Introduction to Fluid Therapy

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Introduction

Fluid therapy is an important component of everyday veterinary medicine. In order for fluid therapy to be effective, we must have a basic understanding of what we are trying to achieve. In veterinary medicine, fluid therapy is a supportive measure, and the underlying disease process that has caused a fluid or electrolyte imbalance must be diagnosed and managed appropriately.

The ultimate goal of any fluid therapy is to improve or maintain the delivery of oxygen to tissues. Oxygen delivery (DO_2) is dependant on cardiac output (CO), hemoglobin (Hb) concentration in blood, and the arterial oxygen concentration of arterial blood. These relationships are summarized in the following equation:

$$\text{Oxygen Delivery } (DO_2) = \text{CO} \times \text{Arterial Oxygen Content}$$

Fluid Compartments

Total body water accounts for 70% of the body's mass. The body is divided into several compartments or spaces. In a fluid therapy plan, each fluid compartment or space must be considered. Body fluid spaces should be imagined as volumes or compartments of water and electrolytes in dynamic equilibrium.

Body fluids are distributed either within cells – the intracellular fluid compartment, or outside cells – the extracellular fluid compartment. Extracellular fluid (ECF) constitutes one-third of the body's water content, and is made up of blood and interstitial fluid. The ECF can be further divided into interstitial fluid (3/4 of the ECF) and intravascular fluid (1/4 of the ECF, or 7% of total body weight).

Cerebrospinal fluid (CSF), gastrointestinal fluid, lymph, bile, glandular and respiratory secretions, and synovial fluid are known as transcellular fluids as they are produced by the action of specific cells. They are readily exchangeable with ECF so can be included in the ECF.

From this information we can see that when we give intravenous fluids we are only accessing a small portion ($^1/_{12}$) of the body's fluid space. Part of our fluid plan must involve the concept that intravenous fluid will redistribute to other fluid spaces within the body.

Types of Intravenous Fluids

Crystalloids

Crystalloids – Crystalloid fluids are electrolyte and dextrose based solutions. Examples include Lactated Ringers' solution, 0.9% NaCl, hypertonic saline, 5% dextrose, and PlasmaLyte. Crystalloid solutions vary in their electrolyte composition, and may be classified as replacement, or maintenance solutions.

1. Replacement crystalloid solutions have a sodium concentration similar to that of normal plasma (140-160 mEq/L). They are generally used to replace electrolytes lost from the plasma such as in shock, vomiting, and blood loss.
2. Maintenance solutions contain sufficient sodium to replace normal daily losses associated with respiration, urination, and sweat. These solutions have a sodium concentration around 70 mEq/L. They also contain more potassium (15-30 mEq/L) than replacement solutions.
3. Hypertonic saline: This is a special group of sodium containing solutions with a very high concentration of Na (3%, 7% or 20% NaCl) that can be used to rapidly pull water into the intravascular space during intravascular volume resuscitation.
4. Dextrose Solutions: 2.5% and 5% dextrose are solutions that provide free water. When administered intravenously, the glucose in the solutions is rapidly metabolized and removed from the intravascular space, leaving 'free water'. The main clinical use of dextrose solutions is in providing free water during maintenance fluid therapy.

Lactated Ringers' Solution (LRS, Hartman's) is a good solution to begin fluid therapy in most instances. Why? – Because it contains sodium, chloride, and potassium in similar concentrations to those found in normal plasma, as well as containing lactate, which is metabolized in the liver to form bicarbonate. The fluid is also isotonic, meaning it is the same concentration as normal plasma. Lactated Ringers' Solution will distribute not only within blood vessels, but also throughout the entire extracellular space. As blood only makes up 25% of the fluid in the extracellular space, as little as 25% of the administered volume of LRS will remain within the vascular space. It may take as little as 30 minutes for up to 75% of an administered volume of LRS to leave the vascular space and equilibrate with the interstitial fluid.

Isotonic crystalloids such as LRS need to be given in large quantities when used to treat hypovolemic states – up to 60-90 ml/kg/hr in dogs, and 25-60 ml/kg/hr in cats – in order to achieve adequate blood volume restoration. Due to the short duration of action, isotonic fluid therapy frequently needs to be supplemented with colloids, protein, or blood administration. Crystalloids may also cause hemodilution – that is they dilute the PCV and total protein. Therefore, large volumes should be used with caution in patients with low PCV and TP.

Sodium Chloride 0.9% solution is an isotonic crystalloid solution made up of sodium and chloride ions. It is generally used in conditions where sodium and chloride losses are significant, or in conditions of elevated serum potassium. Sodium chloride administration may result in a hyperchloremic metabolic acidosis.

0.45% NaCl in 2.5% glucose is a low sodium solution, and is used as a maintenance solution. While the solution is isotonic, upon administration, the glucose is extracted (within seconds) leaving free water, which dilutes the sodium, making the fluid essentially hypotonic, relative to the plasma. As a result, the solution is a very poor blood volume-expanding solution, and should not be used in shock. The addition of potassium chloride at a concentration of 20 mEq/L to this solution however, makes it an ideal solution for maintenance fluid therapy.

Hypertonic saline 7.5% solution is hypertonic relative to plasma, and therefore will draw fluid into blood vessels from the remainder of the extracellular space, and from within vascular endothelial cells. This achieves two things – in patients with hypovolemic shock, it decreases the volume of fluid that needs to be administered to reverse hypovolemia, and thus restores blood volume more rapidly. The effect of hypertonic saline is only short lived, because, like LRS solution, the hypertonic saline will eventually redistribute throughout the extracellular space.

For this reason, we usually combine hypertonic saline with a synthetic colloid (see later) such as pentaspan or dextran 70, to increase the duration of action.

Colloids

Colloids are large molecular weight fluids, and include plasma, plasma bi-products, dextran 70 and pentaspan. Colloids do not readily pass through intact capillary membranes, and therefore remain within the vascular space for a longer time than crystalloid fluid. They may be administered to patients in shock, or in patients that meet one or more of the following criteria:

- Total protein of less than 35 g/l on presentation.
- Albumin of less than 17 g/l on presentation.
- Patients with symptoms of systemic inflammatory response syndrome, peripheral edema.
- Patients with pulmonary contusions, head trauma.
- To achieve small volume resuscitation in patients with suspected abdominal hemorrhage.
- The patient does not appear to be responding adequately or appropriately to crystalloid infusion.
- The patient develops edema (e.g., pulmonary) prior to adequate blood volume restoration.
- As adjunctive fluid therapy in combination with crystalloid fluid therapy.

Dextrans – are large molecular weight sugars (polysaccharides). Dextran 70 is the dextran most commonly used, and it has an average molecular weight similar to that of albumin. Dextrans are metabolized in the liver. The clinical effect of dextran 70 lasts for about 7 hours. Dextrans decrease activity of the blood-clotting factor, factor VIII, and also decrease adhesiveness of platelets, and can therefore prolong clotting times. The activated clotting time (ACT) may become prolonged within 12 hours following dextran administration by as much as 1.5-2 times the normal value. This rarely causes clinical bleeding unless an underlying coagulopathy is present. For this reason, dextrans are relatively contraindicated in patients that are known to have, or are expected to develop a coagulopathy in the acute setting (e.g., snake bite victims).

Pentaspan is made up of extremely large branched glucose polymer molecules, with an average molecular weight about 7 times that of albumin. The clinical effect of Pentaspan lasts for about 7-12 hours. Pentaspan will also prolong clotting times, including the ACT by about 1.5 times the normal value.

Albumin/Plasma/Plasma products – Plasma and albumin is prepared by extracting supernatant from centrifuged whole blood. In a normal animal, albumin contributes the majority of the force called the "oncotic pull", which is responsible for holding body fluid within blood vessels. Albumin does more than exert colloid oncotic pressure – it is also responsible for carrying certain drugs, hormones, metals, enzymes, chemical mediators of inflammation, and toxins. This is why we cannot just give synthetic colloids such as pentaspan or dextran when a patient has a low albumin level. Plasma is given to replace albumin, and to replenish clotting factors when they have become, or are expected to become depleted. The dose of fresh frozen plasma required to raise the total protein by 5 g/L is 22 ml/kg.

Red Blood Cells – as indicated by the equation outlining tissue oxygen delivery, we must have adequate hemoglobin content in blood in order to optimize tissue oxygen delivery. The optimum PCV for any critically ill patient is between 27% and 42%. Once the PCV drops below

20%, tissue oxygenation will be impaired. Animals that have developed an anemia over several days to weeks may have a PCV of lower than 20%, without showing outward symptoms of poor tissue oxygenation unless exerted.

Fluid Therapy Formula

Calculation of the volume of fluid to administer to a patient is essential to ensure the patient receives the correct amount and correct rate of fluid. In general, the following approach is used in formulating a fluid plan:

(a) Calculate the existing fluid deficit: Deficit (ml) = bodyweight (kg) x % dehydration x 1000.

(b) Calculate maintenance fluid requirements: Maintenance requirements = 40-60 ml/kg/day.

(c) Calculate or estimate ongoing fluid losses: Estimation of fluid volume loss (ml/day).

Addition of (a), (b), and (c), will give the volume of fluid required by the patient over a given 24-hour period. Maintenance fluid requirements in dogs are approximately 60 ml/kg/day, and 40-60 ml/kg/day in cats. This is the daily fluid intake required for normal body function. Approximately 27-40 ml/kg/day of fluid is lost from the body as urine. The remaining fluid losses are termed insensible losses, and include loss through the gastrointestinal tract (approximately 15 ml/kg/day) and respiratory tract (approximately 5-10 ml/kg/day). In addition to the maintenance fluid requirements, hydration deficits should be calculated.

Estimates of hydration deficits are typically based on clinical assessment, using skin turgor, mucus membrane moisture etc. The hydration deficit is calculated as a percentage of total bodyweight, multiplied by the patient bodyweight in kilograms. The resultant value gives the hydration deficit in litres.

Further to the calculation of maintenance fluid requirements, and hydration deficits, an estimate of ongoing or contemporary fluid losses should be made. Contemporary losses may occur as a result of vomiting, diarrhoea, polyuria, wounds, drains, pleural or peritoneal, fever, and blood loss.

Fluid Balances

A calculation of fluid balance provides the clinician with information regarding the adequacy of the fluid therapy administered to a patient, and whether the volume of fluid given to a patient is matching their fluid losses. Fluid balance assessment is made by frequent monitoring of the patient, including observation of clinical signs, bodyweight measurement, urine output, PCV, TPP, and measurements of fluid removed from drains if present. Due to the presence of insensible losses, measurement of sensible losses (urinary) should be approximately 2/3 the volume of fluid administered to a patient.

Monitoring Fluid Therapy

The following may be used as indicators as to the adequacy of fluid replacement, and will serve to alert the clinician to ongoing fluid requirements of the patient. As our patients are biological entities, it is important to remember to evaluate and treat the patient, and not to blindly follow calculated or estimated fluid, acid base, and electrolyte requirements.

1. **Bodyweight:** measure bodyweight at least once daily. Declining bodyweight suggests inadequate fluid replacement in the presence of ongoing fluid loss. Additionally, inadequate caloric intake will also manifest as weight loss in patients, and may suggest that nutritional support is indicated.

2. **Physical Examination:** Allows assessment of the presence of fluid losses from the gastrointestinal tract, assessment of urine output, and fluid losses due to pyrexia, wounds, and pleural and peritoneal cavities.

   (a) Heart rate: The presence of tachycardia may suggest hypovolaemia, pain, electrolyte imbalances, or cardiac disease.

   (b) Mucus membranes: The mucus membrane color depends on peripheral capillary blood flow, hemoglobin concentration, and tissue oxygenation. Pale mucus membranes may suggest blood loss, anemia or shock. Mucus membranes may be tacky if the patient is dehydrated.

   (c) Capillary refill time: provides a crude measure of tissue perfusion. Normal capillary refill time is less than 2 seconds. A prolonged capillary refill time suggests decompensating shock, hypotension, or heart failure. If the capillary refill time is rapid, (<1 second), it may indicate compensatory shock, fever, pain or anxiety.

   (d) Skin turgor: The presence of skin tenting implies dehydration, or cachexia.

   (e) Thoracic Auscultation: The presence of increased lung sounds during fluid therapy may suggest pulmonary edema, over-hydration, or pulmonary infiltration with cells and fluid.

   (f) Pulse quality: Pulse quality will generally improve with correction of hypovolaemia.

3. **Urine production:** Accurate assessment of urine output requires a closed urinary collection system. Normal urine output in dogs and cats is between 1.25 and 1.6 ml/kg/hr. If urine output falls below 1.0 ml/kg/hr, conditions causing reduced cardiac output and renal perfusion should be investigated to prevent the development of acute renal failure.

4. **Blood Values:**

   (a) Packed cell volume (PCV): Is an indicator of red cell mass, and is best measured using a microhematocrit method. Elevated PCV values are commonly associated with splenic contraction, or hemoconcentration due to dehydration. Decreasing PCV values may be associated with blood loss, hemolysis, or in some cases hemodilution.

   (b) Total Plasma Protein (TPP): Is an indicator of colloid oncotic pressure, although serum albumin is a more accurate measure. A falling TPP may indicate protein loss, or hemodilution, and may justify the use of colloidal fluid support.

   (c) Electrolytes: Sodium, potassium and chloride concentrations should be measured at least once daily. The most accurate means by which appropriate electrolyte replacement solutions should be given to a patient is by the measurement of urinary electrolytes. Serum electrolyte analysis may provide evidence of an electrolyte disorder, and allow the clinician to adjust fluid therapy appropriately.

5. **Central venous pressure (CVP):** Should be measured in patients where the risk of volume overload is greater than usual – for example in patients with cardiovascular disease, oliguria or anuria, or pulmonary vascular injury such as occurs with pulmonary contusions or acute respiratory distress syndrome (ARDS). Measurement of central venous pressure

requires the placement of a central venous line. CVP gives an indication of the ability of the heart to pump a given intravascular volume. CVP most closely reflects right atrial pressures. A value of 0-5 cm H_2O is normal. Values greater than 10 cm H_2O indicate elevated right atrial pressures, and are suggestive of volume overload. CVP values below 0 cm H_2O are found in patients during stress or exercise, or hypovolemia. Optimal CVP values in the critical care patient are between 5 and 8 cm H_2O.

The Ten Rules of Fluid Therapy

1. Correct intravascular volume deficits
2. Normalize blood hemoglobin concentrations
3. Normalize intravascular colloid oncotic pressure
4. Correct electrolyte imbalances
5. Correct acid-base imbalances
6. Correct hydration deficits
7. Provide fluid therapy for ongoing losses
8. Maintain fluid balance
9. Provide appropriate electrolyte replacement
10. Diagnose and manage any underlying disorder

Useful Values for Fluid Therapy

- Normal blood volume (ml) = 7% bodyweight (kg) x 1000
- Normal hemoglobin concentration = 10 g/dL
- Normal Albumin concentration = 28-39 g/L
- Daily fluid requirements = 40-60 ml/kg/day
- Daily sodium requirement = 75-80 mEq/L
- Daily potassium requirement = 15-30 mEq/L

Summary

This is a brief overview of fluid therapy for small animal patients. The choice of fluid(s) given to a patient depends on many variables based on clinical and clinical pathology findings and knowledge of the pathophysiology of the disease process being treated. It is important to realize that there may be more than one acceptable fluid therapy plan for the same patient. Fluid therapy plans may be altered depending on the patient status, clinical signs, disease process, and the results of monitoring response to therapy and clinical pathology.