TABLE 1

Intravascular Volume Assessment

Criteria	Hypovolemia	Hypervolemia*
Patient history	Vomiting, diarrhea, decreased water intake, anorexia or hyporexia, respiratory signs, fever, blood loss and hemorrhage	Iatrogenic fluid overload, polydipsia, salt intoxication, osmotic agent administration
Physical examination findings	See Table 2 Can occur with severe dehydration (>12%) May see evidence of hemorrhage (bleeding, epistaxis, etc.)	Bounding pulse quality, new cardiac murmur, wet lung sounds, ocular/nasal discharge, jugular vein distention, peripheral edema
Blood pressure or electrocardiogram findings	Hypotension, arrhythmia	Arrhythmia
Laboratory test results	Hyperlactatemia, metabolic acidosis, acute anemia, hypoproteinemia (may be secondary to hemorrhage)	Hemodilution of packed cell volume, blood urea nitrogen, and electrolytes
Diagnostic imaging results (e.g., radiography, ultrasonography, computed tomography)	Microcardia, small caudal thoracic vena cava, caudal vena cava collapsibility index >27%	Abdominal venous distension, caudal vena cava collapsibility index <27%, pleural effusion, ascites, retroperitoneal effusion, perirenal effusion

*Usually occurs in conjunction with signs of overhydration of the interstitial space (see Tables 4 and 5).

TABLE 2

Stages and Clinical Signs of Hypovolemic Shock

	Heart rate	CRT	MM color	Peripheral pulses	Peripheral blood pressure	Extremities	Body temperature
Compensatory							
Cat	Rarely recognized (seconds to a few minutes in duration)						
Dog	Normal or increased	1-2 s	Normal or red	Bounding	Normal or increased	Normal temperature to touch	Hypothermic, hyperthermic or normothermic
Early decompensatory							
Cat	Normal or decreased	>2 s	Pale	Weak	Low	Cool to touch	Hypothermic
Dog	Increased	>2 s	Pale to white	Weak	Normal or decreased	Cool to touch	Hypothermic, hyperthermic or normothermic
Late decompensatory							
Cat	Decreased	>2 s or absent	White	Absent	Low or unable to obtain	Cool to cold to touch	Hypothermic
Dog	Normal or decreased	>2 s or absent	White	Absent	Low or unable to obtain	Cool to cold to touch	Hypothermic, hyperthermic or normothermic

CRT, capillary refill time; MM, mucous membrane

TABLE 3

Estimated Interstitial Dehydration (%) Based on Physical Examination Findings[a]

Estimated % Dehydration	Physical Examination Finding
<5%	• Not detectable
5–6%	• Some change in skin turgor
6–8%	• Mild decreased skin turgor • Dry mucous membranes*
8–10%	• Obvious decreased skin turgor • Retracted globes within orbits
10–12%	• Persistent skin tent due to complete loss of skin elasticity • Dull corneas** • Evidence of hypovolemia
>12%	• Hypovolemic shock • Death

Note: There is substantial clinical variation in the correlation between clinical signs and degree of dehydration, so this is an estimate only.

[a] Reprinted from Silverstein DC and Hopper K, eds., *Small Animal Critical Care Medicine*, 3rd ed., Rudloff, E, Assessment of hydration, p. 1054-58, Elsevier (2022), with permission from Elsevier.

*Xerostomia can be present in AKI and CKD patients without dehydration.
**Retracted globes may also be present.

TABLE 4

Extracellular Hydration Status Assessment Parameters and Expected Changes from Baseline in Patients Receiving Hypo- or Over-hydration[a]

Parameter	Hypohydration	Overhydration
Skin turgor	↓	↑
Mucous membrane moisture	↓	↑
Packed cell volume	↑	↓
Total protein	↑	↓
Blood urea nitrogen	↑	↓
Urine osmolality	↑	↓
Urine specific gravity	↑	↓

[a] Reprinted from Silverstein DC and Hopper K, eds., *Small Animal Critical Care Medicine*, 3rd ed., Rudloff, E, Assessment of hydration, p. 1054-58, Elsevier (2022), with permission from Elsevier.

TABLE 5

Additional Clinical and Diagnostic Findings That May Indicate Overhydration/Fluid Overload

Acute weight gain

Respiratory signs
- Tachypnea
- Cough
- Moist lung sounds
- Labored breathing
- Diagnostic imaging findings consistent with pleural effusion, ascites, and/or pulmonary edema

Edema
- Chemosis
- Subcutaneous edema
- Organ edema and dysfunction (e.g., gastrointestinal signs, altered mentation, arrhythmia)

Serous nasal discharge

Cavitary effusion

Polyuria in the absence of renal failure

Shivering

Restlessness

TABLE 6

Conditions That Pose Challenges When Addressing Individual Fluid Compartment Needs

Condition	Challenge
Hypovolemic shock in cats	• Cats typically develop bradycardia, hypothermia, and hypotension. • This triad of events makes cats more susceptible to hypervolemia and overhydration compared with dogs, when similar fluid resuscitation strategies are used (see Table 2).
Increased capillary permeability (e.g., due to systemic inflammation, burns, trauma)	• Can result in both hypovolemia and overhydration.
Acute congestive heart failure in a patient receiving diuretics and afterload reducers	• Can result in poor perfusion and signs of shock due to cardiovascular dysfunction.
Osmotic diuretic therapy or uncontrolled hyperglycemia	• Can lead to hypervolemia and reduced interstitial and intracellular water volume.

TABLE 7

Endpoints to Monitor for Hypovolemia and Dehydration

Fluid Status	Hypovolemia	Dehydration
Initial parameters	(See Table 2)	(See Table 3)
Initial treatment strategy	• 5-10 mL/kg (cat), 15-20 mL/kg (dog) of a buffered isotonic fluid over 15 minutes • Assess perfusion parameters at the end of each bolus.	• Calculate replacement volume and deliver over 12–24 hours. • Assess patient parameters throughout the fluid delivery period with the goal of correcting the full dehydration deficit within 12–24 hours.
End points	• Improvement in heart rate, CRT, blood pressure, and mentation	• Improved skin turgor, mucous membranes, and urine specific gravity and increased body weight and urine output
End point treatment strategy	• If vitals have returned to normal, then assess if dehydration needs to be addressed and continue with a rehydration fluid plan. • If vitals have improved but not normalized, repeat the same or lower-volume bolus and reassess.	• If end points have returned to normal, then assess if oral ingestion is possible. If not, continue with maintenance fluid plan. • If dehydration has not completely resolved, recalculate fluid requirements and deliver over an additional 12–24 hours.

CRT, capillary refill time

TABLE 8

Composition of Commonly Used Crystalloids[1,2,3,4]

	Osmolarity (mOsm/L)	pH	Na (mEq/L)	Cl (mEq/L)	K (mEq/L)	Mg (mEq/L)	Ca (mEq/L)	Dextrose (g/L)	Buffers
REPLACEMENT CRYSTALLOID FLUIDS									
Hypertonic Crystalloids									
3% NaCl	1027	5.0	513	513	0	0	0	0	None
5% NaCl	1711	5.0	856	856	0	0	0	0	None
7.5% NaCl	2464	5.2	1283, 1232	1283, 1232	0	0	0	0	None
23.4% NaCl	8008	5.0	4004	4004	0	0	0	0	None
Isotonic Crystalloids									
0.9% NaCl	308	5.6, 5.7 (4.5 - 7.0)	154	154	0	0	0	0	None
Plasma-Lyte A	294	7.4	140	103	5	3	0	0	Acetate, Gluconate
Plasma-Lyte 148	294	5.5	140	98	5	3	0	0	Acetate, Gluconate
Normosol R	294	7.4, 6.6	140	98	5	3	0	0	Acetate, Gluconate
Lactated Ringer's	273	6.7	130	110	4	0	2.7	0	Lactate
MAINTENANCE CRYSTALLOID FLUIDS									
Hypotonic Crystalloids									
Plasma-Lyte 56 in 5% dextrose	363	5.0 (4.0 - 6.5)	40	40	13	3	0	50	Acetate
0.45% NaCl	154	5.5	77	77	0	0	0	0	None
0.45 NaCl in 2.5% dextrose	280	4.5	77	77	0	0	0	25	None
5% dextrose in water	253	5.0, 4.3 (3.2 - 6.5)	0	0	0	0	0	50	None
Normosol M in 5% dextrose	363	5.2	40	40	13	3	0	50	None

1. Rudloff E, Hopper K. 2021. Crystalloid and colloid compositions and their impact. *Frontiers in Veterinary Science*. 8:639848.
2. Strandvik GF. 2009. Hypertonic saline in critical care: a review of the literature and guidelines for use in hypotensive states and raised intracranial pressure. *Anaesthesia*. 64(9):990-1003
3. Holden D, et al. 2023. Hypertonic saline use in neurocritical care for treating cerebral edema: A review of optimal formulation, dosing, safety, administration and storage. *American Journal of Health-System Pharmacy*. 80(6):331-342.
4. Carr CJ, et al. 2021. An audit and comparison of pH, measured concentration, and particulate matter in mannitol and hypertonic saline solutions. *Frontiers in Neurology*. 12:667842.

TABLE 9

Fluid Therapy Dosing According to Stage of Fluid Requirements

Stage	Formula	Rate of Administration	Comments
Resuscitation	**Cat:** 5–10 mL/kg **Dog:** 15–20 mL/kg	15 min	Assess perfusion parameters after bolus. May repeat bolus as needed.
Rehydration	Total fluid deficit (L) = Body weight (kg) × % Dehydration (as a decimal)	Over 12–24 hr	Ongoing losses should be assessed through inputs and outputs and incorporated into the fluid plan.
Maintenance	**Dog:** a. 60 mL/kg/day b. 132 × BW (kg)$^{0.75}$ c. 30 × BW (kg) + 70 = mL/kg/day **Cat:** a. 40 mL/kg/day b. 80 × BW (kg)$^{0.75}$ c. 30 × BW (kg) + 70 = mL/kg/day **Pediatric:** Dog: 3 × adult dose Cat: 2.5 × adult dose	Over 24 hr	Also incorporate enteral water, liquid diets, and IV medications into the total volume of the fluid plan.

BW, body weight

The *2024 Fluid Therapy Guidelines for Dogs and Cats* are available at aaha.org/fluid-therapy.

TABLE 10

Empirical Subcutaneous Fluid Therapy Recommendations

Subcutaneous Fluid Dose	Frequency	Type of Fluid	Comments
20–30 mL/kg	Once or twice a day	• Lactated Ringer's, Plasma-Lyte, or Normosol R • 0.9% NaCl has a low pH and may be painful. Avoid SC use.	• Deliver to multiple sites depending on volume and skin elasticity. Maximum amount is 10–20 mL/kg per site.

SC, subcutaneous

TABLE 11

Guidelines for Potassium Supplementation in Fluids

Serum Potassium Concentration	Suggested Potassium Dose	Suggested Potassium Added to Isotonic Crystalloids at 60 mL/kg/Day for a 10-kg Dog (25 mL/hr)
<2.0 mEq/L	0.5 mEq/kg/hr	200 mEq/L
2.0–2.5 mEq/L	0.3–0.4 mEq/kg/hr	120–160 mEq/L
2.6–3 mEq/L	0.2–0.25 mEq/kg/hr	80–100 mEq/L
3.1–3.5 mEq/L	0.1–0.15 mEq/kg/hr	40–60 mEq/L
>3.5 mEq/L	0.05 mEq/kg/hr	20 mEq/L

TABLE 12A

Approach to Fluid Therapy in Hyponatremic Patients

1. Is hyponatremia acute or chronic?

ACUTE	CHRONIC
A. Raise the serum sodium concentration as quickly as possible. B. Administer isotonic crystalloids with a sodium concentration greater than the patient's serum sodium concentration. C. Recheck serum sodium concentrations 2–4 hr after starting therapy to assess therapeutic response, then recheck them every 6–8 hr afterward.	A. It takes 24–48 hr for the brain to compensate for hyponatremia. B. Correct chronic hyponatremia slowly to prevent osmotic demyelination syndrome. C. Increase the serum sodium concentration by no more than 0.5 mEq/L/hr for a maximum total correction of 10–12 mEq/L/day.

2. Does the patient have clinical signs of hyponatremia?

A. Clinical signs include vomiting, disorientation, and seizures secondary to cerebral edema.
B. If symptomatic, treat with 3, 5, or 7.5% hypertonic saline at a recommended dose of 2–6 mL/kg given over 10–15 min.[1]
C. In human patients, serum sodium concentration increases of 4–6 mEq/L are often enough to alleviate clinical signs.[1]

3. Is the patient hypovolemic?

A. Perform fluid resuscitation: 5-10 mL/kg (cats) or 15-20 mL/kg (dogs) given rapidly over 15–30 min with a buffered isotonic solution capable of expanding the intravascular space (Table 12c).[1]
B. Repeat as needed until perfusion parameters are restored.
Maintenance or hypotonic fluids (0.45% NaCl, 5% dextrose in water) have low sodium concentrations and are not indicated to treat hypovolemia.[1]

4. Does the patient have chronic hyponatremia without neurologic signs?

A. Slowly correct the sodium concentration at a maximum rate of 0.5 mEq/L/hr or 10-12 mEq/L/day.
B. Treat asymptomatic patients with mild water restriction and monitor their serum sodium concentrations.
C. Use the Adrogue-Madias formula below to calculate the expected change in sodium concentration when 1 L of a specific fluid type is administered (see Table 12c).[2]

Expected change in serum sodium concentration with 1 L of fluid =
Fluid sodium concentration − serum sodium concentration / (total body water + 1)
Where total body water = body weight in kg × 0.6

1. Adrogué HJ, Tucker BM, Madias NE. Diagnosis and management of hyponatremia: a review. *JAMA.* 2022;328(3):280-91.
2. Heinz J, Cook A. Evaluation and management of the hyponatremia patient. *Today's Veterinary Practice*. 2022;12(2). February 10, 2022. Available at https://todaysveterinarypractice.com/internal-medicine/evaluation-and-management-of-the-hyponatremic-patient/. Accessed January 4, 2024.

TABLE 12B

Common Causes of Acute and Chronic Hyponatremia in Dogs and Cats

Acute	Chronic*
• Consumption of large amounts of fresh water leading to acute water intoxication • Infusion of significant volumes of non replacement fluids (e.g., administering a 5% dextrose in water solution to a dehydrated patient)	• Congestive heart failure • Hypoadrenocorticism • Liver dysfunction • Nephrotic syndrome • Renal and gastrointestinal sodium loss *Consider that patients with vague clinical signs for longer than 24–48 hours likely have chronic hyponatremia.

TABLE 12C

Sodium Concentration of Isotonic Crystalloids

Lactated Ringer's solution	130 mEq/L
Plasma-Lyte A	140 mEq/L
Normosol R	140 mEq/L
0.9% NaCl*	154 mEq/L

* Evidence in human patients suggests that 0.9% NaCl may be detrimental to kidney health.[1,2]

1. Ostermann M, Randolph AG. Resuscitation fluid composition and acute kidney injury in critical illness. *New England Journal of Medicine.* 2022;386(9):888-889.
2. Sigmon J, May CC, Bryant A, Humanez J, Singh V. Assessment of acute kidney injury in neurologically injured patients receiving hypertonic sodium chloride: does chloride load matter? *Annals of Pharmacotherapy*. 2020;54(6):541-546.

TABLE 12D

Calculating Expected Changes in Sodium Concentration

Stevie, a 10 kg, 5-year-old, male neutered Jack Russell terrier, presented for evaluation of vomiting and diarrhea of 72 hours duration. Stevie was mildly lethargic, but all perfusion parameters (heart rate, capillary refill time, blood pressure, pulse quality) were normal, and no other abnormalities were found on physical examination. Stevie's serum sodium concentration was 115 mEq/L.

Stevie is presumed to have chronic hyponatremia because clinical signs have been present for longer than 48 hours. Stevie does not have neurologic signs, so treatment with a hypertonic saline bolus is not indicated. An isotonic crystalloid bolus is also not indicated because Stevie's perfusion parameters are normal.

To correct the hyponatremia, the Adrogue-Madias formula was used with Normosol R as the fluid of choice:

Expected change in serum sodium concentration with 1 L of Normosol R =

$$\frac{140 \text{ mEq/L} - 115 \text{ mEq/L}}{(10 \text{ kg} \times 0.6) + 1} = 3.57 \text{ mEq/L}$$

Therefore, 1 L of Normosol R will change Stevie's sodium concentration by ~3.5 mEq/L.

If Stevie is treated at 25 mL/hr (60 mL/kg/day), ~600 mL of Normosol R will be administered over 24 hours, which will estimate the sodium change at 2.1 mEq/L.

For a faster correction rate, hypertonic saline may be infused into Normosol R to increase fluid sodium concentration using this formula:

Fluid Na = Patient Na + [Target increase in patient's NA over set time x (TBW + Volume of fluids administered over set time)][1]

TBW = body weight in kg × 0.6

1. Heinz J, Cook A. Evaluation and management of the hyponatremia patient. *Today's Veterinary Practice*. 2022;12(2). February 10, 2022 Available at https://todaysveterinarypractice.com/internal-medicine/evaluation-and-management-of-the-hyponatremic-patient/. Accessed January 4, 2024.

TABLE 13A

Approach to Fluid Therapy in Hypernatremic Patients

1. Is hypernatremia acute or chronic?	
ACUTE	**CHRONIC**
• Use hypotonic intravenous fluids to correct. • Can undergo rapid sodium concentration correction without the risk of cerebral edema. • Calculate the free water deficit and administer at an appropriate rate (see #3 below). • Monitor sodium concentrations every 4-6 hours.	• It takes 24–48 hours for the brain to compensate for hypernatremia. • Correct chronic hypernatremia slowly to prevent cerebral edema. • Decrease serum sodium concentration by no more than 0.5 mEq/L/hr for a maximum total correction of 10–12 mEq/L/day (see #3 below).
2. Is the patient hypovolemic?	
• Perform fluid resuscitation with a buffered isotonic solution capable of expanding the intravascular space. • Maintenance or hypotonic fluids (0.45% NaCl, 5% dextrose in water) have low sodium concentrations and are not indicated to treat hypovolemia. • Fluids listed in Table 12c are suitable options to treat hypovolemia (5-10 mL/kg [cat] and 15-20 mL/kg [dog] given over 15–30 minutes and repeated as needed) until perfusion parameters are restored.	
3. Calculations for chronic and acute hypernatremia	
Estimate the amount of water lost (free water deficit). Administer fluids that are relatively dilute compared with plasma. **Free Water Deficit (FWD) in Liters (L) = [(Patient Na/Desired Na) -1] × (0.6 × Weight [kg])**	Modify the calculation of the free water deficit according to whether hypernatremia is acute or chronic, using the subsequent formulas: **FWD replacement time (hr) for acute hypernatremia = Patient Na − Target Na**[1] **FWD replacement time (hr) for chronic hypernatremia = (Patient Na − Target Na) × 2**[1] In general, replace the free water deficit by administering 5% dextrose in water.
4. Is the patient dehydrated?	
• Simultaneously treat by administering a buffered isotonic crystalloid (Table 12c). • Correct dehydration over 12–24 hours to minimize shifts in sodium.[1] • Recheck sodium concentrations every 4–6 hours to prevent dramatic changes. • Limit drinking water until the patient's sodium is close to the target concentration.	

1. Heinz J, Cook A. Evaluation and management of the hyponatremia patient. *Today's Veterinary Practice*. 2022;12(2). February 10, 2022. https://todaysveterinarypractice.com/internal-medicine/evaluation-and-management-of-the-hyponatremic-patient/. Accessed January 4, 2024.

TABLE 13B

Common Causes of Acute and Chronic Hypernatremia in Dogs and Cats

<table>
<tr><th>ACUTE</th><th>CHRONIC</th></tr>
<tr><td rowspan="3">Intake of large amounts of sodium chloride (ingestion of salt water, homemade playdough, or salt)</td><td>Hypotonic fluid losses (diarrhea, peritonitis, vomiting, kidney disease)</td></tr>
<tr><td>Nephrogenic diabetes insipidus</td></tr>
<tr><td>Heatstroke</td></tr>
<tr><td colspan="2">Infusion of replacement fluids or hypertonic fluids may lead to acute or chronic hypernatremia, depending on how often the patient’s sodium concentration is rechecked during hospitalization.</td></tr>
</table>

The *2024 Fluid Therapy Guidelines for Dogs and Cats* are available at aaha.org/fluid-therapy.

TABLE 14

How to Formulate Dextrose-Containing Fluids

Amount of 50% Dextrose Solution Added to 1L Bag of Isotonic Crystalloids*	Final Dextrose Concentration
25 mL	1.25%
50 mL	2.5%
100 mL	5%

*Remove an equivalent amount of the isotonic crystalloid fluid from the bag before adding dextrose.

TABLE 15

Clinical, Radiographic, and Ultrasonographic Findings Associated with Fluid Overload

Clinical Findings	Radiographic Findings	Ultrasonographic Findings
• Increased body weight (>10%) • Tissue edema (intermandibular area, limbs, paws, dependent regions, chemosis) • Serous nasal discharge • Serous discharge from endotracheal tube in anesthetized patients • Increased respiratory rate or effort • Reduced SPO_2 • Novel murmur, novel gallop sound • Gastrointestinal signs (abdominal distention, vomiting, diarrhea, inappetence, anorexia) • No change in blood pressure; hypertension rarely associated with fluid overload except in AKI/CKD.[1,2]	• Body wall edema • Pleural effusion • Pulmonary edema • Cardiomegaly • Enlarged pulmonary artery • Enlarged caudal vena cava • Enlarged pulmonary vein • Loss of serosal detail • Distended intestines	• Subcutaneous edema • Pleural effusion • B-lines • Enlarged La:Ao • Enlarged caudal vena cava • Decreased caudal vena cava collapsibility index • Ascites • Intestinal wall thickening • Ileus • Hyperechoic mesentery and pancreas • Hepatic congestion • Gallbladder wall edema • Perirenal edema

AKI, acute kidney injury; Ao, aorta; CKD, chronic kidney disease; La, Left atrium; SpO2, oxygen saturation

1. Cole LP, Jepson R, Dawson C, Humm K. Hypertension, retinopathy, and acute kidney injury in dogs: A prospective study [published correction appears in *J Vet Intern Med*. 2020 Nov;34(6):3168]. *J Vet Intern Med*. 2020;34(5):1940-1947.
2. Park S, Lee CJ, Lee M, et al. Differential effects of arterial stiffness and fluid overload on blood pressure according to renal function in patients at risk for cardiovascular disease. *Hypertens Res*. 2019;42:341–353.

TABLE 16

Intravenous Fluid Delivery Modes

Method of Delivery	Considerations
Fluid pump	• Limits of very high and, possibly, very low rates of administration • Maximum administration rate can limit ability to rapidly deliver a bolus with large fluid volumes
Syringe pump	• Limited to small volumes • Attach the extension set close to the IV catheter to ensure patient receives the infusion in a timely manner
Gravity drip set	• Need to calculate drip rate: Fluid rate (mL/h) × Drip factor (gtt/mL)/3600 = gtt/s • Patient movement or changes to bag placement can affect drip rate • Close monitoring is essential because there are no alarms
Buretrol	• Used in conjunction with a fluid pump • Prevents delivery of large fluid volume to small patients • Allows for smaller volumes of additives, leading to less waste in smaller patients or in cases of frequent changes to fluid plans
Syringe	• Hand administration of small volumes • Do not leave attached to a patient while unattended
Pressure bag	• Ideal when volume to be infused over given time exceeds the capabilities of a fluid pump and gravity set

gtt, drop; s, second

TABLE 17

Peripheral Intravenous Catheter Placement and Care Checklist

Large bore/ gauge, short cannula	• Larger gauge, short catheters provide less resistance to blood flow than longer, smaller gauge catheters.[1] Ideal to have in place should a need for rapid infusion arise.
Aseptic preparation and care	• See the *AAHA Infection Control, Prevention and Biosecurity Guidelines* protocol for IV catheters at www.aaha.org/resources/2018-aaha-infection-control-prevention-and-biosecurity-guidelines/
Secure catheter	• Secure the first piece of tape to the catheter as an anchor. Use the smallest amount of tape possible and tab the tape ends for easy removal. • Use additional bandage material as needed. Be careful not to secure too tight or too loose to avoid swelling or premature dislodgement.
Daily maintenance	• Check catheters at least two times per day. Fully unwrap bandage material covering the tape to examine the catheter site for signs of swelling or thrombophlebitis. Remove the catheter and place another one if indicated. • Evidence in human patients shows that routine catheter replacement does not provide any benefit over replacing peripheral catheters when clinically indicated.[2]
Clean ports when disconnecting	• Wipe ports with isopropyl alcohol. • Needleless injection and connection ports are preferred.

1. Reddick AD, et al. Intravenous fluid resuscitation: was Poiseuille right? *Emerg Med J*. 2011;28(3):201-2.
2. Webster J, Osborne S, Rickard CM, Marsh N. Clinically-indicated replacement versus routine replacement of peripheral venous catheters. *Cochrane Database Syst Rev*. 2019;1(1):CD007798.

TABLE 18

Monitoring Fluid Delivery

Method of Delivery	Monitoring
Fluid pump **Buretrol**	• Set TVI to 0 at start. Document every 2–4 hours. • Set VTBI for time frame between checks.
Syringe pump	• Set TVI to 0 at start. Document every 2–4 hours. • Set VTBI for time frame between checks.
Gravity drip set **Pressure bag**	• Mark top of fluids on bag at start and document every 1–2 hours. • Monitor more frequently due to a higher risk of changes in volume delivered (e.g., every five minutes for volumes delivered over 15-20 minutes).
Syringe	• Use only for bolus administration. Do not leave attached to patient.

TVI, total volume infused; VTBI, volume to be infused

TABLE 19

Evaluation and Monitoring Parameters That May Be Used for Patients Receiving Fluid Therapy[a]

- Pulse rate and quality*
- Capillary refill time
- Mucous membrane color
- Respiratory rate and effort
- Lung sounds
- Skin turgor
- Body weight
- Urine output
- Mental status
- Extremity temperature
- Packed cell volume/total solids
- Total protein
- Serum lactate
- Urine specific gravity
- Blood urea nitrogen
- Creatinine
- Electrolytes
- Blood pressure
- Venous or arterial blood gasses
- O_2 saturation

[a] Reprinted from Davis H, Jensen T, Johnson A, et al. 2013 AAHA/AAFP fluid therapy guidelines for dogs and cats. *J Am Anim Hosp Assoc.* 2013;49(3):149-59.

* Including cardiac auscultation to identify new murmurs

TABLE 20

Methods to Monitor Fluid Outputs and Inputs

Urine output • Urinary catheter with a closed collection system • Absorbent training pads • Non absorbent litter • Free-catch urine collection during walks
Vomit and diarrhea volume estimates
Feeding tube • Amount delivered • Amount of residual content in stomach
Body weight
Drain output

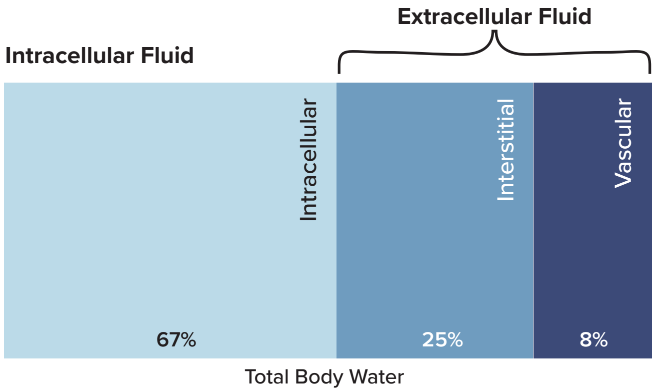

FIGURE 1

Normal distribution of body water

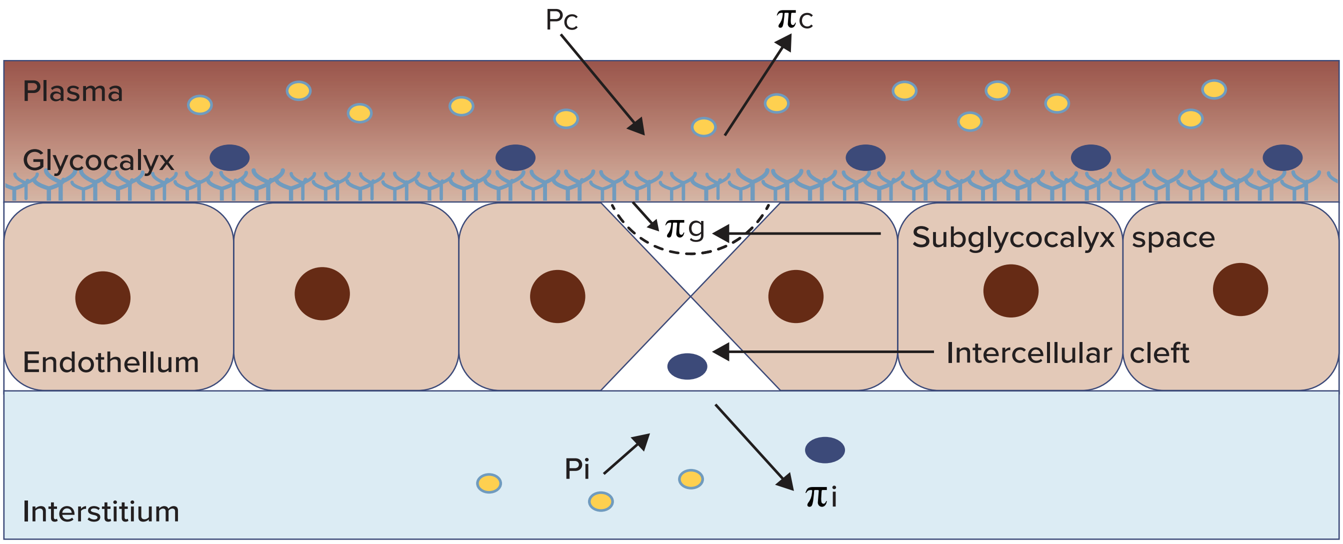

FIGURE 2

Modified Starling hypothesis[a]

Modified Starting hypothesis of fluid flux across the capillary membrane. Filtration force = $([P_c - P_i] - \sigma [\pi_p - \pi_g])$. P_c, Capillary hydrostatic pressure; P_i, Interstitial hydrostatic pressure; π_p, plasma oncotic pressure; π_i, interstitial oncotic pressure; π_g, glycocalyx oncotic pressure

[a] Reprinted from Silverstein DC and Hopper K, eds., *Small Animal Critical Care Medicine*, 3rd ed., Waddell L., Colloid osmotic pressure and osmolality, p. 1055, Elsevier (2022), with permission from Elsevier.

Hypovolemia

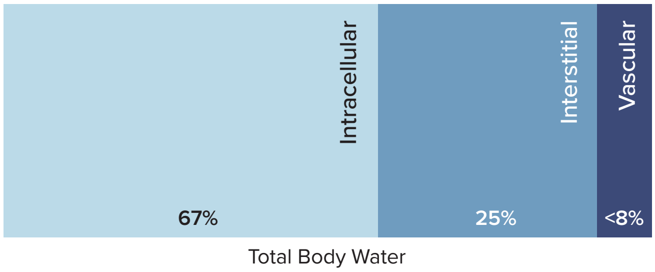

FIGURE 3

Hypovolemia results in a decreased volume within the vascular space. Acute hypovolemia primarily affects this compartment. As the severity and duration of hypovolemia persist, it can affect other compartments as well.

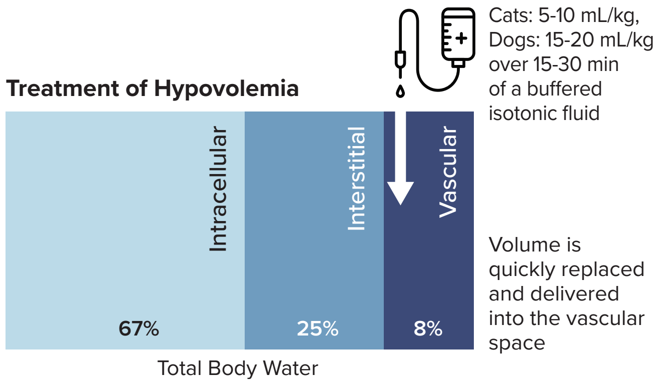

FIGURE 4

Treatment of hypovolemia requires rapidly delivering fluid into the vascular space to restore the effective circulating volume.

Dehydration and Euvolemia

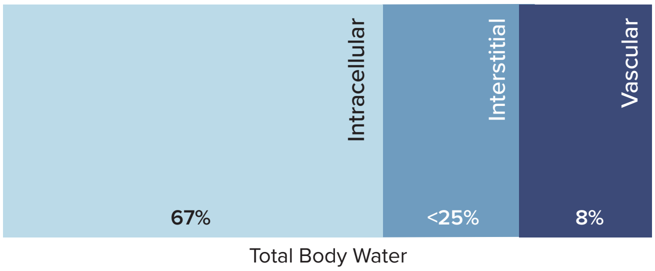

FIGURE 5

Dehydration results in a decreased volume within the interstitial space.

The *2024 Fluid Therapy Guidelines for Dogs and Cats* are available at aaha.org/fluid-therapy.

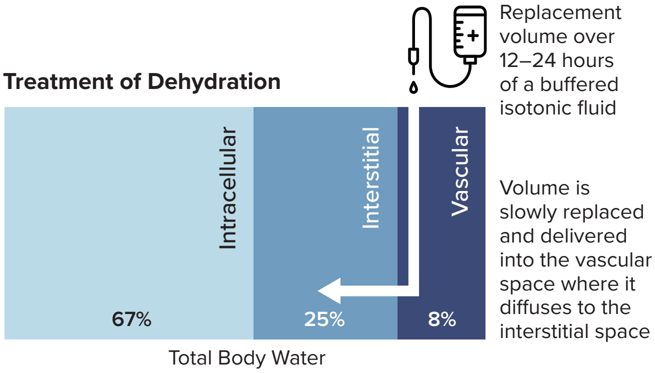

FIGURE 6

Treating dehydration requires slow, sustained delivery of intravascular fluids, which will be slowly absorbed into the interstitial space over 12-24 hours. Subcutaneous and oral routes are not depicted; however, these routes also correct dehydration.

Severe Dehydration and Hypovolemia

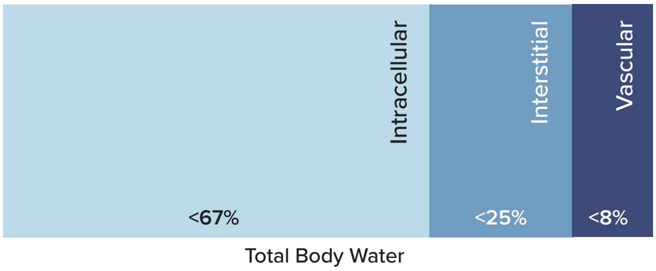

FIGURE 7

Dehydration results in a decreased volume within the interstitial space. As dehydration worsens, it can affect the vascular and intracellular compartments as well, leading to dehydration with concurrent hypovolemia.

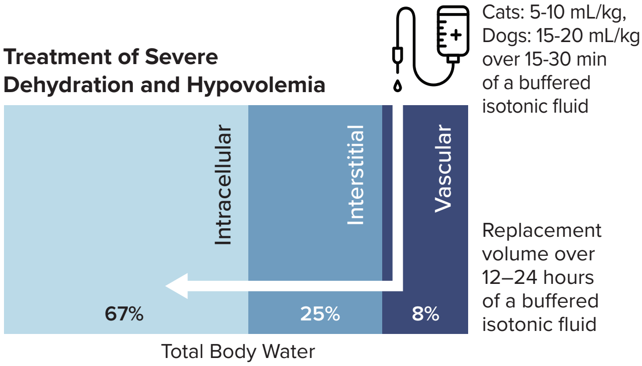

FIGURE 8

Treatment of severe dehydration and hypovolemia requires a two-fold strategy. First, correct hypovolemia by rapidly delivering intravascular fluids and restoring the effective circulating volume. Once the hypovolemia has resolved, address dehydration with the slow and sustained delivery of intravascular fluids administered over 12-24 hours.

Is the patient adequately hydrated despite fasting?

- yes → Start crystalloid fluid therapy at 3–5 mL/kg/hr
- no → Estimate percent dehydration and correct volume deficit before anesthesia

If the patient becomes hypotensive (mean arterial pressure <60 mm Hg) during the procedure:

↓

Assess depth of anesthesia and reduce vaporizer setting if possible.

↓

Assess body temperature and provide active warming as needed.

↓

Administer additional analgesics, sedatives, and local anesthetics if possible to help reduce vaporizer setting.

If hypotension persists:

↓

Administer a crystalloid fluid bolus: 5 mL/kg over 10 minutes

If hypotension is refractory to crystalloid fluid administration:

↓

1. Administer sympathomimetic therapy if needed:
   - Ephedrine 0.05–0.2 mg/kg IV bolus
   - Norepinephrine CRI 0.05–1 µg/kg/min
   - Dobutamine CRI 1–10 µg/kg/min
   - Epinephrine CRI 0.05–1 µg/kg/min
2. Administer a colloid bolus: 2–5 mL/kg over 10 minutes.
3. In patients with severe or ongoing hemorrhage, address with appropriate blood products such as whole blood or packed red blood cells.

If hypotension resolves:

↓

Return to the initial 3–5 mL/kg/hr of crystalloid fluid therapy, unless there is suspicion of fluid overload.

FIGURE 9

Fluid Therapy During Anesthesia

CRI, continuous rate infusion

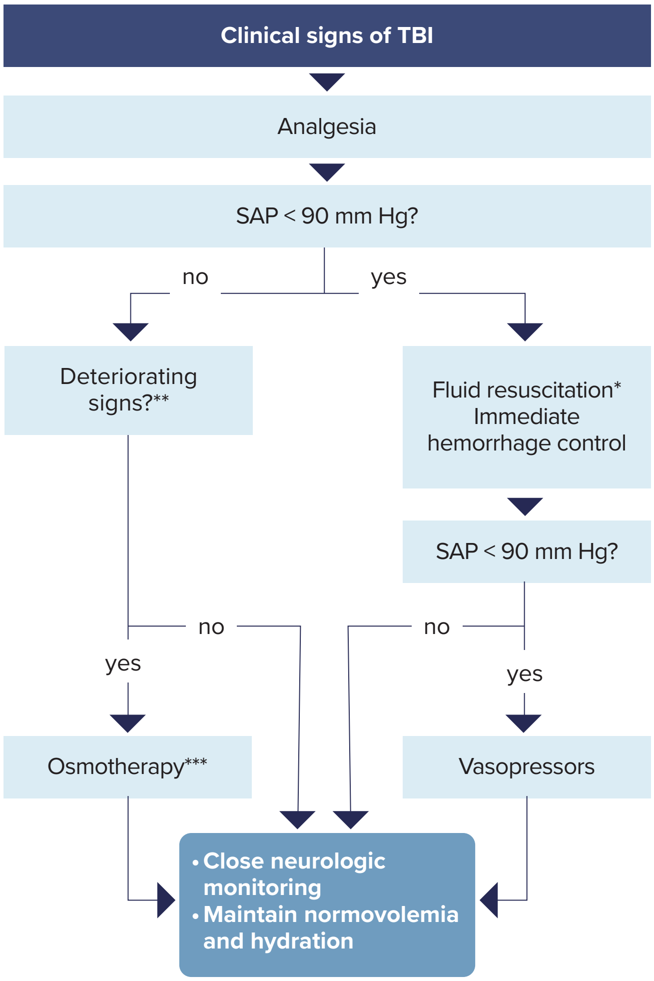

FIGURE 10

Approach to Fluid Therapy for Dogs and Cats with Traumatic Brain Injury

* Fluid resuscitation techniques can be any one of the following or a combination thereof: (1) 10–20 mL/kg crystalloids (Plasma Lyte or Normosol-R) IV rapid infusion up to 60–90 mL/kg. (2) 5–10 mL/kg 6% HES (tetrastarch) IV rapid infusion up to 40–50 mL/kg. (3) 5–10 mL/kg plasma rapid infusion IV up to 20–30 mL/kg. (4) 3–4 mL/kg 7% HTS IV over 10–15 min. (5) Whole blood or pRBC, if indicated.

**Altered level of consciousness with or without bilateral or unilateral miotic pupils; unresponsive mid range pupil(s) or mydriasis; loss of the oculocephalic reflex; bradycardia with hypertension (Cushing reflex); posturing (opisthotonus, decerebellate, decerebrate); alteration of the respiratory pattern.

***1 g/kg mannitol IV up to 3 doses *q* 60–90 min OR 3–4 mL/kg 7% HTS IV.

[d] Reprinted with permission from Pigott A, Rudloff E. Traumatic brain injury–a review of intravenous fluid therapy. *Front Vet Sci*. 2021;8:643800.

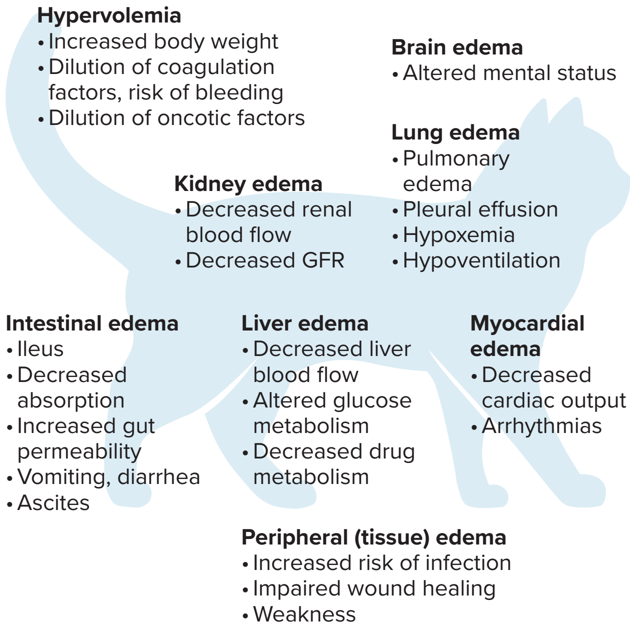

FIGURE 11

Impact of Fluid Overload on Organ Function

The *2024 Fluid Therapy Guidelines for Dogs and Cats* are available at aaha.org/fluid-therapy.

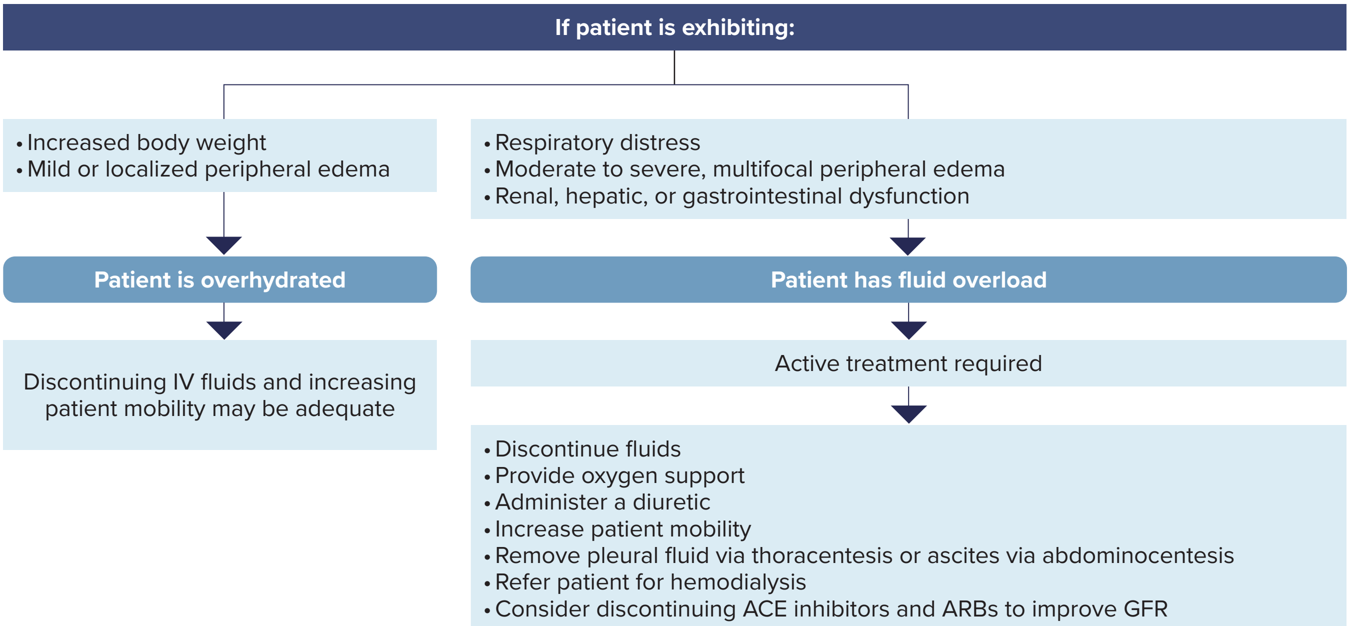

FIGURE 12

Fluid Overload Therapy Algorithm

ACE, angiotensin-converting enzyme; ARBs, angiotensin receptor blockers; GFR, glomerular filtration rate