PEER REVIEWED

PATIENT TREATMENT
IV fluid therapy is a skill veterinary technicians utilize daily.

CONTINUING EDUCATION

INTERNAL MEDICINE

Fluid Calculations:
Keeping a Balance

MEET THE AUTHOR

***Angela Thorp**, CVT, VTS (ECC, SAIM)*
1st Pet Veterinary Centers, Chandler, Arizona

Angela has been in the veterinary field for over 25 years, obtaining her CVT and AAS in Veterinary Technology through DEVTP, and later obtaining her VTS in Emergency & Critical Care. She is a charter member of the Academy of Veterinary Internal Medicine Technicians (AIMVT), served as past president of the previous state technician association in Arizona and committee chair for the exam committee of AVECCT. Currently she serves as Executive Secretary of AVECCT and a Domain Chair of the AVECCT Nursing Standards Committee. Angela is also the NAVTA State Representative for Arizona. In 2001, she was awarded the Technician of the Year from the Arizona Veterinary Medical Association. She lectures, has been published, and currently serves the Team Director at 1st Pet Veterinary Centers.

Fluid calculations are part of daily life in modern veterinary practice. Usually, though, veterinarians do the calculating, don't they? Is it important for veterinary technicians to cultivate these skills? A variety of veterinary calculators are now available to calculate fluid estimates for the patient, but knowledge of how to properly calculate fluids is vital for veterinary technicians to develop and maintain because it deepens the understanding of the patient's condition.

Maintaining a proper fluid balance in the body is essential to life and the patient's longevity. Fluid balance, electrolyte balance, and acid-base balance work together to maintain homeostasis within the body. A variety of diseases, conditions, and surgical interventions can disturb this balance. Fluid therapy can be used for a variety of reasons including: treating shock, blood loss, and dehydration; preventing dehydration; treating systemic disease; providing supportive care during anesthesia; and providing diuresis.

Technicians need to understand these intricate processes in order to properly assess, administer, and monitor fluid therapy. Inappropriate fluid therapy may result in overhydration or fluid overload, electrolyte deficiencies, acid/base imbalances, rapid fluid shifting, and potential complications of IV catheter use. We will explore the physiology of body fluids, how to assess a fluid imbalance, administering and monitoring fluid therapy, and various types of fluids.

PHYSIOLOGY OF BODY FLUIDS

Having a fundamental understanding of the physiology of body fluids is key in treating patients and understanding fluid calculations.

PEER REVIEWED

An understanding of total body water volumes aids in fluid therapy: for example, knowing that fluid loss from young puppies takes a much higher percentile of their body weight, making fluid replacement vital, and, conversely, understanding that fluid administration to an obese patient may need to be based on their lean or ideal body weight rather than their actual weight. In dogs and cats, body water averages 60% of their body weight.[1] The variation is often attributed to the patient's age and nutritional status. Very young dogs and cats have as much as 70% to 80% total body water,[2] while older pets may have as little as 50% to 55%.[2] Fatty tissue contains much less water than do muscle, organs, and soft tissue, so overweight animals tend to carry less water per pound proportionally to lean dogs.

FIGURE 1. Critical patients can be especially challenging. Heatstroke causes hypertonicity but may also cause fluid overload with lung injuries.

FIGURE 2. Closed collection sets are the best way to accurately monitor urine production.

Total body water in a normal-weight dog is estimated to be 534 to 660 mL/kg.[1] Two-thirds (about 40%) of the total body water is stored in cells within the intercellular fluid (ICF), and one third of total body water is stored in the extracellular fluid (ECF).[3] ECF is composed of both interstitial fluid volume (ISF, ~15%), transcellular fluid (~1%), and intravascular fluid volume (IVF, ~5%).[3] Approximately three fourths of the ECF consists of ISF, with the remaining fourth being IVF.[3] The interstitial area is the space between cells where fluid is held in a gel-like form in a proteoglycan/collagen matrix. The electrolyte composition of ICF and ECF are very different and play a key role in fluid balance. Fluids between all of these compartments are under a continual dynamic equilibrium. Fluids and electrolytes continually shift, primarily because of osmosis from a low- to a high-sodium concentration. Osmolar, hydrostatic, and oncotic pressures all regulate the balance of fluid movement. Osmotic pressure is the primary determinant of this exchange.[1] Osmotic pressure is the potential pressure of a solution directly related to its solute concentration.

Normal fluid losses that occur daily are considered to be approximately 50 mL/kg per day.[2] Urination makes up approximately 20 mL/kg per day, fecal losses make up approximately 10 mL/kg per day, and respiratory and skin losses make up the additional 20 mL/kg per day.[2] In healthy animals, some of these losses are replaced with food intake. Fluid losses not compensated for by food intake can stimulate thirst mechanisms or other compensatory means, such as the sympathetic nervous system, angiotensin II, and renal sodium excretion.

Hypertonicity, hypovolemia, and hypotension can be detected by various means in the body in attempt to compensate. Hypertonicity occurs when enough free water has been lost to increase the concentration of solutes in body fluids to a level greater than normal plasma osmolality (285 to 295 mOsm/kg).[1] The hypothalamus detects the hypertonicity (increase in plasma concentration) and stimulates thirst. In patients in which hyper- or hypo-osmolality is suspected, osmolality can be calculated by using the following formula: [1]

$$\mathbf{P_{osm} = [2(Na^+ + K^+)] + [glucose\ (mg/dL)/18] + [blood\ urea\ nitrogen\ (mg/dL)/2.8]}$$

TABLE 1 Electrolyte Composition in Body Fluids[5]

FLUID	CATION				ANIONS			
	SODIUM	POTASSIUM	CALCIUM	MAGNESIUM	CHLORIDE	BICARBONATE	PHOSPHATE	PROTEIN
IVF	138-152	4	2.5	1	102-104	27	1	14-17
ISF	130-145	4	1.5	1	110-117	27	1	–
ICF	10-14	110-157	û	15-34	10	4-10	26-40	50

Based on information from reference 1.

In a healthy patient, hypertonicity, any detectable decrease in extracellular fluid volume, or circulating volume can be detected by the following:

- The hypothalamus stimulates thirst and prompts the patient to drink, which restores fluid volume.
- Osmoreceptors that release antidiuretic hormone cause an increase in water reabsorption from the kidneys, which restores fluid volume.
- Reduced blood flow stimulates a renin-angiotensin-aldosterone system.
- Various sympathetic nervous system responses compensate for losses for a time until fluid volume is restored by one of the above means.

Therefore, when a patient is presenting to the veterinary hospital in shock with dehydration deficits or with other fluid imbalances, these mechanisms can't keep that patient's fluid balance in check (**FIGURE 1**). It's up to the veterinary professional to intervene quickly and fluid support.

ASSESSING FLUID IMBALANCES

Fluid imbalances have many causes. Water losses and dehydration can also result in a variety of electrolyte and acid/base imbalances. Pure water deficits may also result from excessive panting, water deprivation, or diseases such as diabetes insipidus. It's important to assess the type of fluid and/or electrolyte losses that occur in order to determine appropriate replacement fluids. If fluid losses are hypotonic, the ECF will become hypertonic.[4] Isotonic losses will allow the ECF to remain in an isotonic state. Hypertonic losses result in the ECF becoming hypotonic. The resulting osmolality of the body is an important factor to consider in fluid replacement in order to monitor any potential shifts in osmolality.

Electrolytes play a large role in the balance of fluids within the body. The table provides approximate compositions of electrolytes in the various fluid compartments and protein (primarily albumin in g/dL) levels, which are involved in maintaining oncotic pressure (**TABLE 1**).

Evaluation of urine specific gravity (USG) can help determine a patient's fluid balance (**FIGURE 2**). USG is a measure of solute concentration in the urine, which is affected by the ability of the renal tubules to dilute glomerular filtrate. The number of molecules in urine (as well as their weight and size) can also affect USG. Isosthenuria (USG, 1.008 to 1.015) occurs when the USG and osmolality of the urine are equal to those of the plasma. Hyposthenuria (USG < 1.008) occurs when USG and osmolality decrease. Hypersthenuria (USG > 1.015) occurs when the USG and osmolality increase or are greater than what is present in the plasma. A USG of >1.030 in dogs and >1.035 in cats indicates adequate concentrating ability of the kidneys.

Dehydration cannot be detected clinically until a patient is at least 5% dehydrated. Patients can appear clinically normal, so the patient's history must be factored in to consider whether losses incurred may have resulted in subclinical (<5%) dehydration.[6] A thorough history, including information on frequency and approximate amounts of abnormal losses (eg, vomiting, diarrhea, and drainage from wounds), and presence of polyuria and /or anorexia, should be obtained. Fever or excessive panting may be additional causes of excessive fluid loss. Previously recorded body weight from medical records can be helpful to assess total body water losses.

Dehydration above 5% may be observed clinically, so a physical exam must be performed. The exam should include evaluation of mucus membrane color, capillary refill time, heart rate, respiratory rate, pulse quality, warmth of extremities, skin turgor, and assessment for blood loss. In assessing skin turgor, it's important to note the patient's age and body condition score (BCS). Older cachectic patients have reduced skin turgor without dehydration. Overweight or obese patients, on the other hand, may not reveal decreased skin turgor despite significant dehydration.

Packed cell volume, total protein, blood urea nitrogen, and creatinine in relation to USG may all be evaluated as part of this assessment. Elevations in any of these laboratory tests may indicate dehydration. Some signs of severe fluid depletion include:

- Pale, dry mucous membranes
- Reduced urine output/concentrated urine
- Microcardia (on thoracic radiography)
- Sunken eyes
- Cool extremities
- Slow capillary refill time
- Weak, rapid pulse
- Poor skin elasticity

By combining all the information from the patient's history and complete physical exam, the degree of dehydration of the patient may be assessed. However, this assessment is only an approximation and may indicate substantially less than the actual loss (**FIGURE 3**). See **TABLE 2** for a guide on dehydration estimates.

ESTIMATING FLUID REPLACEMENT THERAPY

Once the degree of dehydration is approximated, the amount of fluid volume required to resuscitate the patient may be calculated. Fluid deficits can be calculated by using the following formulas[5] (1 lb of water = 454 mL; 1 kg of water = 1000 mL):

FIGURE 3. Dehydration deficits should be calculated in order to ensure deficit replacement.

Percentage dehydration × body weight (lb) × 454 × 0.80 g

or

Percentage dehydration × body weight (kg) × 1000 × 0.80 g

The fluid deficit is multiplied by 0.80 because we want to give 75% to 80% of a patient's total fluid deficit within the first 24 hours of resuscitation. Daily maintenance volumes must be added to the deficit volume to provide the total fluid to administer in the first 24 hours. Maintenance volumes of fluids are considered to replace normal ongoing losses.

TABLE 2 PHYSICAL FINDINGS IN DEHYDRATION[4,5]

DEHYDRATION (%)	HISTORY OF FLUID LOSS	DRY MUCOUS MEMBRANES	TACHYCARDIA	DECREASED SKIN TURGOR	DECREASED PULSE PRESSURE	SHOCK
<5	+	-	-	-	-	-
5-6	+	+	-	-	-	-
7	+	+	+	+	-	-
10	+	+	+	+	+	-
12	+	+	+	+	+	+

Maintenance volumes have been estimated as 65 to 75 mL/kg per day.[4] Some practitioners calculate water requirements in the same fashion as used for calculating basal energy requirements[4] (1 kcal energy = 1 mL water) by using a formula such as (30 × body weight in kg) + 70. The alternate calculation (70 × body weight in kg0.75) is recommended for very small patients (under 2 kg) or very large patients (over 50 kg). Ongoing additional losses must also be considered and factored into the fluid therapy plan. Any calculation is an approximation and is no substitution for monitoring throughout fluid resuscitation—these calculations may underdose one patient or overdose another.

For the first 24 hours of fluid therapy, use the following formula:[4]

Dehydration deficit × 0.80 + maintenance volume + ongoing losses

If shock is present, shock doses must be provided rapidly, in addition to the other replacement volumes. Shock volumes may be up to 60 to 90 mL/kg for dogs and 40 to 60 mL/kg for cats.[4] This volume should be given in increments of 20 mL/kg (dogs) or 10 mL/kg (cats) rapidly over 10 to 20 minutes and the response monitored. If there is no response, then boluses can be repeated up to the maximum shock volumes if necessary. If the response after any bolus is sufficient, then the fluid rate should be adjusted. If the patient's response to crystalloid is not sufficient, then colloids may be added, starting with IV boluses of 5 mL/kg, up to 20 mL/kg.[4] Continuous rate infusions of hetastarch may be continued when needed at rates of 20 to 40 mL/kg per day.

FLUID TYPES

Crystalloids

Crystalloids are the most commonly used replacement fluids (**TABLE 3**). Crystalloids that are isotonic and noncolloidal are considered to be balanced, with a composition close to that of ECF, with sodium as the primary electrolyte. Crystalloids contain solutes composed of both electrolytes and nonelectrolyte solutes. Isotonic crystalloids can be given rapidly to expand the intravascular space and improve circulation, improving oxygenation to tissues in cases of shock, as they pass readily through cell membranes with up to 75% of crystalloids moving out of the intravascular space within 1 hour of administration. This feature makes them especially indicated for patients with dehydration. Normosol-R (**hospira.com**), 0.9% NaCl, lactated Ringer's solution, and Plasma-Lyte (**baxterhealthcare.com**) are all considered to be isotonic crystalloid replacement fluids and are commonly used in veterinary

TABLE 3 FLUID TYPES AND COMPOSITIONS[3]

TYPE OF FLUID	NA+	K+	CL	CA+	MG+	BUFFER	GLUCOSE	OSMOLARITY	PH
0.9% NaCl	154	0	154	0	0	0	0	308	5
Normosol-R	140	5	98	0	3	27	0	296	6.4
Lactated Ringer's solution	130	4	109	3	0	28	0	398	5
Plasma-Lyte 148	140	10	103	5	3	47	0	312	5.5
0.45% NaCl	77	0	77	0	0	0	0	154	5
0.45% NaCl with 2.5% dextrose	77	0	77	0	0	0	25	280	4.5
5% dextrose in water	0	0	0	0	0	0	50	170	4

Electrolytes noted in mEq/L; glucose in mg/dL; buffer in mmol/L; osmolarity in mOsm/L.

PEER REVIEWED

FUNDAMENTALS

Maintaining a proper fluid balance in the body is essential to life and the patient's longevity.

medicine. However, 0.9% NaCl is considered an unbalanced isotonic solution because its composition is not similar to that of ECF (**FIGURE 4**).

The choice of fluid to administer to a patient depends on the disease process and the type of fluids that may have been lost. Additional electrolyte supplementation may be required. Fluids such as lactated Ringer's solution, Normosol, and Plasma-Lyte are considered alkalinizing fluids because they contain buffers that the body can convert to bicarbonate after administration: Lactated Ringer's solution contains lactate, and Normosol (**FIGURE 5**) and Plasma-Lyte contain acetate. Lactated Ringer's solution should not be used in patients receiving blood products because of the calcium content in this fluid.

Hypertonic crystalloid solutions, such as 7% NaCl, have higher than normal sodium concentrations, which make fluid shift from the ISF and ICF into the vascular space. It's often used for treatment of shock or head trauma because of this immediate shift of fluids. The shift is temporary but can be helpful in treating these conditions. Hypertonic saline should not be given to patients that are dehydrated because they don't have enough fluid to shift and would develop hypernatremia.

Hypotonic crystalloids, such as 5% dextrose in H2O and 0.45% NaCl with 2.5% dextrose, have a sodium concentration lower than that of plasma. They are not to be administered rapidly because of their potential to cause red blood cell lysis. These solutions are generally given with dextrose because the metabolism of the dextrose creates free water, replacing free water deficits in patients with certain disease processes. They may also be used for hypernatremia, hyperkalemia, hyperosmolality, congestive heart failure, or liver disease.

FIGURE 4. Sodium Chloride 0.9% is an isotonic replacement fluid.

FIGURE 5. Administration of fluids through an IV pump is essential.

Colloids

Colloids (non-blood-based) are synthetic large-molecular-weight substances contained in an IV solution, such as hydroxyethyl starch (hetastarch). Colloids often contain a mixture of molecule sizes, which keeps the fluids in the vascular space longer, but still have a relatively short half-life (25 hours according to the hetastarch package insert) and may require continuous infusion. Colloids are useful because they exert a strong oncotic effect and expand plasma volume. In patients that are hypoproteinemic, they can help maintain colloid oncotic pressure. Colloids can effectively elevate colloid osmotic pressure by 8 to 10 mm Hg. Mild to moderate elevations in serum amylase may be seen in patients receiving hetastarch because plasma amylase degrades this solution (amylopectin is the main constituent of this fluid). Hetastarch is based in a 0.9% NaCl solution, so it's important to monitor sodium levels in patients receiving prolonged infusions or large volumes of this fluid. Crystalloids must still be administered in order to replace dehydration deficits.

PUTTING IT ALL TOGETHER

A variety of information needs to be considered when developing a fluid plan and calculating fluids. These questions can help evaluate the needs of each individual patient:

BOX 1

Steps to Calculate Fluid Replacement Therapy

CASE: A 5-year-old, 62-lb dog is presented because of 3 days of vomiting. The patient has the following vital signs: heart rate, 160 beats/min; good pulses; respiratory rate, panting; mucous membranes, pink/tacky; decreased skin turgor.

- **Is evidence of shock (perfusion derangements) present?**
  - The heart rate is elevated for such a large dog. Give initial 20 mL/kg fluid bolus and monitor response. Patient weighs 28.2 kg. Calculations: 28.2 (kg) × 20 mL/kg bolus = 564 mL
  - Patient receives bolus of 570 mL. Heart rate and blood pressure normalize after 1 bolus.
- **Is the patient dehydrated?**
  - Yes. This patient fulfills many criteria for dehydration.
- **What is the approximate percentage of dehydration?**
  - This patient demonstrates:
    - History of fluid loss
    - Tacky mucous membranes/gums
    - Decreased skin turgor
    - Elevated heart rate
  - This patient is approximately 7% dehydrated.
- **What is the dehydration deficit?**
  - 0.07 (percentage dehydration) × 28.2 kg × 1000 = 1974 mL fluid deficit
  - Only 80% replaced in first 24 hours = 1974 mL × 0.8 = 1579 mL
- **Are there ongoing losses?**
  - Because the patient has vomiting and diarrhea, ongoing losses are expected.
  - Outputs must be tracked and calculated and replaced by adding to the overall fluid rate later on.
  - This patient vomited once (~100 mL) and had diarrhea twice (~125 mL) within the first 4 hours in hospital. Total losses = 225 mL. This is replaced over the next 4 hours by adding 56 mL/h to the overall fluid rate.
- **What is the maintenance rate for this patient?**
  - (28.2 kg × 30) + 70 = 916 mL/d
  - 916/24 hours = 38 mL/h
- **What is the initial fluid rate for this patent in the first 24 hours of treatment?**
  - After shock bolus:
    - Dehydration + maintenance
    - 1579 mL + 916 mL = 2495 mL over 24 hours

    or

    - 104 mL/h
    - Plus ongoing losses of 38 mL/h = 142 mL/h

PEER REVIEWED

1. Is evidence of shock (perfusion derangements) present?
2. Is the patient dehydrated?
3. What is the approximate percentage of dehydration?
4. What is the dehydration deficit?
5. Are there ongoing losses (through vomiting, diarrhea, polyuria, pyrexia, panting, other)?
6. What is the maintenance rate for this patient?
7. What is the total initial fluid rate for this patient in the first 24 hours of treatment?

BOX 1 provides an example of how to calculate fluid replacement and develop a plan.

SUMMARY

Fluid therapy is an integral part of emergency and critical care medicine. Appropriate use of fluid types and amounts is vital for obtaining positive outcomes in patients. To best care for these patients, technicians must understand the body's fluid balance and systems to maintain that balance, fluid composition and use, and knowledge of diseases and disease processes (beyond the scope of this article). By providing diligent care in this regard, technicians play a vital role in the outcome of their patients. **TVN**

References

1. DiBartola S, Wellman M, Kohn C. Applied physiology of body fluids. In: DiBartola S, ed. *Fluid, Electrolyte and Acid-Base Disorders in Small Animal Practice*, 3rd ed. (St. Louis, MO: Saunders Elsevier); 2006:3-26.
2. Donohoe C., Battaglia A, Steele A. *Small Animal Emergency and Critical Care for Veterinary Technicians*, 3rd ed. (St. Louis, MO: Saunders Elsevier); 2016:61-77.
3. Liss D. Fluid therapy, electrolyte, and acid-base disorders. Norkus C, ed. *Veterinary Technician's Manual for Small Animal Emergency and Critical Care*. (Ames, IA: Wiley-Blackwell); 2012:433-453.
4. Silverstein D. Daily intravenous fluid therapy. In: Silverstein D, Hopper K, eds. *Small Animal Critical Care Medicine*. (St. Louis, MO: Saunders Elsevier); 2009:271-280.
5. DiBartola S, Wellman M, Kohn C. Applied physiology of body fluids. In: DiBartola S, ed. *Fluid, Electrolyte and Acid-Base Disorders in Small Animal Practice*, 3rd ed. (St. Louis, MO: Saunders Elsevier); 2006:3-26.
6. DiBartola S, Bateman S. Introduction to fluid therapy. In: DiBartola S, ed. *Fluid, Electrolyte and Acid-Base Disorders in Small Animal Practice*, 3rd ed. (St. Louis, MO: Saunders Elsevier); 2006:325-343.

CONTINUING EDUCATION

Fluid Calculations: Finding a Balance

LEARNING OBJECTIVES

After considering the following article, veterinary technicians will be better able to distinguish the differences in the physiology of fluids in the body, know how to assess and calculate fluid requirements for patients, be able to determine which fluid types to select, and know how they benefit veterinary patients.

OVERVIEW

This article will provide the veterinary technician with an overview of physiology of fluids and various methods of calculating fluid rates, as well as monitoring and nursing care of patients receiving fluid therapy.

The article you have read has been submitted for **RACE approval for 1 hour of continuing education credit** and will be opened for enrollment when approval has been received. To receive credit, take the approved test online for free at **vetfolio.com/journal-ce**. Free registration on **VetFolio.com** is required. Questions and answers online may differ from those below. Tests are valid for 2 years from the date of approval.

1. **Of total body weight in water, what ratio of percentage per compartment is correct?**
   a. 40% ICF, 20% ECF
   b. 20% ICF, 40% ECF
   c. 15% ICF, 5% ECF
   d. 33% ECF, 66% ICF

2. **Normal fluid losses equal what volume each day?**
   a. 30 mL/kg per day
   b. 40 mL/kg per day
   c. 50 mL/kg per day
   d. 60 mL/kg per day

3. **Fluid imbalance is a result of which cause?**
   a. Panting
   b. Dehydration
   c. Weight gain
   d. Diabetes insipidus

4. **Which of the following fluids contains the least amount of sodium?**
   a. Plasma-Lyte
   b. Normosol
   c. Lactated Ringer's solution
   d. 0.9% NaCl

5. **A cat presents with decreased skin turgor, sunken eyes, and tachycardia. How dehydrated is the cat?**
   a. <5%
   b. 7%
   c. 10%
   d. 12%

6. **A 7-year-old, 42-lb dog is presented for 1 day of vomiting with the following vital signs: heart rate, 140 beats/min; slightly decreased pulses; respiratory rate, panting; mucous membranes, pink/tacky; decreased skin turgor; 10% dehydrated. Calculate the estimated total fluid replacement volume needed in the first 24 hours, considering that there are not ongoing losses.**
   a. 1500-1600 mL
   b. 1800-1900 mL
   c. 2100-2200 mL
   d. 2500-2600 mL

7. **Which of the following is NOT an example of a crystalloid?**
   a. Plasmalyte
   b. 5% dextrose in water
   c. Hetastarch
   d. 0.45% NaCl

8. **Which of the following best represents incremental shock fluid bolus volumes for felines?**
   a. 10 mL/kg
   b. 20 mL/kg
   c. 30 mL/kg
   d. 40 mL/kg

9. **A patient with a history of fluid loss, dry mucous membranes, tachycardia, and decreased skin turgor is approximately what percentage dehydrated?**
   a. 5%
   b. 7%
   c. 10%
   d. 12%

10. **Calculate the dehydration deficit for a 90-lb dog that is 7% dehydrated.**
   a. 1040 mL
   b. 1300 mL
   c. 1900 mL
   d. 2870 mL