

KASHVET VETERINARIAN RESOURCES

FLUID THERAPY AND SELECTION OF FLUIDS

INTRODUCTION



Formulating a fluid therapy plan for the critical small animal patient requires careful determination of the current volume status. Once a need for fluids has been established, it must be determined which fluid compartment (s) are involved in the pathology (intravascular, interstitial, or intracellular) and what components need to be supplemented or reduced in the fluids administered. The volume and rate of administration will be guided by pathologic conditions such as cardiac disease, systemic inflammatory response syndrome diseases, fluid loss into the third body fluid space, blood pressure, and pulmonary and cerebral edema. The volume of fluid and rate of administration must be more accurate in the critically ill than in the usual hospital patient. The kidneys and cardiovascular system, which can correct most fluid therapy miscalculations, may be compromised in the critically ill animal. Fluid therapy is used to replace intravascular volume (perfusion), to replace interstitial fluid volume (dehydration), or to correct electrolyte abnormalities (hypercalcemia, hypokalemia, hyper- or hyponatremia). It is important to understand the dynamics that occur between the fluid compartments and the specific components of each fluid to select the best fluid for the individual situation.

FLUID COMPARTMENT DYNAMICS

Sixty per cent of body weight is water. Of this water, $\frac{2}{3}$ is intracellular, and $\frac{1}{3}$ is extra cellular. Of the body water that is extra cellular, $\frac{1}{4}$ is intravascular, and $\frac{3}{4}$ is interstitial. The membranes separating these compartments are freely permeable to water, which moves under the force of osmotic pressure until the osmolality of each compartment is equal. When "free water" (no osmotically active particles) is added to one body compartment, it is distributed evenly throughout all body water compartments. The replacement of 3 L of free water in the intravascular space results in a net increase of only 250 mL in the intravascular volume after equilibration; ~30 min later, only 8% of the free water infused remains in the intravascular space. When an isotonic solution with plasma is infused, distribution of the fluid is different. With no difference in osmolality, there is no osmotic pressure to cause the water to move into the intracellular space. The membrane separating the intravascular and interstitial compartments is freely permeable to water and small ions, while the membrane surrounding the intracellular space is not. But only $\frac{1}{4}$ of the volume of isotonic fluids infused remains in the intravascular space after 30 min due to the influences of osmotic and hydrostatic forces. The intravascular and interstitial fluid compartments are separated by a semi permeable membrane. In solution in the intravascular compartment are large molecular weight molecules, called colloids, that cannot easily cross the membrane because of the minute size of the membrane pore.

The force exerted on the membrane due to the osmotic gradient created by these colloids is called the colloidal osmotic pressure (COP). The natural particles in blood that create COP are proteins—globulins, fibrinogen, and albumin. Albumin is the smallest, ~69,000 Daltons, and most numerous. Whether or not fluid remains in the intravascular space or moves into the interstitium is the result of the differences between the COP and hydrostatic pressure in the two compartments. When intravascular hydrostatic pressure is increased over COP, membrane pore size increases, or intravascular COP becomes lower than interstitial COP, fluid moves into the interstitial space. When this is replenishing an interstitial volume deficit, the result is rehydration. An excessive volume is edema. The usual pressure pushing the fluid across the semi permeable membrane is 17 mm Hg. A total protein of 5.2-5.4 g/dL usually creates a COP of 17 mm Hg. A total protein below this range indicates that colloids should be included in fluid therapy; continued administration of crystalloids will increase the intravascular hydrostatic pressure, further dilute total protein, and accelerate fluid flow across the membrane.

FLUID COMPARTMENT DEFICITS

Fluid deficit in the intravascular space results in poor perfusion and inadequate tissue oxygenation. This volume deficit results in a lower vessel wall tension and stimulation of the baroreceptors. Perfusion parameters include heart rate, pulse intensity, capillary refill time, mucous membrane color, and rectal temperature. Fluids (colloids) must be administered that will remain in the intravascular space, increase the vessel wall tension, and obliterate the need for the baroreceptor compensatory response. Most animals with an intravascular deficit (poor perfusion) also have concurrent extra vascular deficits that warrant the simultaneous administration of colloid and crystalloid solutions. Fluid deficit in the extra vascular space (interstitial and intracellular) causes dehydration. This results in tenting of the skin, dry mucous membranes, sunken eyes, and dullness to the cornea. However, perfusion can be adequate. To replenish the extra vascular spaces, crystalloid fluids that are the same tonicity as plasma are used. Crystalloids are water-based solutions with low molecular weight molecules that are freely permeable to the capillary membrane. The concentration of these molecules in relation to normal plasma indicates the tonicity of the fluid. If the concentration is similar to normal plasma, the solution is called isotonic. Over 75% of the isotonic crystalloid administered IV will be in the extra vascular space within 1 hr in a normal animal; this is due to the normal fluid shifts between fluid compartments. Physical and laboratory parameters are used to assess hydration. The following gross physical findings can be used as a guideline to estimate the percentage of dehydration in many animals. Semidry oral mucous membranes, normal skin turgor, and eyes maintaining normal moisture indicate 4-5% dehydration. Dry oral mucous membranes, mild loss of skin turgor, and eyes still moist indicate 6-7% dehydration. Dry mucous membranes, considerable loss of skin turgor, eyes retracted, and weak rapid pulses indicate 8-10% dehydration.

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Very dry oral mucous membranes, complete loss of skin turgor, severe retraction of the eyes, dull eyes, possible alteration of consciousness, and thready weak

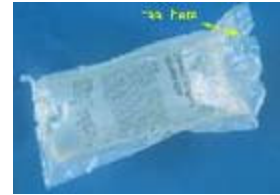
pulses indicate 12% dehydration. It is important to note at least two common clinical situations in which these physical guidelines are misleading. First, the chronic emaciated animal may have metabolized the fat from around its eyes and the collagen in the skin. These animals have poor skin turgor and sunken eyes but may be normally hydrated. In this situation, assessment of mucous membrane moisture, PCV, and total proteins is important. Second, the animal with rapid fluid loss (third body fluid space) will require a greater volume of fluid than would be estimated from physical signs. Fluid will shift rapidly from the intravascular compartments into these spaces before clinical evidence of interstitial fluid loss is seen. Both situations require evaluation of PCV and total solids before dehydration can be estimated. The intravascular space can be replenished using crystalloid solutions alone. However, large quantities of crystalloids can be required to provide volumes sufficient to blunt the baroreceptor response after 1 hr of infusion. For example, if a dog loses 500 mL of fluid from the intravascular compartment, to have this volume remaining intravascularly after 1 hr of administration, 2,000 mL of fluids must be administered. Of this volume, 500 mL will remain intravascularly (if the COP, hydrostatic pressures, and vessel wall integrity are normal) and 1,500 mL will move interstitially. The extra interstitial volume for a short period does not cause a problem in most animals, and normal renal function will eventually excrete the additional volume. However, the brain and heart do not have "forgiving" interstitial spaces in disease, and additional interstitial fluid can cause organ failure. Many disease processes result in increased permeability of the capillaries of the body. These diseases are a result of systemic inflammatory responses and include parvovirus diarrhea, pancreatitis, septic shock, massive trauma, heat stroke, cold exposure, burns, snake bite, and systemic neoplasia. Increased vessel permeability is an additional factor that favors movement of crystalloid fluid from the intravascular space into the interstitial space. This makes maintaining intravascular volume difficult. A combination of a large molecular weight colloid (to hold the water in the vessels) and crystalloids (to replenish the interstitial spaces) is recommended. In addition, many of these animals have a third body fluid space (a space within the body cavity where fluid from the local interstitial and intravascular spaces leak). This is most likely due to significant regional inflammation. The end result is massive fluid requirements, which makes maintaining fluid balance (especially intravascular) difficult. It is almost impossible to predict how much fluid will be required to maintain perfusion and hydration in these critically patients. Fluid selection becomes critical, and monitoring central venous pressure and blood pressure is indicated.

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FLUID SELECTION

Overview

Criteria for proper fluid selection begins with deciding where the deficit is and deciding the type of fluid to administer: crystalloid versus colloid, or a combination of both.



Colloids

When colloids are to be administered, it must be decided whether natural colloids (eg, plasma or whole blood) or a synthetic colloid is to be used. When the animal requires RBC, clotting factors, antithrombin III, or albumin, blood products are the colloids of choice. During maintenance therapy, when the albumin is <2 g/dL, fresh frozen plasma is the colloid of choice. However, as many as 6 u of plasma can be required in large dogs to achieve the total desired oncotic effect. Therefore, plasma should be administered until the albumin is >2 g/dL, and then synthetic colloids are used to add the remaining volume. When the initial goal is to rapidly improve perfusion in an animal without obvious significant blood loss, a synthetic colloid can achieve the desired volume expansion rapidly. However, when massive fluid and protein extravasation through the capillaries due to the actions of inflammatory mediators, decreased systemic vascular resistance, continued loss into third body fluid spaces, and ongoing fluid losses (through vomiting, diarrhea, fever, or excessive urination) are anticipated, total body albumin is significantly decreased, intravascular and interstitial volume deficits occur, and supranormal colloidal oncotic pressure is required. Choices of synthetic colloids include gelatins, dextran, and hydroxyethyl starch (HES).

Hetastarch is a polymeric substance made from a waxy species of either maize or sorghum and is composed primarily of amylopectin (98%). Hetastarch is the type of HES that is clinically available at this time. Hetastarch has an average molecular weight of 450,000 daltons and a half-life of 25.5 hr. Infusions increase the intravascular volume equal to or greater than the volume infused. Care must be taken to avoid intravascular overload. Hetastarch is associated with minor alterations in laboratory coagulation measurements but not with clinical bleeding. Dilutional effects on coagulation cells and proteins are produced in response to the volume expansion of the plasma. In shock, hetastarch can be given at 10-20 mL/kg as a rapid IV bolus in dogs. When systemic inflammatory response syndrome diseases cause increased capillary permeability, hetastarch at 20 mL/kg/day is given after the initial boluses as a constant rate infusion to maintain the colloidal oncotic pressure. In cats, administration is done similar to small volume fluid therapy. Perfusion is monitored, and hetastarch is given in increments of 5 mL/kg slowly over 5-8 min, and repeated until pressures and cardiac output are acceptable. In cats, hetastarch is then immediately administered at 10-15 mL/kg, every 24 hr, as a constant rate infusion (~3-5 mL/hr/cat).

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Dextran 40 has an average molecular weight of 20,000-40,000, and dextran 70 has an average molecular weight of 70,000, with half-lives of 2.5 hr and 25.5 hr, respectively. Dextran 40 has been associated with acute renal failure, anaphylaxis, and a bleeding diathesis. Dextran 70 has rarely been associated with acute renal failure. Blood glucose and bilirubin values can be falsely increased. Dextrans can also interfere with blood crossmatching. Dextran is not an anticoagulant, but its antithrombotic effects are due to hemodilution of blood and to a temporary change in the function of factor VIII:Ag, which decreases platelet aggregability and thrombus stability. Dosage and administration guidelines are the same as for hetastarch.

A modified fluid gelatin (Vetaplasma™), produced from cattle-bone gelatin, prepared by gradual controlled heating and chemical hydrolysis of raw material, is available. The average molecular weight of this gelatin preparation is 22,000-24,000 daltons. The osmotic effect lasts only 4-6 hr. Little is known about the overall degradation of gelatins in blood and whether or not proteolytic enzymes are responsible for hydrolysis or about removal of the extravasated chemically modified gelatins. General antibodies to raw unmodified gelatin are found in animals, including man. The incidence of anaphylactic reactions is higher for the standard modified fluid gelatins than for either dextran or HES. A dilutional coagulopathy has been reported but has not been associated with renal failure. Dosage and administration guidelines are the same as for hetastarch.

Crystalloids

The particular crystalloid to administer is determined by the measured or estimated sodium and potassium concentrations and by the osmolality of both the animal's serum and the fluid to be administered. The pH of the fluid infused is important, as is the animal's serum protein or albumin concentration. When blood parameters are unknown, it is best to select a fluid with electrolyte content, pH, and osmolality most like serum (eg, lactated Ringer's, Plasmalyte-A®, Normosol-R®).

Sodium Content: When serum sodium estimations are normal, a balanced electrolyte solution can be used for volume replacement. Lactated Ringer's, Normosol-R®, and Plasmalyte-A® are isotonic solutions with sodium concentrations similar to that of serum. In animals with decreased serum sodium content, volume replacement should be with isotonic saline (0.9%). If the serum sodium is measured at <115 mEq/L (resulting in neurologic abnormalities), care must be taken not to increase the sodium concentration too quickly. Increased serum sodium values most commonly reflect a loss of solute-free water. The animal should be reperfused and rehydrated using an isotonic fluid. Then the free water can be replaced using 2.5% dextrose in half-strength lactated Ringer's, 2.5% dextrose in half-strength saline, 0.45% saline, or 5% dextrose in water. This must be done carefully, and the sodium concentration lowered slowly. Solutions containing low sodium, such as 2.5% dextrose in half-strength lactated Ringer's, are indicated in cardiogenic shock when sodium administration and its resultant

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fluid shift can lead to volume overload and worsening of edema. These solutions can also be used as maintenance solutions in animals in which renal function is compromised.

Potassium Content: When serum potassium estimations are normal, a balanced electrolyte solution can be used. Hypokalemia can be difficult to recognize clinically. Few clinical situations warrant potassium supplementation beyond the content of lactated Ringer's or Plasmalyte-A® during initial volume replacement. Once the animal has been stabilized, potassium chloride should be added to the fluids, administered at a rate ≈ 0.5 mEq/kg body wt/hr. Serum potassium values should be obtained before supplementation when possible. In animals with hyperkalemia, fluids should be selected carefully. When oliguric renal failure is suspected as the cause of the hyperkalemia, potassium-free solutions, such as 0.9% saline, should be used for volume replacement. Clinical conditions requiring potassium-free solutions include acute and chronic oliguric renal failure, heat stroke, adrenal insufficiency, and massive muscle breakdown. When it is determined that the hyperkalemia will resolve after volume replacement and fluid diuresis (such as in feline urethral obstruction), a balanced electrolyte solution should be used. These solutions have a normal pH and promote potassium excretion.

Osmolality: Osmolality is defined as the number of solute particles per unit of solvent. Four main serum components are responsible for normal serum osmolality: sodium, potassium, blood urea nitrogen, and glucose. Normal serum osmolality is 290-310 mOsm/L. Animals with increased serum glucose or sodium or markedly increased BUN values have hyperosmolar serum. Fluids that do not contribute significantly to serum osmolality (eg, Lactated Ringer's, Normosol-R®, Plasmalyte-A®, and normal saline) should be used for volume replacement. Solutions that are slightly hypotonic (eg, 2.5% dextrose in half-strength lactated Ringer's) may be required for maintenance. Hyperosmolar solutions include hypertonic saline and Normosol-M® with 5% dextrose, or any isotonic fluid that has glucose added. Except for hypertonic saline, the hyperosmolar glucose-containing solutions are meant to be maintenance solutions used in animals in which fluids are not shifting rapidly from the vascular compartment to a third body fluid space. They are usually not used as volume replacement solutions. Hypertonic saline provides a supranormal concentration of sodium and is generally given in a 3%, 7%, or 7.5% solution. The effect of the IV administration of hypertonic saline solutions is to rapidly draw water from the interstitial space into the intravascular space (due to the attraction of sodium for water) and to rapidly expand the intravascular volume. However, it must be remembered that adequate interstitial fluid is required to get the desired effect. In addition, because these solutions are crystalloids, the fluid will extravasate into the interstitium within 1 hr in a normal animal, and possibly sooner in a diseased animal. It is common practice to administer hypertonic saline with a colloid, so that the water

brought into the intravascular space can be at least partially retained there by the colloid. Hypertonic saline is given at 6-8 mL/kg in dogs and 2-6 mL/kg in cats. Hetastarch is given at 20 mL/kg in dogs and 10-15 mL/kg (more slowly in 5 mL/kg boluses) in cats. Crystalloids are given at a rapid rate, with the volume titrated to effect.

Rates and Volume of administration

The initial condition of the animal must be accurately assessed through historical, physical and laboratory findings. Inciting causes, duration of signs, and observed loss of body fluids will aid in determining fluid rate and volume. Perfusion and hydration must be determined. Poor perfusion and low blood pressure due to hypovolemia mandate rapid volume replacement, preferably with a combination of colloid and crystalloid. Hypotension associated with heart failure rarely requires rapid volume replacement. In this instance, hypotension is due to poor heart pump action, rather than to hypovolemia. Rates above maintenance are rarely required, and low-sodium fluids should be selected. Animals with pulmonary edema from noncardiogenic causes will have substantial pulmonary capillary leakage leading to volume deficits, both intravascular and interstitial. Judicious fluid therapy using a colloid and crystalloid combination is warranted. When crystalloids alone are used for perfusion, a complete blood volume (dogs: 90 mL/kg; cats: 45-60 mL/kg) can be replaced in 1 hr. When colloids and crystalloids are used together, the colloids are administered as a bolus, and the amount of crystalloids required is reduced by 40-60% of what would have been administered had crystalloids been used alone. Maintenance fluid therapy is meant to replace both ongoing and insensible losses. When there is no vomiting, diarrhea, fever, or loss into the third body fluid space, the average maintenance rate is 40-60 mL/kg/day. With a fever, the maintenance rate increases by 15-20 mL/kg/day. Fluid losses through vomiting, diarrhea, the third body fluid space, and polyuria must be estimated and replaced as indicated. In formulating the overall plan for fluid therapy, the perfusion deficits should be corrected as quickly as possible using a combination of colloid and crystalloid. Then, the interstitial fluid deficit should be estimated by evaluating the degree of dehydration (Fluid Compartment Deficits). This total fluid deficit is divided by the number of hours (generally 6-8) over which the rehydration will occur. The hourly maintenance fluid rate is added to the hourly rate for rehydration to determine the total hourly fluid infusion rate. Hydration status should be closely monitored to determine if the rate or volume requires adjustment.

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