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 colloids 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 Willebrand-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 (epinephrine, dopamine, vasopressin), whereas depressed myocardial contractility can be treated with a positive inotrope (dobutamine).

References