Intravenous fluid administration is recommended during general anesthesia, even during short procedures.

The traditional IV fluid rate of 10 mls/kg/hr during general anesthesia is under review.

Knowledge of a variety of IV fluids, and their applications, is essential when choosing anesthetic protocols for different medical procedures.

Anesthetic drug effects on the cardiovascular system

- Almost all anesthetic drugs have the potential to adversely affect the cardiovascular system.
- General anesthetic vapors (isoflurane, sevoflurane) cause a dose-dependent, peripheral vasodilation.
- Alpha-2 agonists initially cause peripheral hypertension with reflex bradycardia leading to a dose-dependent decreased patient cardiac index. As the drug effects wane, centrally mediated bradycardia and hypotension are common side effects.
- Phenothiazine (acepromazine) tranquilizers are central dopamine and peripheral alpha receptor antagonists. This family of drugs produces dose-dependent sedation and peripheral vasodilation (hypotension).
- Dissociative NMDA antagonists (ketamine, tiletamine) increase sympathetic tone soon after administration. When dissociative NMDA antagonists are used as induction agents in patients with sympathetic exhaustion or decreased cardiac reserve (morbidly ill patients), these drugs could further depress myocardial contractility.
- Propofol can depress both myocardial contractility and vascular tone resulting in marked hypotension. Propofol’s negative effects on the cardiovascular system can be especially problematic in ill patients.
- Potent mu agonist opioids can enhance vagally induced bradycardia.

Why is IV fluid therapy important during general anesthesia?

- Cardiac output (CO) equals heart rate (HR) X stroke volume (SV); IV fluids help maintain adequate fluid volume, preload, and sufficient cardiac output.
- Oxygen delivery to the tissues (DO2) equals CO X arterial blood oxygen content (CaO2); without adequate blood volume (relative and/or absolute hypovolemia) cardiac output decreases, which results in decreased peripheral oxygen delivery, thus tissue ischemia.
- General anesthesia, by nature, depresses (shocks) autonomic, cardiovascular responses and homeostasis. Cardiovascular problems related to general anesthesia occur even with ASA status 1 patients. Intra-operative blood loss will contribute to total circulatory volume loss and therefore exaggerate the cardiovascular depressant effects of general anesthesia.
- In response to hypovolemia, the body preferentially centralizes blood circulation toward the vital organs and away from peripheral tissues.
- Subcutaneous fluid administration during general anesthesia does not replace IV administration as a means to maintain blood volume. Subcutaneous fluids are absorbed poorly during general anesthesia due both to a circulatory shift away from peripheral circulation and an inevitable hypothermia.
- Intravenous fluids can help maintain a patent IV catheter during general anesthesia, which allows for emergency drug administration, if needed.

Perioperative fluid therapy should be tailored to patient requirements

- Appropriate fluid type, rate, and volume should be considered important elements of a patient’s overall anesthetic protocol. Each patient is unique and every anesthetic protocol should be tailored to individual patient anesthetic requirements.
- Patient history, thorough physical exam, and subjective and objective data (laboratory, radiographic) are necessary to plan appropriately an anesthetic protocol.
- Ideally, patient stabilization, including fluid losses, electrolyte imbalances, trauma, and respiratory and cardiovascular diseases should occur prior to anesthesia; however, in emergency situations, anesthetic patient stabilization may not be possible.
Anesthesia fluid therapy; crystalloids (Dibartola)

- Isotonic, polyionic replacement fluids, such as LRS, are popular IV fluids used during general anesthesia.
- Replacement fluids resemble extra-cellular fluid composition and are designed to resupply body fluids and electrolytes within the cardiovascular and interstitial spaces. Within 30 minutes after replacement fluid administration, nearly 80% is lost from the vascular space into the interstitium.
- Replacement fluids can be used to help alleviate acute hypovolemia.
- Maintenance fluids are designed to fill rapidly the interstitial space. Maintenance fluids should NOT be used for volume resuscitation.
- There are many different formulations of crystalloid fluids available. Indications of each kind depend on individual patient needs such as hypovolemia, dehydration, illness, electrolyte, and acid-base imbalances.
- In the last six years the volume of perioperative crystalloid administration has come under scrutiny. An article written in 2008 by Chappell, et al., questioned the existence of a third space and the research that first established fluid rates during general anesthesia. Traditionally, perioperative fluid administration for veterinary patients has largely mimicked, without solid scientific basis, human recommendations. A publication in 2010 by Boscon, et al., in demonstrated that not only did urine production in healthy, anesthetized dogs consistently decrease, it was coupled with an increase in body water weight. In 2013 an article in JAHAA provided new recommendations for fluid therapy with veterinary anesthesia patients. Based on these recommendations, canine fluid rates should start at 5 ml/kg/hr, feline rates at 3 ml/kg/hr, and fluid formulation, volumes, and rates should be adjusted according to individual patient needs.

Anesthesia fluid therapy; colloids

- Replacement crystalloids are beneficial to help expand rapidly the vascular space when increased blood volume is needed. Unfortunately large volumes of crystalloid potentially can lead to issues such as dilutional hypoalbuminemia, dilutional coagulopathies, decreased pulmonary function, decreased tissue oxygenation, and increased water weight. Approximately 80% of the volume of intravenous crystalloids equilibrate with the interstitial space within 30 to 45 minutes after administration. Unless the underlying cause of hypovolemia is corrected, more crystalloid therapy will be required to help maintain cardiac output, which, in turn, worsens tissue edema.
- Colloids are fluids that contain large, complex molecules. Like crystalloids, colloids can be used for intravenous fluid expansion; however, unlike crystalloids, colloids remain intravascular as long as the endothelial barrier remains intact.
- There are two major categories of colloids, natural and synthetic. Natural colloids are blood components including packed RBCs, plasma, platelet-rich plasma, etc. Generally, the primary synthetic colloids used in modern medicine are hydroxyl ethyl starches (HES). The two most common HES products used in veterinary medicine are Hetastarch® and Vetstarch®. Vetstarch® is the only HES colloid approved for veterinary use.
- There are two principles the general practitioner should understand regarding HES colloids: molecular weight (MW) and C2/C6 substitution ratios. HES colloids are divided into 3 groups according to their average molecular weights: high MW (>400 kDa); medium MW (200-400 kDa); and low MW (<200 kDa) solutions. The molecular weight determines duration of action, the larger the MW the longer the duration of action. The C2/C6 ratio is the ratio of carbon position 2 substitutions to carbon position 6 substitutions. The C2/C6 ratio determines the adverse side effects. The larger the C2/C6 ratio the greater the coagulopathic potential. An ideal HES product would be one with a large MW (long DOA) and small C2/C6 ratio (fewer side effects). Unfortunately, the MW of the product mirrors the C2/C6 ratio. Larger MW products have larger C2/C6 ratio and vice versa for smaller MW products.
  - Hetastarch®: 450/0.7 (MW = 450 kDa, C2/C6 ratio = 0.7)
  - Vetstarch®: 130/0.4 (Mw = 130 kDa, C2/C6 ratio = 0.4)

- Indications for colloid administration include hypovolemia, hypoalbuminemia, and hypotension. Because HES colloids are large molecules, similar to albumin, they tend to remain in the vascular space adding to the colloidal oncotic pressure. Administration of HES will contribute its own volume, plus a third of its volume in water drawn from the interstitial space, to the total blood volume. Some practitioners prefer to use HES plus a crystalloid combination (50:50), which can be very effective for rapid IV volume loading. Another option, which provides even more rapid vascular expansion, is HES plus hypertonic saline.
- HES can be used as the primary fluid therapy in hypoalbuminemic patients during general anesthesia with or without crystalloids. HES can also be given as intermittent IV boluses to help mitigate hypotension.
- Coagulopathies are the primary, adverse effects of HES products dictated by the C2/C6 molecular substitution ratio. All HES products have the potential to inhibit the Von Willebrand factor (vWF) and factor VIII resulting in platelet dysfunction, or type 1 Von Willdebrand-like syndrome. Because of these concerns, an anecdotal, maximum dose HES colloids of 20 ml/kg/day was established for human patients. Veterinary medicine simply borrowed this dose and
applied it to animal patients. Based on the principle of the C2/C6 molecular substitution ratio, an across-the-board, “maximum” dose for all HES products in all patients does not make medical sense. In addition, multiple studies have demonstrated the coagulopathic effects of HES products are clinically irrelevant unless the patient has a preexisting coagulopathy (vWD in Doberman Pinschers).

- Recently, there have been concerns with the administration of HES in human, septic patients, which resulted in acute renal failure. Although there has not been a cause and effect established, the FDA has issued a warning regarding HES use in humans with septicemia. Acute renal failure associated with HES use in septic veterinary patients has NOT been documented. The FDA warning does NOT apply to veterinary medical practice.
- Acute fluid overload, especially in cardiac patients, can occur when colloids are administered rapidly in large volumes. Care should be taken when using colloids (any IV fluids) in patients with known cardiac disease.

**Mitigating hypotension during anesthesia in the small animal patient**

- Most organ systems in the body autoregulate their own blood perfusion within a systemic mean arterial pressure (MAP) range of 60 – 150 mmHg. Outside this range blood perfusion autoregulation becomes a product of systemic blood pressure. When MAPs fall below 60 mmHg, the risk of tissue ischemia increases.
- The number one cause of hypotension in anesthetized veterinary patients is excessive anesthetic depth. Having one person dedicated to monitoring the anesthetized patient and who understands how to assess depth of anesthesia is essential for safe anesthetic practice.
- Bradycardia can contribute to hypotension because CO is a function of HR X SV. Several factors contribute to bradycardia during general anesthesia, including hypothermia and the pharmacodynamics of anesthetic drugs. Patients should be kept warm (> 97 °F) during general anesthesia, and an anticholinergic can be administered to help treat bradycardia resulting from high vagal tone.
- Absolute hypovolemia results in systemic hypotension. Ongoing surgical blood loss should be treated with IV fluid administration, including crystalloids and colloids. Extensive hemorrhage (> 20% patient blood volume) can be managed with IV hypertonic saline, HES, and crystalloids until replacement blood therapy can be conducted.
- One cause of relative hypovolemia is systemic vasodilation and/or depressed myocardial contraction. It is advisable to secure adequate blood volume (rule out absolute hypovolemia) before treating hypotension pharmaceutically. Systemic vasodilatation can be treated with a vascular pressor agent (ephedrine, dopamine, vasopressin), whereas depressed myocardial contractility can be treated with a positive inotrope (dobutamine).

**References**


Intermittent positive pressure ventilation using mechanical ventilators has not been used traditionally in veterinary practice. Modern mechanical ventilators have become more affordable and easier to operate, allowing an increase use in clinical practice. Understanding the mechanics, function, and physiological effects of mechanical, intermittent, positive pressure ventilation is necessary in order to safely, and effectively, ventilate anesthetized veterinary patients.

Terminology and physiology
- Minute ventilation (VE) = Respiratory rate (f) X Tidal volume (TV).
- Under normal physiological conditions PCO2 dictates minute ventilation (Ve). Oxygen has little effect on Ve unless the PO2 falls below 60 - 70 mmHg.
- CO2 crosses the blood brain barrier where it combines with water in the CSF. Carbonic anhydrase in the CSF facilitates the formation of carbonic acid which then dissociates into hydrogen and bicarbonate ions. The hydrogen ions then interact with the chemoreceptors of the dorsal respiratory group:
  \[ \text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^- \]
- Hypoventilation is synonymous with increased PCO2 whereas hyperventilation is synonymous with decreased PCO2.
- With increased PCO2, respiratory drive will increase, with decreased PCO2, respiratory drive will decrease.
- IPPV = intermittent positive pressure ventilation, PIP = peak inspiratory pressure, PEEP = positive end expiratory pressure
- There are many ways one can control ventilation with anesthetized patients: the reservoir bag, a demand valve, or a mechanical ventilator to name a few.

Indications for controlled ventilation
- Hypoventilation: Hypercapnea, drug induced respiratory depression, trauma, disease, and others.
- Poor oxygenation: Five causes of hypoxemia include: low fraction/pressure of inspired oxygen; inadequate VT; O2 diffusion impairment; ventilation to perfusion mismatch (V/Q mismatch), and pulmonic/anatomic cardiac shunt.
- Depth of inhalant anesthesia: Anesthetized patients, while breathing anesthetic vapors spontaneously, cycle naturally between levels of light and deep planes of general anesthesia. Controlled ventilation provides a constant rate of inhaled anesthetics, thus eliminating the variability of inhalant general anesthesia.
- Surgeries that involve the loss of negative pressure and mechanical tethering between the visceral and parietal pleurae require intermittent positive pressure ventilation.
- Specific pulmonary diseases require assisted ventilation during general anesthesia, examples include: chest trauma, diaphragmatic hernia repair, severe alveolar diseases, and pleural diseases.
- Patients with conditions that may significantly limit VT, such as pregnancy or obesity, should receive ventilatory support during general anesthesia.
- In reality, indications for controlled ventilation are not always well defined. Ventilators are useful tools during general anesthesia, however; they should be used according to each patient’s individual and should never replace human intervention. Always monitor patients under general anesthesia receiving mechanical ventilation closely. Mechanical ventilators can induce serious patient pulmonary damage, even death, if not set-up and monitored correctly.

Controlled ventilation
- Mechanical ventilation is based on Ve, which is function of f X VT
- Adjustment of Ve requires changes in ventilation frequency and or volume.
- Volume mode: Volume mode ventilator will deliver a controlled volume of gas (patient’s VT), regardless of the peak inspiratory pressure. The variable factor is pressure. Small animal patient VT is approximately 10-20 ml/kg. Most anesthetic mechanical ventilators are set volume mode or have a volume mode option. During long periods of mechanical ventilation volume mode ventilators can cause pathological changes to the pulmonary tissues.
- Pressure mode: Pressure mode ventilator will deliver a volume gas until a set pressure is reached. The variable factor is volume. Most mechanical ventilators that have pressure mode also have volume mode option. Pressure mode ventilation causes fewer pathologic changes to pulmonary tissues than volume mode ventilation.
• Time-cycled ventilation: Despite volume vs. pressure mode ventilation, almost all mechanical ventilators are time-cycle controlled based on respiratory frequency (breaths per minute). Typically, timing is controlled electronically.

**Basic anatomy of an anesthesia mechanical ventilator**
• Most anesthetic mechanical ventilators have two gas sources. The driving gas is any type of high pressure gas that drives the bellows, from outside, thus pushing (positive pressure) the tidal volume into the patient (compressed O2, medical gas, N₂, CO₂). Maximum pressure of the driving gas should not exceed 50 psi. The breathing system gas is on the inside of the bellows and is continuous with the patient’s breathing circuit. Remember, the driving gas and breathing gas are two, separate gases and should not mix.
• Bellows. Most anesthetic mechanical ventilators use a bellows to push the breathing gas VT into the patient. Bellows are classified as ascending or descending, based on the direction the bellows move during exhalation.
• Control panel. Anesthetic mechanical ventilators have a control panel that allows adjustment of patient VT, breathing frequency, and sometimes I:E ratios.
• Scavenging system. Because the inside of the ventilator bellows is continuous with the patient’s breathing gases, the ventilator attaches to the anesthetic machine scavenging system for evacuation of waste gases.
• Connecting hose and wall plug-in. Anesthetic mechanical ventilators have a hose that connects to the high pressure gas driving the bellows. The hose should be color-coded according to the driving gas; for example, oxygen is green, and medical air is yellow.

**Capnography**
• Under normal physiological conditions the primary indication for mechanical ventilation during general anesthesia is patient CO₂. There are two ways to monitor patient PCO₂: arterial blood gas analysis and/or end-tidal PCO₂ (PETCO₂, capnography). Although arterial blood gas analysis is more accurate, it is also expensive and impractical. Capnography provides a useful, and practical, means to monitor patient PCO₂, and is recommended for all anesthetized patients undergoing mechanical ventilation under general anesthesia.
• There are two categories of capnographs: main-stream, which analyzes the patient’s exhaled breath adjacent to the endotracheal tube, and side-stream, which removes a sample of the patient’s breath and delivers it to an analyzer away from the patient.
• Capnography is based on the principle that end-tidal exhaled PCO₂ (PETO₂) is roughly equal to pulmonary arterial PCO₂ (PaCO₂).
• Graphical illustration of the PETCO₂ over time is called a capnogram. Capnograms are useful for visually monitoring an anesthetized patient’s PCO₂ and other problems that can develop, such as a leak in the breathing system.

**Final considerations**
• A patient’s delivered VT should be set according to a desired PIP and PETO₂ rather than to the calculated VT.
• Maximum PIP for small animal patients is 20 cm H₂O; otherwise, barotrauma could occur to the patient’s pulmonary tissues (alveoli).
• IPPV causes a decrease in mean arterial pressure due to a reversal of the physiological thoracic blood pump.
• Positive end-expiratory pressure can be used to help facilitate oxygenation via maintaining opened alveoli.

**References**
Local and regional anesthesia are common practices in large animal veterinary medicine. In the past, locoregional techniques have been underutilized in small; however, recently there has been a surge in their use with small animal practice.

Most common locoregional anesthetic techniques used for large animal surgery can also be adapted to small animals.

A good understanding of basic anatomy, pharmacology of local anesthetic drugs, and patient physiology is essential in order to safely, and effectively, utilize local and regional anesthetic techniques.

Combining local and regional anesthetic techniques with parenteral analgesics can provide small animal practitioners more flexibility and better options for pre-, intra- and post-operative pain management.

Physiology of and concepts regarding pain

- Acute pain is considered a normal, healthy, and protective physiological response to noxious stimuli. Chronic, centralized pain, or wind-up pain, is considered a pathological, abnormal expression of pain.
- The dose of general anesthetics needed to abolish the effects of nociception is close to that which can abolish autonomic responses. High doses of general anesthetic drugs significantly depress the cardiovascular, respiratory, and thermoregulatory systems in the body. Analgesic modalities before, and during, surgery help decrease the dose of general anesthetics needed to provide immobility without loss of autonomic tone.
- Transduction: Mechanical, chemical, or thermal injury is converted to an electrical impulse by Aβ (quick pain) and C nociceptors (slow pain).
- Transmission: The noxious electrical impulse is transmitted from the periphery to the spinal cord via Aβ and C sensory neurons. The synapse between the sensory neurons and the spinal cord occurs at lamina II (substantia gelatinosa) in the dorsal spinal horn.
- Primary (spinal) modulation: Within the spinal cord the afferent, noxious sensory impulse undergoes initial analysis. The spinal cord upgrades or downgrades the severity of the noxious stimulus and communicates that information to the brain. An unconscious reflex arc is the result of primary (spinal) modulation.
- Projection: After primary modulation, the noxious information is then projected to the brain via several tracts: two examples are the spinocervicothalamic (fast pain) and spinoreticular (slow pain) tracts.
- Secondary (cerebral) modulation: Within the conscious brain noxious afferent input is perceived as pain. Unconsciousness (anesthesia) blunts, or abolishes, secondary nociceptive modulation.
- Animals and humans share similar anatomical and physiological nociceptive structures for the production, conduction, and modulation of pain.
- Pain assessment in animals is based on anthropomorphic comparisons, subjective, and objective criteria.
- Pain is the conscious perception of nociception. Nociception is the physiological processes that involves the conversion of a noxious stimulus to an electro-chemical impulse and modulation in the CNS.
- The perception of pain does not occur during general anesthesia; however, without analgesic modalities the process of nociception still occurs, which can lead to centralized, or wind-up pain.
- Providing analgesics before surgery is called pre-emptive analgesia. Studies have shown that preemptive analgesia significantly decreases the likelihood of hypersensitivity associated with surgical pain.
- Preventive analgesia is a term that describes a comprehensive pain control plan that includes pre-, intra- and postoperative therapies. Preventive analgesia has been well established in human medicine but not yet in veterinary medicine.

Local and regional anesthetic techniques in small animal practice

- Lidocaine and bupivacaine are the most common local anesthetics used in small animal practice.
- Local anesthetics are fast-sodium channel blocking agents. In their bottles local anesthetics are acidic and inactive. When injected into the body (comparatively alkaline), the local anesthetic molecules dissolve into HCl salts and active bases. The active bases diffuses across the nerve epineurium and cell membrane into the cytoplasm and block sodium channels.
Toxic effects of local anesthetic depend on the drug. Lidocaine causes dose-dependent neuro- and cardio-toxic effects. Bupivacaine has potent cardio-toxic effects. Inadvertent intravenous injection of local anesthetics must be avoided; therefore, always aspirate before injecting.

Most locoregional anesthetic techniques can be performed blindly; however, a peripheral nerve locating device (nerve stimulator) can help increase the success and safety of the procedures.

Quincke needles are designed specifically for locoregional techniques. Quincke needle bevels are blunter which allows for a better feel as the needle dissects through tissue planes.

Common regional techniques for dental procedures include mental, infra-orbital, maxillary, and mandibular nerve blocks. Auriculopalpebral and the greater auricular nerve blocks can be useful for procedures involving the ear such as, ear flushes and surgery.

The brachial plexus infiltration block can be used for surgeries involving the distal forelimb. A carpal ring block can be used for surgeries involving the forepaw such as declaws and digit amputations.

Lumbosacral epidural regional techniques are very useful for surgeries involving the hips and distal rear legs. The most common drugs used for lumbosacral epidurals is the combination of preservative free (PF) morphine and PF bupivacaine. Feline lumbosacral epidurals using PF morphine and PF bupivacaine can be done also; however, it is important to remember the feline spinal cord ends at S1 compared with the canine spinal cord, which ends at L5-6.

Caudal epidural techniques can be used to provide regional anesthesia during perineal surgeries and facilitate urethral relaxation for catheter placement in blocked male cats.

Infiltration catheters (soaker catheters) have manufactured fenestrations at their distal ends so that, when buried in the surgical wound, local anesthetics can be injected into the tissues providing a field of anesthesia.

References
Acute Pain Management: Pharmaceutical Options
Andrew Claude, DVM, DACVAA
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- Systemic analgesic drugs are the mainstay of small animal veterinary pain management.
- Options regarding parenteral analgesics in small practice are often governed by cost and clinician experience.
- Utilizing the same analgesic drugs, regardless of the surgical procedures, is not good analgesic case management. Having a good understanding of a variety of analgesic options, for dogs and cats, can be a valuable addition to help expand clinical practice.

Rules of thumb
- Animals share similar anatomical and physiological nociceptive properties as humans; therefore, animals likely have similar pain experiences as humans.
- Pain in animals is difficult to quantify and evaluation is based on a combination of objective and subjective anthropomorphic attributes.
- Pain is the conscious perception of nociception. General anesthesia abolishes consciousness; therefore, pain is not perceived during general anesthesia. Nociception is the physiological process by which a noxious stimulus is transduced into an electro-chemical impulse and carried to the central nervous system. Nociceptive, physiological processes continue to occur during general anesthesia unless analgesics are employed.
- According to the Veterinarian’s Oath, veterinarians have an obligation to prevent and relieve animal suffering, including pain.
- If there is a suspicion an animal patient is painful, it is better to treat for pain than to ignore the concern.

Concepts regarding nociception and pain management in veterinary patients
- Transduction: Mechanical, chemical, or thermal injury is converted to an electrical impulse by Aβ (quick pain) and C nociceptors (slow pain).
- Transmission: The noxious electrical impulse is transmitted from the periphery to the spinal cord via Aβ and C sensory neurons. The synapse between the sensory neurons and the spinal cord occur at lamina II (substantia gelatinosa) in the dorsal spinal horn.
- Primary (spinal) modulation: Within the spinal cord the afferent, noxious sensory impulse undergoes initial analysis. The spinal cord upgrades or downgrades the severity of the noxious stimulus and communicates that information to the brain. An unconscious reflex arc is the result of primary (spinal) modulation.
- Projection: After primary modulation the noxious information is then projected to the brain via several tracts; two examples are the spinocervicothalamic (fast pain) and spinoreticular (slow pain) tracts.
- Secondary (cerebral) modulation: Within the conscious brain noxious afferent input is perceived and translated into pain. Unconsciousness (anesthesia) blunts, or abolishes, secondary nociceptive modulation.
- Providing analgesics before surgery is called pre-emptive analgesia. Studies have shown that preemptive analgesia decreases significantly the likelihood of hypersensitivity associated with surgical pain.
- Preventive analgesia is term that describes a comprehensive pain control plan, which includes pre-, intra-, and postoperative nociceptive therapies. Preventive analgesia has been well established in human medicine but not yet in veterinary medicine.
- Analgesic drugs help reduce/abolish pain by interfering with the nociceptive process(es).
- The dose of general anesthetics needed to produce unconsciousness is far less than what is required to abolish the effects of nociception. The dose of general anesthetics needed to abolish the effects of nociception is close to that which can abolish autonomic responses. High doses of general anesthetic drugs significantly depress the cardiovascular, respiratory and thermoregulatory systems in the body. Analgesic modalities before, and during, surgery help decrease the dose of general anesthetics needed to provide immobility without loss of autonomic tone.
- A pre-emptive pain scale evaluation can help the clinician formulate a patient’s analgesic therapy plan. A pre-emptive pain scale is a subjective pain assessment done pre-operatively based on the anticipated degree of pain. Analgesic drug potency, dose, and frequency of administration can be tailored according to the pre- and post-operative pain evaluation.
Parenteral analgesics in veterinary small animal practice

- Common concerns with parenteral analgesic drugs in small animal practice include unwanted sedation, extra expense, controlled drug issues, unpredictable results, drug knowledge of the attending veterinarian, and client compliance.
- Opioids are the primary parenteral analgesic used for human and veterinary surgery. Mu agonist opioids are an excellent choice to help provide effective pre- intra- and post-operative pain relief for animal patients. There are many mu agonist opioid drugs available, including opioid products that are absorbed transdermal.
- Butorphanol, a mu antagonist, kappa agonist opioid, has limited analgesic capabilities and a short duration of action. Butorphanol should not be considered a primary analgesic for surgical pain, especially in dogs.
- Buprenorphine is a partial mu agonist opioid, has a good analgesic profile, and long duration of action for both dogs and cats.
- NSAIDs relieve pain via their anti-inflammatory abilities making them extremely versatile analgesic drugs. There are many NSAID options for both dogs and cats; however, judicial use of these drugs should be limited to normal, healthy patients. Contraindications for NSAID include concurrent steroid administration, concurrent other NSAIDs, renal and hepatic diseases, gastrointestinal diseases, coagulopathies, pregnancy, dehydration, and other circulatory diseases.
- Common, and effective, adjunctive analgesic choices include lidocaine, ketamine, and alpha 2 agonists.

References
The pharmacokinetic and pharmacodynamic effects of anesthetic and analgesic drugs differ between dogs and cats. Cats are NOT small dogs.

Unfortunately, analgesic options for feline patients are limited compared with analgesic options for canine patients.

Important points regarding feline patients
- Due to feline aloof behavior, it can be difficult for clients to notice subtle changes with their cat’s health. Cats typically do not show obvious signs of pain; instead, they become withdrawn and hide.
- Generally speaking, feline responses to anesthetic and analgesic drugs are unpredictable compared with canine responses.

Physiology of nociception and feline pain
- Transduction: Mechanical, chemical, or thermal injury is converted to an electrical impulse by Aβ (quick pain) and C nociceptors (slow pain).
- Transmission: The noxious electrical impulse is transmitted from the periphery to the spinal cord via Aβ and C sensory neurons. The synapse between the sensory neurons and the spinal cord occurs at lamina II (substantia gelatinosa) in the dorsal spinal horn.
- Primary (spinal) modulation: Within the spinal cord the afferent, noxious sensory impulse undergoes initial analysis. The spinal cord upgrades or downgrades the severity of the noxious stimulus and communicates that information to the brain. An unconscious reflex arc is the result of primary (spinal) modulation.
- Projection: After primary modulation, the noxious information is then projected to the brain via several tracts: two examples are the spinocervicothalamic (fast pain) and spinoreticular (slow pain) tracts.
- Secondary (cerebral) modulation: Within the conscious brain noxious afferent input is perceived as pain. Unconsciousness (anesthesia) blunts, or abolishes, secondary nociceptive modulation.
- Providing analgesics before surgery is called pre-emptive analgesia. Studies have shown that preemptive analgesia significantly decreases the likelihood of hypersensitivities associated with surgical pain.
- Preventive analgesia is term that describes a comprehensive pain control plan which includes pre-, intra- and postoperative therapies. Preventive analgesia has been well established in human medicine but not yet in veterinary medicine.
- The Brondani multi-dimensional composite feline pain scale was recently validated for the English language. Before the Brondani feline pain scale there was no validated pain scale for cats.
- Pain is not always considered a major component of many feline diseases. Saddle thrombosis, for example, is a clinical condition secondary to feline cardiac disease and causes extensive, acute ischemic muscle pain. Regardless of the disease, pain evaluation, and therapy, should always be part of the clinical plan.
- Identifying pain in cats can be difficult. Cats do not outwardly express pain. Sometimes an owner noticing a change in his or her cat’s behavior is the only indication of discomfort. Clinical signs of acute pain in cats include a tucked or crouched posture, reluctance to move, ears facing forward, focused eyes, lip licking, guarding, and purring.

Analgesic options for feline patients
- Opioids are considered the backbone of analgesia in both human and veterinary medicine. Mu agonist opioids have been known to cause opioid-related hysteria (dysphoria) and hyperthermia in cats. Although both conditions merit concern their clinical relevance is questionable and both can be reversed using naloxone. Morphine and hydromorphone are mu agonist opioids that are most likely to cause side effects in cats whereas oxymorphone, methadone, and fentanyl are the least likely.
- Butorphanol is a mu antagonist, kappa agonist opioid and has good effects in cats; however, its duration of action is only 30 – 45 minutes.
- Buprenorphine is a partial mu agonist opioid and, in cats, provides excellent analgesia for up to 6 to 8 hours in cats.
- Alpha 2 agonists provide both sedation and analgesia. Dexmedetomidine is an excellent major tranquilizer for cats because it provides predictable results, good analgesia, can be combined with other drugs, and is the choice tranquilizer for cats with hypertrophic cardiomyopathy (HCM).
• Dissociative NMDA antagonists (ketamine, tiletamine) also provide consistent sedation and analgesia in cats; however, this family of major tranquilizers is contra-indicated in cats with HCM.

• NSAIDs are good analgesic choices in healthy cats. It is recommended practitioners administer these drugs judiciously, monitor their patients closely, and communicate to their clients regarding potential adverse side effects from NSAIDs.

• In addition to parenteral analgesics, locoregional techniques can be extremely valuable when used for pain management in cats. Examples of common locoregional procedures in cats include nerve blocks of the mouth and eyes, brachial plexus blocks, forepaw and rear-paw ring blocks, and lumbosacral and caudal epidurals.

References
Neonatal, Pediatric, and Geriatric Anesthesia
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- Neonates are not considered routine candidates for veterinary anesthesia. Due to their size and anatomical and physiological differences, puppies and kittens be challenging to anesthetize safely.
- Early spays and neuters before adoption is a common practice, and knowledge regarding pediatric physiology and pharmacokinetics of anesthetic drugs is essential for successful anesthesia.
- Like us, our pets are living longer. Although most of the customary principles of veterinary general anesthesia are applicable to geriatric patients; there are important differences that should be considered.

Definitions: neonatal, pediatric puppies and kittens
- In humans, the neonatal period is from birth to 4 weeks and the pediatric period is 4 weeks to approximately 2 years old. Adults are considered twenty years and older.
- In small animal veterinary medicine, puppies and kittens are considered neonates from birth to 2 to 4 weeks old, and pediatric patients are 4 to 8 weeks old. Beyond 8 to 12 weeks, puppies and kittens are considered young adults.

Physiological differences of neonatal and pediatric small animal patients.
- Respiratory system: Neonatal puppies and kittens have a greater prevalence of upper airway obstruction due to their large tongues and small airway openings. As they age and tissues grow, these unique anatomical challenges improve in most species except in brachycephalic breeds.
- Rapidly growing puppies and kittens have a high oxygen demand; therefore, they require a high minute ventilation compared with adults. Their tidal volume and functional residual capacity are fixed; therefore they depend on respiratory frequency to meet metabolic oxygen demands. Respiratory control and autonomic responses are immature and easily depressed by anesthetic drugs. Puppies and kittens under the age of 8 weeks old are highly susceptible during anesthetic procedures to apnea and hypoxia.
- Cardiovascular system: Neonates and puppies/kittens (<8 – 12 weeks old) depend on HR to alter cardiac output. They have limited ability to adjust their myocardial contractility, thus stroke volumes are fixed. Unfortunately, they are also prone to bradycardia due to immature sympathetic responses and susceptibility to hypoxemia. Because of their immature vascular and autonomic systems, they cannot rely on vascular tone to help regulate mean arterial pressures (MAP) or tissue perfusion. Neonatal and pediatric blood pressure is almost entirely a function of cardiac output.
- Bottom line: Neonatal and pediatric puppies and kittens require oxygen supplementation and ventilation support, whereas bradycardia should be avoided during general anesthesia.
- Hematopoiesis: Neonatal and especially pediatric puppies and kittens under 12 weeks old, do not tolerate blood loss. Hematopoiesis does not begin effectively until approximately 12 weeks of age and fetal hemoglobin is rapidly being removed, making these young patients highly susceptible to anemia. Adult small animal patients can tolerate up to a 20% surgical blood loss, while neonatal and pediatric patients are limited to a loss of 4%.
- Renal and hepatic systems: Although neonatal, pediatric puppy/kitten kidneys and livers are anatomically developed, they are immature functionally until 8 to 12 weeks of age. Their ability to biodegrade anesthetic drugs is slow, resulting in rapid pharmacodynamic effects and slow recoveries. Their renal function, fluid balance, and ability to concentrate urine are undeveloped, making these young animals susceptible to dehydration and intolerant of excessive fluid administration. Glycogen production and storage are inadequate making them susceptible to hypoglycemia.
- Thermoregulation: Neonatal and pediatric small animal veterinary patients have a high surface area with underdeveloped ability to thermoregulate. Severe hypothermia is of great concern during general anesthesia in small patients and may cause brady-arrhythmias, delayed recoveries and possibly death.

Anesthetic considerations for neonatal and pediatric small animal patients
- Do not fast neonatal and pediatric patients before anesthesia; otherwise, there is a risk of hypoglycemia. The current recommendations are to allow the baby to nurse or feed until anesthesia for patients < 6 weeks old, withhold food no more than 2-3 hours for 6 to 8 week olds, monitor blood glucose at least every 30 to 60 minutes, and administer IV 2.5% dextrose if blood glucose drops below 80-100 mg/dl.
- Anesthetic drugs will produce profound effects and last longer in neonatal and pediatric veterinary patients. Use injectable and premedications judiciously. More often it is better to mask induce neonatal patients, intubate, and place an IV catheter without using premedications.
• When using injectable drugs, it is recommended to avoid those known to have slow half-lives and require extensive biodegradation (acepromazine for example). Water soluble, short acting drugs, with known antagonists (midazolam, methadone, butorphanol, for example), at lower doses are better choices. Due to the risk of marked bradycardia and decrease cardiac output, alpha two agonists are not recommended in puppies and kittens under 8 weeks old.
• Avoid blood loss and use caution when administering IV fluids so as to not overload delicate cardiovascular systems.
• Monitor heart rate, ventilation, and oxygenation, body temperature, and blood glucose closely during general anesthesia. Employ external warming devices and bubble wrap extremities to help maintain body temperatures near normal.
• Post-operative care should include supplemental oxygen and heat, monitor blood glucose, and supplemental dextrose, as needed, and provide appropriate analgesics.

Definitions: geriatric dogs and cats
• Dorland’s Medical Dictionary (27th ed.) defines geriatric as “old age” or elderly. Most people consider human geriatrics as 65 years old because Medicare eligibility begins. Technically, there is no specific age that defines “geriatric” in humans.
• Dogs that have lived 75 – 80% of their lifespan are considered geriatric, which for small breeds is greater than 10 years old, large breeds 6 – 10 years old.
• Cats are considered geriatric when they are 12 years old and older.

Important considerations for veterinary geriatric anesthesia patients
• Increased age is NOT equivalent to increased risk of general anesthesia unless there are concurrent disease processes. Brodbelt, et al., estimated the risk of anesthetic depth increased up to 7 times for veterinary geriatric patients greater than 12 years old.
• Biological and physiological age is more important than chronological age when considering anesthesia in older patients.
• Geriatric veterinary patients have blunted homeostatic responses, including autonomic and somatic reflexes.
• Underlying disease processes and urgent care should be treated before commencing to general anesthesia.

Physiological/pharmacological considerations for veterinary geriatric anesthesia patients
• Due to decreased metabolic demand, minute ventilation and cardiac output are reduced. The geriatric pulmonary system is less compliant, resulting in an increased work of breathing. Assisted ventilation during general anesthesia is recommended.
• Increased age results in a greater influence of vagal tone and reduced cardiac sympathetic responses. Myocardial and/or degenerative cardiac changes are seen more frequently in elderly veterinary patients, including valvular endocardiosis in small breed dogs and HCM in hyperthyroid cats.
• Although renal and hepatic organ systems continue to work sufficiently in older patients, with age there is a gradual loss of functional capacity. It is advisable to include a CBC and plasma chemistries as part of the pre-anesthetic work-up with geriatric patients. Decreased cardiac output results in decreased hepatic blood flow, which can lead to prolonged drug metabolism and slower patient recoveries.
• Geriatric veterinary patients generally handle most anesthetic drugs and protocols without concern. Clinical differences include increased sensitivities to anesthetic drugs, decreased MAC of inhalant anesthetics, and prolonged recoveries. The exact cause of increased sensitivities to anesthetic drugs seen with geriatric patients is unknown.
• Anesthetic drug recommendations for veterinary geriatric anesthesia patients include lower drug doses and use of short acting, water soluble anesthetic drugs that have known antagonists. Examples of anesthetic drugs used commonly with geriatric veterinary patients include benzodiazepines, opioids, propofol, alfaxalone, isoflurane, sevoflurane, and others.
• Low doses of alpha two agonists are safe to use in geriatric dogs with normal cardiac function. Dexmedetomidine is the drug of choice for elderly cats with HCM; however, ketamine should be avoided.
• Geriatric patients have a higher risk of cognitive dysfunction, which may make them more susceptible to emergence delirium and confusion during anesthesia recovery.
• Judicial dosing of Tramadol is necessary for geriatric patients receiving serotonin/norepinephrine uptake, or MAO inhibitors (selegiline), to avoid serotonin syndrome.

References
Postanesthetic Care of Small Animal Patients
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- The recovery period is not always regarded as a vital component of an anesthetic procedure.
- In veterinary anesthesia the majority of adverse events occur during recovery.

Anesthetic recovery
- Anesthetic recovery is the interval from the cessation of anesthetic drug delivery to the point at which the patient is extubated and has voluntary motor control.
- Factors that affect the length of recovery include patient health, length of the anesthetic procedure, anesthetic protocol, and patient, post-anesthetic body temperature.
- According to a Brodbelt, et al., study in 2007, greater than 50% of the canine and feline anesthetic related adversities occur during recovery.
- Thorough planning of the anesthetic event, anticipating problems, and keeping good anesthetic records during the pre-, intra-, and post-operative periods is essential.
- All anesthetic patients have the potential for poor recoveries. Difficult anesthetic recoveries can be due to multiple factors, including emergence delirium, dysphoria, inadequate analgesia, and general patient discomfort. In these cases, it is often advisable to delay the recovery to avoid further stress or injury to the recovering patient.

Anesthetic recovery: patient monitoring
- In the 2008, Brodbelt, et al., article, the authors speculated that inadequate patient monitoring may have been the primary factor behind anesthetic recovery periods being over represented by increased mortality rates in small animal anesthetic procedures.
- Anesthetic monitoring should NOT end at recovery; instead, it should continue until the patient is extubated and has returned voluntary muscle control.
- The degree of monitoring, and parameters evaluated, depend on the procedure performed and the patient’s health. Patient monitoring should include at least cardiovascular and respiratory status, body temperature, analgesia, and patient (dis)comfort. Post anesthetic, patient monitoring parameters should be included within the patient’s anesthetic records.

Anesthetic recovery: extubation
- Indications for patient intubation include decreasing the risk of aspiration, securing the patient’s airway, and providing a means for assisted ventilation. Patient intubation should be included with any procedure that involves a level of sedation or anesthesia in which the patient has lost motor control and therefore the ability to guard the larynx.
- Extubation should be performed when the recovering patient has regained laryngeal or pharyngeal sensation and reflexes, such as gagging, swallowing and chewing.
- Brachycephalic breeds have an increased risk of post-extubation, upper airway obstruction. During sedation and anesthesia excessive peri-laryngeal tissues and hypoplastic tracheas predispose these patients to pharyngeal obstruction. Ventilatory function should be monitored closely with brachycephalic breeds during pre-operative sedation and post-operative recovery, and it is prudent to have induction agent, a laryngoscope, and an endotracheal tube immediately available in case of upper airway obstruction.

Anesthetic recovery: other breed/species issues
- Alaskan malamutes, Siberian huskies and Labrador retrievers have a genetic polymorphism that predisposes these breeds to a high incidence of opioid-related dysphoria. Problems related to opioid use in those breeds tend to be individualistic; however, it is advisable to use lower doses, especially in Nordic breed dogs. Opioid dysphoria in any breed (or species) can be reversed using naloxone.
- Post-anesthesia related feline blindness (deafness) was reported as early as 2001. Unlike the dog, which has two arterial blood supplies to the brain (internal carotid and basilar arteries), cats have only one cerebral blood supply (maxillary artery). Spring-loaded mouth gags, used during procedures requiring mandibular extension (dentals), in cats can result in obstruction of the maxillary arterial blood flow causing cerebral ischemia, central blindness, and/or deafness.
Anesthetic recovery: supplemental oxygen
Post-operative oxygen supplementation is most beneficial in patients with compromised respiratory function, sick patients, obese and pregnant patients, and brachycephalic breeds.

Anesthetic recovery: patient welfare
- Post-anesthetic monitoring goes beyond recording a patient’s physiological and analgesic parameters. Post-anesthetic monitoring, more importantly, includes observing the patient’s general welfare.
- Post-anesthetic patient welfare considerations encompass the entire patient-condition during recovery, including physiological, analgesic, patient comfort, body temperature, and human interaction.
- Human touch and voice have a calming effect on animal patients recovering from general anesthesia. It is important that an individual remain with the recovering animal patient in order to maintain post-anesthetic monitoring and provide patient comfort.

Anesthetic recovery: body temperature
- Post-anesthetic patient hypothermia is the number one complication related to general anesthesia in human and veterinary medicine. The combination of dose dependent depression of the thermoregulatory centers, due to anesthetic drugs, and a cold surgical environment can result in significant loss of body heat.
- In human medicine, the discomfort of post-anesthetic hypothermia and uncontrollable shivering is well documented.
- Hypothermia can predispose to bradycardia, delayed recovery, and post-operative shivering.
- It is imperative to mitigate patient hypothermia throughout the entire anesthetic event, including recovery, by employing external heat sources such as warm water circulating blankets and forced warm air blowers.
- Intra- and post-operative patient hyperthermia is uncommon in veterinary medicine. Primary causes of anesthesia-related hyperthermia in animal patients include preoperative fever and iatrogenic sources such as excessive external heating.
- Malignant hyperthermia-like syndrome (MH) has not been proven to be a genetic condition in dogs or cats; however, there have been documented cases involving grey hounds and a Siberian husky that demonstrated a clinical condition similar to MH in humans.

Anesthetic recovery: reversal agents
There are times when it is beneficial to reverse anesthetic drugs and hasten recovery; however, judgment is necessary weighing the advantages of drug reversal versus allowing slower recoveries. When reversing the sedative effects of some anesthetic drugs, opioids and alpha 2 agonists for example, analgesic properties will be reversed also.

References
Pain Medication: A Win, Win Situation for You, Your Patients, and Your Clients
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- Historically, it was believed animals did not feel pain or perceived pain differently than did humans. An example of a misconception regarding post-operative pain in animal patients was that pain following surgery benefited animals because it limited movement thus preventing further injury.
- Animals and humans share similar anatomical and physiological nociceptive structures for the production, conduction, and modulation of pain.
- Pain assessment in animals is based on anthropomorphic comparisons, subjective, and objective criteria.

Ethical principles of pain management in veterinary medicine
- The Veterinarian’s Oath states, “...the protection of animal health and welfare, the prevention and relief of animal suffering...” Does the Veterinarian’s Oath still apply today?
- Since recorded history humans have consistently demonstrated a keenness toward domesticking and caring for animals. Unfortunately, the historical relationship between humans and animals is tainted with various forms of animal cruelty.
- Modern biology presented similarities between humans and animals, thus proving animals were not distinct from humans.
- Charles Darwin’s theory of evolution transformed the perception of the relationship between animals and humans.
- In United States, the 1966 Animal Welfare Act and The National Institutes of Health Reauthorization Acts set the stage for social, economic, and legislative actions leading to the modernization of the concept of animal welfare.
- As modern medicine became more scientifically based, pain, although always recognized as an entity of pathology, was difficult to accept because it never completely had a scientific explanation.
- Veterinary medicine was founded originally to benefit the animal agricultural industry and military use of horses. Anesthesia and analgesia were primarily means to help control large animals, protect personnel, and the value of the patient.
- Although human medicine has made tremendous advancements in pain management veterinary medicine still lags behind.
- Society’s views of animal pain and welfare have changed dramatically since the Animal Welfare Act was passed in 1966. Today, society no longer tolerates unnecessary animal suffering. The ease of information from the world-wide internet allows people to self-educate on subjects in pet health and welfare. Clients no longer consider pain management options as a luxury for their pet but instead as a mandatory part of an overall procedure.
- Two primary factors that will contribute to the veterinary industry losing significance in society are refusal to change and refusal to charge. Each one of us, as a representative of the veterinary industry, has an obligation to remain educated regarding pet health issues (including pain management), and be the primary source of information about pet welfare for clients, and clients have an obligation to realize financially the importance of veterinarians’ expertise in the health and welfare of their pets.

References
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