRI) supplement to inhalant anesthesia and in the post-operative period

- A synergistic supplement to local anesthetics in regional nerve blocks

Side effects:

Can be very significant, often impacting cardiovascular function

- Stimulation of post-synaptic alpha-2 receptors causes constriction of blood vessels resulting in significant, yet transient, hypertension.
- The body responds with a decrease in heart rate (reflex bradycardia).



- Clinically, the peripheral vasoconstriction can cause significant blanching of the gums and, sometimes, decreased palpable pulse pressure.
- Use of an alpha-2 agonist in combination with other medications (usually ketamine and butorphanol) helps to decrease the dose required and mitigates these cardiovascular effects.

Notes

Parasympathetic (cholinergic) nervous system–"housekeeping"

- The parasympathetic, cholinergic system is functionally and anatomically separate from the sympathetic (adrenergic) system.
- Primarily responsible for effects that are essentially opposite of the sympathetic pathways
- Receptor types include nicotinic and muscarinic receptors; however, the division between receptors is not as clear in the parasympathetic system.

Table 1.18

Cholinergic pathway		Potential effects
Agonists	Acetylcholine Bethanechol	■ Decreased heart rate ■ Increased respiratory secretions ■ Increased gastrointestinal motility ■ Increased secretion of gastric fluid ■ Increased urination
Antagonists/ anticholinergic drugs	Atropine Glycopyrrolate	■ Increased heart rate ■ Decreased respiratory secretions ■ Decreased salivation ■ Effects may be mediated by vagus nerve

Utilizing anticholinergic drugs

Clinical use:

- Anticholinergic drug therapy will not always cause an increase in heart rate.
- Administration of an anticholinergic drug (atropine or glycopyrrolate) does not increase the heart rate above the basal rate.
  - **Increased heart rate is a result of decreased vagal tone.**
    - Innervation from the vagus nerve to the heart helps control normal heart rate.
    - The vagus nerve functions to slow the heart rate by inhibiting the sinoatrial node or "pacemaker" of the heart.
  - Heart rate may be elevated after administration of anticholinergic drugs due to the presence of epinephrine in the system affecting the beta-1 pathways.
    - Beta-1 pathway must be stimulated (*e.g.*, via epinephrine release) if the heart rate is to be increased above the basal rate with administration of anticholinergics.
- Anticholinergic drug administration blocks the ability of the heart to slow in response to appropriate vagal stimulation.
  - May result in unwanted tachycardia (elevated heart rate)
  - Pets with a normal heart rate and blood pressure before anesthesia rarely benefit from pre-emptive anticholinergic administration.
  - **Not applicable to pediatric pets**
    - **Pediatric cardiac output is much more dependent upon heart rate.**
    - Preventing bradycardia is very important.
    - An anticholinergic is included as a premedication in pediatric protocols.

Side effects:

- Tachycardia after anticholinergic drug administration is difficult to manage therefore careful and cautious use of anticholinergics is warranted.
  - Supporting subsequent increased myocardial oxygen demand with supplemental oxygen, and administering IV fluids to support circulating volume, is helpful.
  - If tachycardia is present prior to anticholinergic drug administration, give supplemental oxygen and IV fluids and postpone induction of anesthesia until the heart rate normalizes or the primary cause is identified and treated (*e.g.*, pain).

Table 1.19

Examples for use of anticholinergic drugs

Physical examination reveals bradycardia or significant bradycardia develops during a procedure

HR	Mean Arterial Pressure (MAP)	Comments	Use of anticholinergic
50 BPM	100 mm Hg	Bradycardia is tolerated with a normal MAP as perfusion should be maintained	Not indicated Monitor HR and BP
50 BPM	50 mm Hg	Bradycardia may not be tolerated with a below normal MAP as this would be expected to result in poor perfusion	Consider use of an anticholinergic to improve perfusion

Stressed/fractious pet physiology

Stressed versus fractious

The terms "stressed" and "fractious" are often used interchangeably, and while there may be physiologic similarities, the stressed or anxious pet should not be treated as a fractious pet.

Stressed pets may also be described as fearful, anxious or distressed.

- Fractious pets may also be described as unruly, reactive or difficult to control. They may or may not have an underlying reason (*e.g.*, pain) for their behavior.

A stressed pet may be considered as one:

- Demonstrating signs such as:
  - Inappropriate urination
  - Defecation or anal sac expression
- Freezing, hiding or attempting to hide or escape away from the handler
- Requiring more than one member of the hospital team to restrain due to fearful behaviors
- More subtle signs include:
  - Lip licking
  - Blinking
  - Turning away
  - Panting, etc.

A fractious pet may be considered as one:

- Demonstrating overt displays of aggressive behavior (growling, snapping or biting)
- Requiring more than one member of the hospital team to restrain as a result of reactive or fearful behaviors

Stress may be significant even when a pet is not fractious. Examples include:
Pets that are in pain

- Pets that are experiencing an airway obstruction
- Pets that are fearful

Epinephrine may be present in both the stressed and the fractious pet, mediating the physiologic responses. However, the circulating half-life of epinephrine is short. The danger to the stressed pet may be reversed or minimized by:

- Providing sedation
- Minimizing stress triggers
- Giving time
- Implementing a counter-conditioning plan

- **Fractious pets are stressed, but not every stressed pet is fractious**
- **Remember that the most common reason for both stress and fractious behaviors in pets is fear**
- **Both stressed and fractious pets may pose a safety risk to themselves and hospital associates**

Stressed and/or fractious pets are at a greater risk for adverse events associated with anesthesia

The best decision for the stressed or fractious pet may be to stop the procedure and reschedule for a later time

Identify potential stress triggers for pets and reschedule for a time when stresses can be minimized.

- Considerations for potential triggers:
  - Exposure to other pets and unfamiliar people
  - Environmental (e.g., activity, smell, noise)
  - Gender of hospital associate
  - Handling techniques of hospital associate
  - Unfamiliar kennels/carriers/crates
- Implement a counter-conditioning plan (see References for details)

Anesthetic implications

Periodically there may be stressed or fractious pets where anesthetic procedures are medically indicated and cannot be postponed or rescheduled.

Stressed and fractious pets release a significant amount of catecholamines (e.g., epinephrine, norepinephrine) that lead to physiological effects such as tachycardia, hypertension, tachypnea (increased respiratory rate), hyperthermia (increased body temperature) and mucous membrane color changes.

All these effects increase the risk of anesthesia in these pets. Close monitoring of the cardiovascular, respiratory and central nervous systems is required to anticipate complications and prevent adverse anesthetic events.

Stressed or fractious cats pose a particular challenge to adverse anesthetic events, due to the potential for underlying cardiac disease.

- HCM in cats is often subclinical and not evident until the cat is physiologically challenged (as with anesthesia) or the disease is advanced.
- One study demonstrated cardiomyopathy in 15 percent of apparently normal cats.[4]
- Hypertrophic myocardial changes render pets more susceptible to myocardial hypoxia, ischemia and arrhythmias.
- During stressful episodes such as anesthesia and surgery, activation of the sympathetic nervous system leads to an accelerated heart rate, decreased cardiac filling time and myocardial perfusion and increased myocardial oxygen demand.

Stressful episodes may exacerbate cardiac disease and cause clinical decompensation

Handle stressed/fractious cats with extreme caution and remember that the best decision for the pet may be to postpone anesthesia

Acepromazine in stressed/fractious pets and "epinephrine reversal"

- Epinephrine is often released endogenously during stressful events.
  - Epinephrine stimulates both alpha and beta receptors.
- When acepromazine (an alpha-1 antagonist) is given as a premedication it blocks the effect of epinephrine on alpha, but not beta receptors (beta receptors are still stimulated).
  - Arteriole constriction does not occur but heart rate and contractility are increased.
  - This vasodilation results in pooling of the circulatory volume in the peripheral vascular bed skeletal muscles.
    - As a result, there is decreased venous return, reduced preload and decreased cardiac output, resulting in a relative hypovolemic shock.
      - This is termed "epinephrine reversal".

Avoid acepromazine in fractious pets

Table 1.20

Treatment of acepromazine-induced epinephrine reversal = administration of crystalloid fluids and/or colloids

	Canines	Felines
Crystalloids	20 mL/kg bolus Repeat as needed up to 80 mL/kg	5 mL/kg bolus Repeat as needed up to 40 mL/kg
Colloids	5 mL/kg bolus Repeat as needed or begin constant rate infusion (CRI) up to 20 mL/kg/day	2.5 mL/kg bolus Repeat as needed or begin CRI up to 10 mL/kg/day

Monitor cardiac output and adjust fluid therapy and supportive measures as medically indicated:

- Heart rate
- Blood pressure
- Mucous membrane color, etc.

References and suggested reading for physiology:

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Notes