Go With the Flow:
The Basics of Fluid Therapy for Small Animal Veterinary Technicians

Fluid therapy is one of the most common therapies provided in small animal medicine. Patients are given fluids for many reasons, and the number of available fluids is growing. Knowing why fluids are ordered, the goals and limitations of fluid therapy, and how fluids are chosen is a key competency for veterinary technicians. This article reviews some of the reasons fluid therapy may be ordered for a patient, how to administer and monitor fluid therapy, and the fluid types available in the United States.

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BODY WATER COMPARTMENTS

To understand fluid therapy and its applications, one must first understand the distribution of fluid and water in the body (**FIGURE 1**). Total body water (TBW) comprises approximately 60% of a patient's body weight.[1] Approximately 67% of TBW is found inside the body's cells and is referred to as intracellular fluid (ICF). The remaining 33% of TBW is the extracellular fluid (ECF), which is further divided as follows:

- Interstitial fluid, which bathes cells and tissues (~24% of TBW)
- Plasma, the liquid portion of blood, which constitutes most of intravascular volume (~8%–10% of TBW)
- Transcellular fluid, which comprises of synovial joint fluid, cerebrospinal fluid, bile, and the fluid in the linings of the peritoneal cavity, pericardium, and pleural space (~2% of TBW)

A helpful rule of thumb to simplify the distribution of fluids in the body is the 60:40:20 rule: 60% of a patient's body weight is water, 40% of body weight is ICF, and 20% of body weight is ECF.[1]

The body is considered a closed system, meaning that any fluid lost must come from one of the compartments listed above. In the case of hemorrhage, for example, fluid is lost from the intravascular space (i.e., plasma) but also from the ICF in the cells lost (e.g., red blood cells, white blood cells). In addition to losses, fluid can and does move between compartments in a dynamic and ever-changing fashion. When providing fluid support to patients, technicians must keep in mind which compartment needs to be replenished or what derangement needs to be corrected. This knowledge helps guide both fluid choice and the method used to administer fluid therapy.

REASONS FOR FLUID THERAPY

Veterinary professionals provide fluid therapy to patients for many reasons, including correction of dehydration, expansion and support of intravascular volume, correction of electrolyte disturbances, and encouragement of appropriate redistribution of fluids that may be in the wrong compartment (e.g., peritoneal effusion).[2]

The first step in determining whether a patient needs fluid therapy is a full physical examination, including collection of a complete history. The

FIGURE 1. Fluid compartments in the body. Total body water (TBW) is 60% of a patient's body weight and can be thought of as separated into distinct compartments, as represented here.

veterinary staff must assess whether the patient is perfusing its tissues well, check for dehydration, and evaluate losses from any of the fluid compartments.[3]

Inadequate Perfusion

Patients that cannot adequately perfuse their tissues require immediate intervention with fluid therapy to restore perfusion and correct shock. *Shock* is defined as the critical imbalance between the delivery of oxygen and nutrients (carried by blood) to tissues and the tissues' demand for these components. If allowed to persist, this imbalance can lead to acute decompensation and death. Restoring perfusion and, subsequently, oxygen and nutrient delivery to tissues is crucial to survival in these patients.[1]

Shock is a life-threatening emergency and must be recognized and treated immediately on presentation. Patients may present with several clinical signs (**BOX 1**), and owners may report a history of recent fluid loss, such as intractable vomiting, severe diarrhea, or hemorrhage. Once shock is recognized, access to the intravascular compartment must be achieved and fluid resuscitation initiated as soon as possible (see Ways to Provide Fluid Therapy), with the goal of restoring intravascular volume and flow, thus improving perfusion and delivery of oxygen and nutrients to starving tissues (**FIGURE 2**).

Oxygen delivery to the tissues (DO_2) depends on cardiac output and arterial oxygen content. Cardiac output

BOX 1 Clinical Signs of Shock

- Vasoconstriction
  - Pale mucous membranes
  - Prolonged capillary refill time
  - Peripheral temperature < core temperature
  - Reduced urine output
- Decreased mentation
- Tachycardia (cats may present with bradycardia)
- Hypotension (poor pulse quality)
- Reduced oxygen saturation (low SpO_2)
- Lactate >2 mmol/L
- Metabolic acidosis

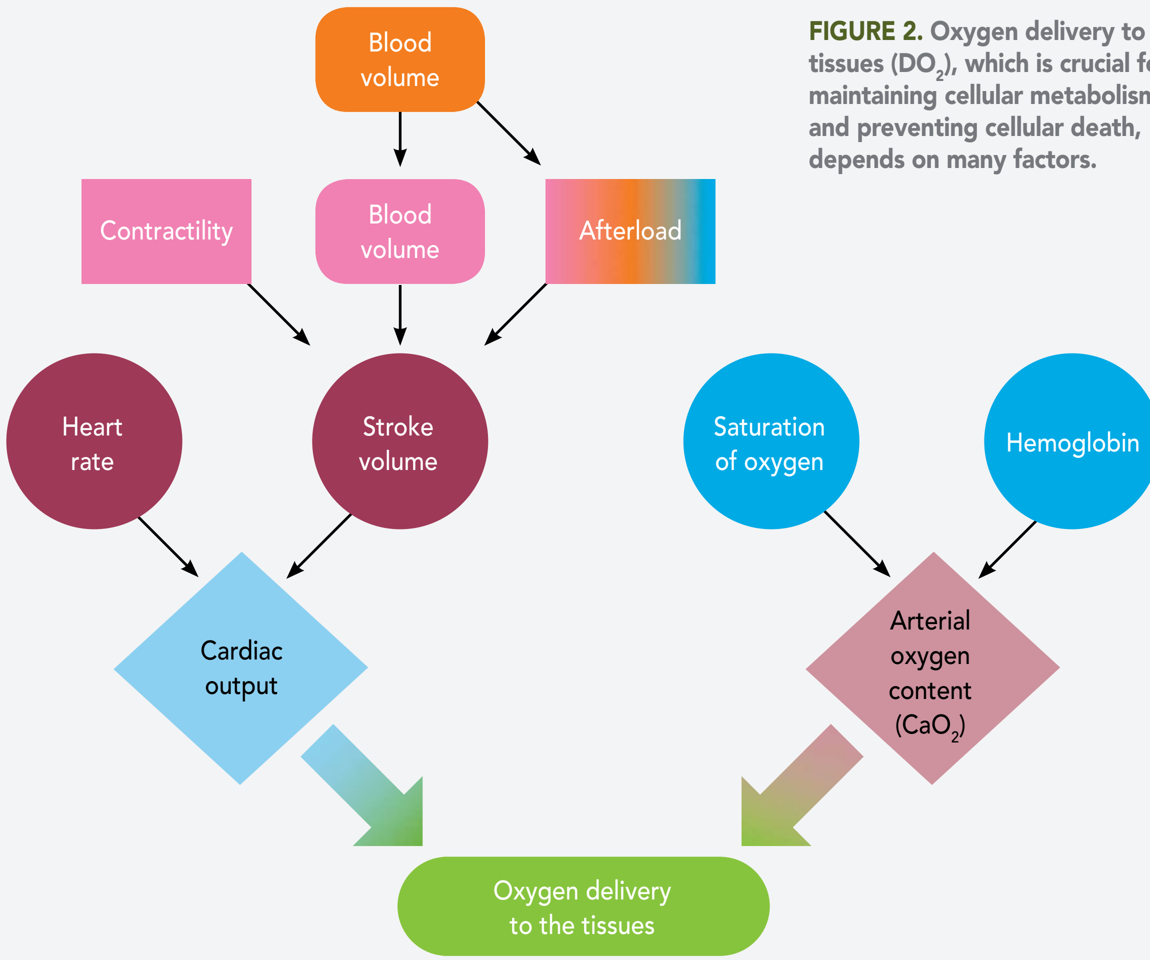

FIGURE 2. Oxygen delivery to the tissues (DO_2), which is crucial for maintaining cellular metabolism and preventing cellular death, depends on many factors.

is the product of stroke volume and heart rate. Stroke volume is defined as the amount of blood ejected from the left ventricle during systole and is a product of preload (the amount of blood entering the heart), afterload (the amount of resistance in the vasculature to the flow of blood from the heart), and contractility (the heart's ability to contract). Once perfusion and, by extension, DO_2 is restored, homeostasis can be reestablished and the shock state will be remedied. Correction of perfusion deficits is demonstrated by normalization of the forward perfusion parameters, listed in **BOX 2**.[1]

Dehydration

Loss of fluid from the intracellular and interstitial compartments leads to dehydration. If severe, dehydration can be detected in derangements in forward perfusion parameters[1] as well as by the tests listed below. Any patient determined to be more than 10% dehydrated is considered severely dehydrated[4] and requires immediate fluid resuscitation and careful monitoring.[5] Dehydration must not be confused with hypovolemia: *dehydration* describes a water deficit in the interstitial and intracellular compartments, whereas *hypovolemia* describes a loss of fluid in the intravascular space.[4]

Hydration status can be assessed using several simple tests. One of the easiest to perform is a skin tent test to check the turgor, or moisture level, of the skin. To perform

BOX 2 Forward Perfusion Parameters

- Heart rate
- Pulse quality
- Respiratory rate
- Mucous membrane color
- Capillary refill time
- Mentation
- Temperature and color of digits

• TECHPOINT •

The skin tent test can be confounded by age, emaciation, and body condition and must be considered in relation to other parameters and physical examination findings.

this test, the skin over the thorax or lumbar region is pulled away from the back. In a well-hydrated animal, the skin immediately returns to its normal resting position. If the tent formed remains standing, it can be an indication of dehydration.[1,5] When performing this test, veterinary technicians can often appreciate a "tacky" or "sticky" feeling in the underlying tissue, which is further evidence of dehydration. The skin tent test can be confounded by both emaciation (decreased turgor even if euhydrated) and obesity (increased turgor in the face of dehydration) and must be considered in relation to other parameters and physical examination findings. Age is another factor to consider: loss of skin turgor progresses with increasing age, and neonates exhibit very little skin tenting even when dehydrated.

Another way to check for dehydration is to feel for moistness on the mucous membranes. This is most easily accomplished by sliding a finger along a patient's gum line or inside the cheeks. If the membranes themselves are dry or sticky, it may indicate dehydration. In the case of vomiting animals, it is necessary to differentiate excess saliva in the mouth from mucous membrane moisture.

In patients with normal kidney function, oliguria can indicate dehydration, and the small amount of urine produced will likely be concentrated (urine specific gravity [USG] >1.030).[5] Other laboratory parameters that change with dehydration include packed cell volume and total protein (PCV/TP) levels, which demonstrate hemoconcentration (high PCV) and hyperproteinemia (high TP) in dehydrated patients[5] due to the loss of the fluid portion of the blood as the body tries to maintain fluid balance and homeostasis. Serial measurements of both USG and PCV/TP can help the veterinary care team evaluate the effectiveness of fluid resuscitation efforts, as both levels should decrease as intravascular volume is restored and the interstitial fluid and ICF compartments are replenished.

Previous, Ongoing, and Anticipated Losses

Consideration of fluid losses is an important part of determining a fluid therapy plan. These losses may have occurred before presentation to the clinic—such as animals with a history of protracted vomiting or diarrhea—or may be anticipated after treatment has been instituted, as is often seen in cases of postobstructive diuresis in cats with urinary obstruction. These losses must be factored in when deciding the type, amount, and route of fluid therapy. When calculating fluid losses, veterinary technicians should include urination, defecation/diarrhea, vomiting, removal of effusions or gastric contents, fluid loss from drains, and insensible losses (such as from panting).

WAYS TO PROVIDE FLUID THERAPY

Even veterinary technicians who have been in practice for only a short while have likely seen fluids given several ways. Oral, subcutaneous, intravenous, intraosseous, and even intraperitoneal routes are all used, depending on the species receiving fluid therapy and why it is needed.

Oral Route

By far the simplest mode of fluid therapy, providing water per os can correct some conditions, including mild salt toxicity and mild cases of dehydration. Providing water via the oral route is as simple as offering the patient a bowl with a premeasured volume of water on a set schedule and measuring the amount consumed. However, in patients that have gastrointestinal pathology (i.e., parvovirus infection) or are unable to consume adequate amounts of water to maintain normal urine production or to establish and maintain fluid homeostasis, other means of fluid resuscitation must be used.

Subcutaneous Route

Subcutaneous fluids are a mainstay of veterinary therapy. Subcutaneous fluid administration is used for many disease conditions, including cases of mild vomiting and diarrhea or mild dehydration, or to support kidney function in animals with chronic kidney disease. It is relatively simple to provide fluids via the subcutaneous route, and many owners can be trained to provide this therapy at home, mitigating the need for hospitalization. As with other therapies given subcutaneously, it takes time for subcutaneous fluids to be absorbed into the bloodstream; thus the subcutaneous route is not appropriate to treat life-threatening conditions such as severe dehydration or shock.

Intravenous Route

IV fluid therapy is very common in veterinary practice and allows practitioners to restore intravascular volume, correct dehydration, and administer IV medications. IV catheter placement is a core nursing competency for veterinary technicians and allows for IV fluid therapy in emergency presentations and hospitalized patients alike. In addition, access to the vascular space allows for other therapies, including transfusions, medications, and parenteral nutrition.

In emergency situations or when a large volume of fluid is needed over a short amount of time, selecting a catheter with a large bore and a short length is preferable to allow for rapid infusion of fluids. This is a function of Poiseuille's law, which governs the flow of fluid through a tube: essentially, the shorter the tube, the smoother the flow, and the larger the tube's diameter, the faster the flow, meaning that large-bore, short catheters are the best choice when a large volume of fluid must be delivered quickly, such as in cases of hypovolemic shock.[6,7] T-ports and additional tubing (e.g., extension sets) may decrease both the amount of fluid and the speed of delivery. In an emergency situation, it is best to minimize any extra IV accessories that might impede flow.

In addition to peripheral access, IV fluid therapy can be delivered through central line catheters. These catheters are longer than typical peripheral IV catheters and reach the central circulation via the vena cava. Central lines are commonly placed in the jugular vein, with the tip of the catheter sitting just outside the entrance to the right atrium to facilitate measurement of central venous pressures, if desired. Jugular central line catheters can be placed with a guidewire (i.e., Seldinger technique) or a peel-away introducer. They are available with multiple lumens to enable sampling, concurrent administration of incompatible fluids, and administration of hypertonic solutions that may cause phlebitis if given peripherally (e.g., dextrose concentrations >7.5%). The central circulation can also be reached with a long, through-the-needle catheter (e.g., Intracath) placed in either the lateral saphenous vein or the medial femoral vein or a peripherally inserted central catheter (PICC) in the same vessels. Because of their long length, smaller bore, and longer time usually required for placement, central catheters are not recommended for emergency fluid therapy, but can be maintained for long periods, making them well-suited to longer-term fluid therapy.

Intraosseous Route

Intraosseus (IO) catheters are an excellent choice for providing drugs and fluids to patients in which IV access is difficult—if not impossible—to obtain in a timely fashion. Patients with severe hypotension or complete cardiovascular collapse (i.e., patients in cardiac arrest), that are severely dehydrated, or in which IV access is not obtainable (as in patients with edema, burns, thrombosis, or obesity) can benefit from placement of a catheter in the medullary cavity of a bone (IO). This route is also very useful in tiny patients, such as neonates and pocket pets (e.g., hamsters, gerbils). The materials are readily available in most, if not all, veterinary practices, and placement may mean the difference between life and death. The IO route is fast and has been proven[8,9] to provide access to the central circulation comparable to the access provided by central venous catheterization, making it the first choice for administration of drugs and fluids when IV access cannot be achieved.

For all of the advantages of the IO route, there are several limitations. Fluid cannot be provided at a rate equivalent to that of IV access, and the needles are not designed for long-term use. Most sources[1,2,4,7,10] recommend removal of IO access devices within 72 to 96 hours of placement to avoid the development of osteomyelitis or bone infections, as long as IV access can be obtained.

MONITORING

Veterinary technicians are responsible for providing therapies in as safe a manner as possible; this includes fluid therapy. Safety can be maintained with vigilant monitoring. To monitor a patient's perfusion status, technicians should observe forward perfusion parameters (BOX 2). Normalization of these parameters is a good indication that fluid therapy is being provided successfully. In the laboratory, technicians can perform serial measurements of PCV/TP and USG. In patients that presented in a state of dehydration with increased PCV/TP, lowering of these values indicates a return to normal fluid levels in the intravascular space and an improvement in overall hydration. Increasingly dilute urine means that the patient's kidneys have detected an increase in intravascular volume and a restoration of overall fluid balance.

One of the easiest and most sensitive ways to monitor fluid therapy in patients is with multiple weight checks throughout the course of therapy. Since TBW is 60% of a patient's body weight, increases in any fluid compartment lead to a commensurate increase in the patient's overall weight. However, an increase >10% from baseline admission weight should prompt an investigation of the possibility that the patient is becoming overhydrated, also known as becoming fluid overloaded.

Fluid overload is a major complication of fluid therapy and can lead to pulmonary edema, ascites, and peripheral edema with the potential for development of compartment syndrome. A patient who becomes tachypneic, develops clear nasal discharge, or is found to have crackles on thoracic auscultation while receiving fluid therapy should be suspected of becoming overhydrated. If these signs are noted, particularly in combination with an increase in body weight, IV fluid therapy should be stopped and the veterinarian should be notified immediately.[11] Chemosis (swelling of the conjunctiva) is a late sign of fluid overload and requires urgent treatment (FIGURE 3), including cessation of IV fluids and potential administration of diuretic agents.

FLUID TYPES AVAILABLE

Several types of fluids are available, ranging from crystalloids to synthetic colloids to natural colloids (i.e., blood products). Each type has its place in the treatment of various conditions and pathologies found in veterinary patients. It is easiest to differentiate fluids based on their purpose: maintenance or replacement therapy. TABLE 1 outlines the components of common maintenance and replacement fluids available to veterinary practitioners in the United States. The resources listed in the Recommended Reading box can provide more detailed explanations of fluid types and their effects.

Crystalloids

Patients presented as an emergency often require immediate intravascular expansion in the form of crystalloid boluses, or large volumes of crystalloid fluids. Crystalloid fluids move quickly from the intravascular space into other fluid compartments, primarily the intracellular compartment. Less than one-third of the crystalloid volume administered

TABLE 1 Composition of Common Veterinary Fluids

FLUID TYPE	COMPONENT (unit)							BUFFER(S)	PRIMARY USE
	pH	Sodium (mEq/L)	Chloride (mEq/L)	Potassium (mEq/L)	Magnesium (mEq/L)	Calcium (mEq/L)	Osmolarity (mOsm/L)		
0.9% Saline	5.5	154	154	0	0	0	308	None	Replacement
0.45% Saline	5.6	77	77	0	0	0	154	None	Maintenance
Plasmalyte A	7.4	140	98	5	3	0	294	Acetate (27 mEq/L) Gluconate (23 mEq/L)	Replacement
Plasmalyte 56	5.0	40	40	13	3	0	363	None	Maintenance
Normosol-R	7.4	140	98	5	3	0	294	Acetate (27 mEq/L) Gluconate (23 mEq/L)	Replacement
Normosol-M	5.0	40	40	13	3	363	363	Acetate (16 mEq/L)	Maintenance
Lactated Ringer's solution (LRS)	6.5	130	109	4	0	2.7	273	Lactate (28 mEq/L)	Replacement
Hetastarch	5.5	154	154	0	0	0	309	None	Colloid

intravenously persists in the vasculature 1 hour after administration,[4] making these fluids an excellent choice for treating dehydration and electrolyte derangements and correcting free water deficits.

Crystalloid fluids can be categorized as follows:

- **Free water:** 5% dextrose in sterile water or 0.45% saline. This hypotonic (i.e., containing fewer solutes than ICF) solution replenishes the interstitial fluid and ICF compartments.
- **Replacement solutions:** These balanced, isotonic solutions are designed to replenish the ECF compartments, including increasing intravascular volume and restoring perfusion. Isotonic fluids contain a solute concentration that approximates that of ICF, and crystalloids that are considered "replacement" fluids **(TABLE 1)** have compositions that closely match the electrolyte balance and pH of ECF,[1] making them ideal to replace losses from that fluid compartment (e.g., dehydration).
- **Maintenance solutions:** These balanced, isotonic solutions have less sodium and more potassium than replacement fluids and may be more suitable for long-term fluid therapy after restoration of intravascular volume and correction of electrolyte derangements. Maintenance fluids are rarely used alone—they are usually combined with a ratio of 0.9% sodium chloride[1] (aka "normal" or "isotonic" saline) to more closely match the composition of the fluid in the intravascular space, preventing unwanted fluid shifts between compartments.
- **Hypertonic solutions:** 7% to 23.4% saline. These fluids contain a solute concentration higher than that of ICF and rapidly expand intravascular volume by drawing water from the interstitial and intracellular compartments. Because of this oncotic pull, hypertonic solutions should never be used in cases of severe dehydration.

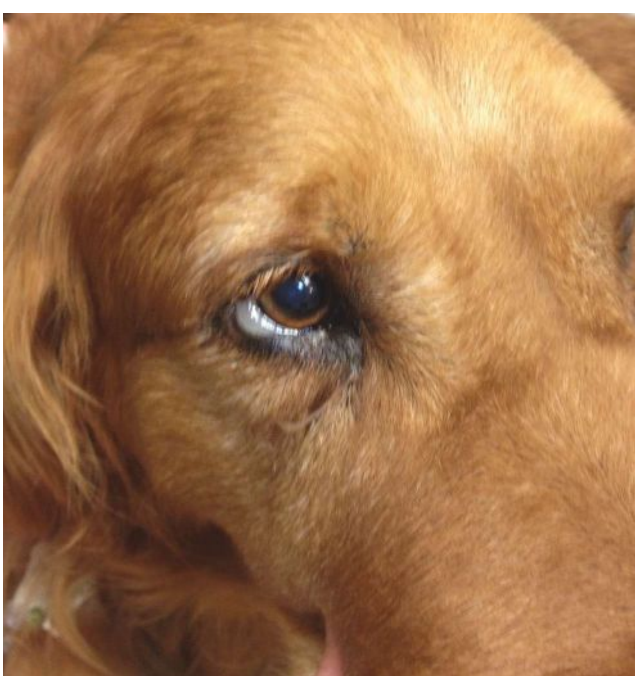

FIGURE 3. Swelling of the conjunctiva without signs of inflammation or irritation is known as chemosis. This is a late sign of fluid overload; it is incumbent on veterinary technicians to recognize earlier signs such as increased respiratory rate and effort, increased breath sounds (e.g., crackles), or clear nasal discharge.

Colloids

Many practitioners also use colloids (either synthetic or natural) in an emergency to expand the intravascular compartment without the risk of fluid overload posed by infusing large volumes of crystalloid fluids. Colloids contain large, osmotically active particles that work to hold fluid in the vasculature after administration.

Synthetic colloids are fluids with large molecules designed to provide oncotic pressure support within the intravascular space. **Natural colloids** are blood products such as whole blood, packed red blood cells (pRBCs), plasma, and albumin. Whole blood and pRBCs have the added benefit of providing oxygen-carrying capacity, helping to prevent and treat hypoxia.

The use of colloids is highly controversial in human medicine and becoming so in veterinary medicine as well,[12] with recent research[13] implicating a link between the use of a synthetic colloid and the development of acute kidney injury in dogs.

BOX 3 Appropriate Fluid Choices for Selected Disease Processes

- **Cardiac disease:** Low-dose maintenance crystalloid, such as 0.45% saline with dextrose (may require potassium and or magnesium supplementation)
- **Vomiting/diarrhea:** Replacement crystalloid, such as lactated Ringer's solution, Normosol-R, or Plasmalyte-A
- **Diabetic ketoacidosis:** Replacement crystalloid, such as lactated Ringer's solution, Normosol-R, Plasmalyte-A
- **Hemorrhage:** Natural colloid, such as plasma, whole blood, pRBCs

DEVELOPING AND IMPLEMENTING A FLUID THERAPY PLAN

There is a helpful guideline when it comes to fluid therapy: *Replace like with like*. This means if a patient has lost blood, that fluid should be replaced with plasma, pRBCs, or whole blood. If a patient has lost body fluids through diarrhea, vomiting, or excessive urination, replacement should be with similarly constituted isotonic crystalloid fluids. While development of the fluid plan is ultimately the veterinarian's purview, it is important for veterinary nurses and technicians to understand the fluids available and for what conditions they might be used in clinical practice.

Fluid therapy in the veterinary hospital or clinic has 3 primary phases, which can overlap and alternate, depending on how a patient presents and the progression of its disease process. The *resuscitation phase* refers to correcting shock and other life-threatening fluid deficits; *the replacement phase* is the time taken to replace dehydration deficits; and the *maintenance phase* covers fluids provided during hospitalization to support and maintain homeostasis. **BOX 3** provides examples of fluid choices in some specific disease processes.

The amount of fluid to be provided to a patient must be calculated carefully, taking into account the need for intravascular volume expansion, the profundity of perfusion deficits, the degree of dehydration, and the severity of electrolyte derangements, among other considerations. **BOX 4** lists common fluid therapy calculation formulas.

CONCLUSION

Understanding the need for fluid therapy, methods of providing fluids, types of fluids available, and how to keep patients safe while providing this vital treatment is a big part of being a veterinary technician. Go with the flow and help patients feel better! ■

Recommended Reading

- → Davis H, Jensen T, Johnson A, et al. 2013 AAHA/AAFP fluid therapy guidelines for dogs and cats. *JAAHA* 2013;49(3):149-159.
- → DiBartola SP, Bateman S. *Fluid, Electrolyte, and Acid-Base Disorders in Small Animal Practice*. 3rd ed. St. Louis, MO: Saunders Elsevier; 2006. Chapters 14 and 23.
- → Pre-Hospital Push. IV catheter size: How much of a difference does it make? http://www.prehospitalpush.com/2016/03/04/iv-catheter-size-how-much-of-a-difference-does-it-make/. Accessed March 30, 2016.

BOX 4 Fluid Therapy Formulas

Calculation of Dehydration Deficit[1]

Body weight (kg) × % dehydration as a decimal = liters of fluid required to correct dehydration

Calculation of Maintenance Fluid Requirements*

Dogs: Body weight (kg)$^{0.75}$ × 132 = 24-hour fluid requirement in milliliters

Cats: Body weight (kg)$^{0.75}$ × 80 = 24-hour fluid requirement in milliliters

Ongoing losses (e.g., from diarrhea, vomiting, or polyuria) must be calculated and added to the total maintenance requirement obtained from these formulas.

*UC Davis School of Veterinary Medicine fluid therapy formula.

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