Fluid Therapy in Your Practice – Katie Rhue, DVM

Three phases should be considered for fluid therapy – resuscitation, dehydration, and maintenance.[1] When considering fluid therapy, there are several questions that should be considered:[1]

1. Is the patient in shock, or otherwise requiring immediate fluid resuscitation?
2. Is the patient dehydrated?
3. Can the patient take in enough water to maintain a normal fluid balance?
4. What type of fluid should be given?
5. By what route should the fluid be given?
6. How rapidly/how much fluid should be given?
7. When should fluid therapy be discontinued?

Resuscitation is typically aimed at patients in shock, or any patient where the fluid deficit is considered to be one of the intravascular volume. Assessment of an intravascular deficit is best achieved by assessing perfusion parameters – heart rate, mentation, pulse quality, mucous membrane color, capillary refill time, and distal extremity temperature +/- core body temperature. An abnormality of one or more of these perfusion parameters is indicative of shock, and as such fluid volume expansion is indicated, typically as a fluid bolus while further assessments are performed to determine the cause of the perfusion abnormality. The exception to this guideline is the case of cardiogenic shock which can typically be suspected based on the history, presence of tachypnea, crackles on thoracic auscultation, and potentially a notable heart murmur (though patients with heart murmurs can experience other forms of shock).

Another question to consider is the hydration status of the patient which is representative of the interstitial and intracellular fluid volumes of the patient (though if dehydration is severe enough or depending on the type of dehydration, intravascular fluid deficits may also be present which would necessitate resuscitative fluids). When assessing hydration status there are several factors to consider, including the patient's weight, skin elasticity, and mucous membranes. For patients that are hospitalized and experiencing fluctuations in their weight from day to day, this is likely most representative of changes in fluid balance. Weight loss in chronic disease states includes loss of muscle mass as well as fluid loss; an anoretic animal may lose 0.1-0.3 kg of body weight per day per 1000 kcal of energy requirement deficit.[1] This is why weighing of hospitalized patients at least once daily (and potentially multiple times daily depending on the patients' disease and status), is extremely important. Decreases in weight about this amount in an anorectic animal likely represent fluid losses that should be addressed and a weight gain over the expected amount for the presumed percentage of dehydration could represent over-hydration of the patient. It is also important to remember that patients with third spacing will not have a change in weight, while losing that fluid volume from the intravascular and interstitial spaces.

When trying to estimate how dehydrated your patient is, it is important to remember that deficits of <5% cannot be detected on physical exam. A deficit of 5-6% is detected as a subtle loss of skin elasticity and patients with a 6-8% deficit have a definite decrease in skin elasticity,

potentially dry mucous membranes, their eyes may be sunken and a slight delay in capillary refill time may be present. A 10-12% dehydration deficit is represented by a complete lack of skin elasticity (i.e. the skin does not move when tented), eyes are sunken, mucous membranes are definitely dry, and the patient is certainly showing evidence of intravascular deficits with a prolongation in capillary refill time, and potentially tachycardia, cool extremities, and poor pulse quality. A deficit of >12% is associated with shock and death is likely imminent. It is important to remember when testing skin elasticity that this is dependent on the amount of SQ fat and elastin, in addition to interstitial volume. Using this parameter to assess hydration status is dependent on the patients' skin turgor prior to dehydration (i.e. skin turgor is already naturally decreased in older and/or emaciated animals due to a decrease in SQ fat and elastin compared to younger animals).

It is also important to monitor patients for signs of overhydration which include shivering, restlessness, serous nasal discharge, peripheral edema, hock or mandibular swelling, chemosis, increased respiratory rate or effort, moist lung sounds, moist cough, tachycardia or bradycardia, or pleural or peritoneal effusion.[2]

Even though a patient may have been resuscitated and rehydrated, they may not have recovered enough to drink and/or eat enough to maintain a normal water balance. These are the patients that require the administration of maintenance fluids to meet their needs. It is important to closely monitor urine production in these patients. if a patient is urinating a large volume of dilute urine without an underlying reason to do so (such as renal dysfunction or diabetes mellitus), excessive fluid administration may be a contributing factor. If the amount of fluids administered is reduced with no change in the amount urinated and/or specific gravity, other causes should be considered, and the fluid rate may need to be increased to match losses to prevent dehydration.

When considering what type of fluid to administer, there are many factors to account for. Our two basic groups are crystalloids and colloids. Crystalloids are solutions containing electrolytes and nonelectrolyte solutes capable of entering all body fluid compartments, and exert their effects primarily on the interstitial and intracellular compartments.[1] Colloids are large scale molecular weight substances that are restricted to the plasma compartment in patients with an intact glycocalyx and endothelium. Colloids primarily exert their effects on the intravascular compartment.[1]

Crystalloids can be broken down further into isotonic, hypotonic, and hypertonic. The tonicity of a solution is determined by the ability of a solution to initiate water movement and is dependent on the presence of impermeant solutes in the solution.[3] A rough estimate of the tonicity of a solution can be found by doubling the sodium concentration of a solution. For example, Plasmalyte 148 has 140 mEq/L of sodium, meaning it has an effective osmolality (or tonicity) of 280 mOsm/kg. As the normal osmolality of plasma is roughly 290-310 mOsm/kg, Plasmalyte 148 is considered to be isotonic. This is in comparison to 0.45% NaCl which has a sodium content of 77 mEq/L so a tonicity of approximately 154 mOsm/kg which is hypotonic. The reason why this distinction is important is this determines which fluids are appropriate as replacement fluids and which are not. This means that isotonic crystalloids (LRS, Plasmalyte 148, Normosol-R, 0.9% NaCl) are frequently appropriate for replacement, while hypotonic

crystalloids (0.45% NaCl, D5W, Normosol-M, Plasmalyte 56), should never be used for replacement. Hypertonic crystalloids (essentially 7.2% NaCl) are appropriate for low volume fluid resuscitation as the extremely high sodium content pulls fluid from the interstitial into the intravascular space. However hypertonic saline should be followed with an isotonic crystalloid to replace the fluid being lost from the interstitial space.

It should be noted that there is growing evidence that 0.9% NaCl should be used with more caution. Due to its lack of buffer and high chloride content, it is an acidifying solution. There is also some evidence in human medicine that 0.9% NaCl may be associated with acute kidney injury, an increased need for renal replacement therapy, and a higher mortality rate compared a balanced crystalloid such as LRS or Plasmalyte.[4] This is an ongoing area of research with a large trial (SMART) currently underway in 5 ICUs at Vanderbilt. Data collection for this trial is set to conclude at the end of April, 2017. While classically 0.9% NaCl was considered the fluid of choice for patients with hyperkalemia (such as those with a urinary obstruction or an Addisonian crisis), the potassium content of a balanced crystalloid is minimal (4 mEq/L for LRS, 5 mEq/L for Plasmalyte A and Normosol R). Additionally, 0.9% NaCl is acidifying and many of these patients are already acidotic. Based on the presence of buffers, balanced crystalloids are alkalinizing which can be beneficial in an acidotic patient. That being said, if a balanced crystalloid is not available, the restoration of adequate perfusion by using any isotonic crystalloid (this includes 0.9% NaCl) is critical and will likely do much to improve a patient's acid-base balance (i.e. if you don't have a balanced crystalloid, using 0.9% NaCl is better than not fluid resuscitating the patient at all).

Crystalloids can also be divided based on whether the solution should be used for replacement or maintenance. Replacement solutions have compositions similar to that of the extracellular fluid compartment while maintenance solutions have more potassium and less sodium than replacement fluids (Normosol-M, Plasmalyte 56). A maintenance solution can be made by using 1L 0.45% NaCl and adding 20 mEq/L KCl as well as 50 ml of 50% dextrose (for a final concentration of 2.5% dextrose).

It is important to note that administering D5W is essentially administering free water to the patient because the glucose is oxidized to carbon dioxide and water. So the only reason to use D5W is to correct a free water deficit (such as in extremely hypernatremic patients). Certain injectable medications such was mycophenolate, amphotericin B require dilution in D5W prior to administration. As severe hypernatremic patients require very close monitoring (I.e. checking sodium levels every 4-6 hours), unless your practice has 24-hour care, more than likely you do not need to carry D5W on a regular basis.

Colloids can be broken down further into natural colloids and synthetic colloids. Plasma and fresh whole blood would be the most commonly encountered natural colloids, while synthetic colloids include Vetstarch, Hetastarch, Voluven, dextrans, and hemoglobin-based oxygen-carrying fluids (Oxyglobin).

Colloids should typically only be used for fluid resuscitation as they exert their main effects on the intravascular space. In severely hypoalbuminemic patients colloids may also be beneficial to prevent the efflux of fluid into the interstitial space leading to tissue and/or organ edema.

While plasma and whole blood can be used for their colloidal effects, the rapid disappearance of albumin from the vascular space limits their use for this effect. The large

amount required to increase albumin levels also limits their effect in treating hypoalbuminemia. Canine or human albumin (made up to a 10-16% solution) are more effective in treating hypotension, however these products come with their own caveats as well and are rarely found outside of 24-hour care facilities. Canine and human albumin are more commonly used to treat hypoalbuminemia than they are used for volume expansion.[5]

Of the synthetic colloids, Vetstarch is often considered to be the safest based on its lower molecular weight compared to some of the other synthetic colloids (130 kDa comparted to 600-670 kDa), in theory lowering the risk of some of the potential complications. While hemoglobin-based oxygen-carrying fluids (Oxyglobin) are very useful in veterinary patients, unfortunately due to complications noted in human patients, this product is no longer available in the United States. Synthetic colloids have been associated with acute kidney injury and coagulopathies in humans; additionally, the use of synthetic colloids in septic patients is associated with an increased risk of mortality. Coagulopathies have been documented in animals associated with synthetic colloids, though typically once the recommended daily dose has been exceeded. Although synthetic colloids are reported to cause decreased platelet function and reductions in factor VIII and von Willebrand factor activity,[6] the clinical relevance of these findings is unknown at recommended doses. However, given these findings, the use of synthetic colloids is not recommended in patients with coagulopathies or those at risk for developing a coagulopathy.

While acute kidney injury secondary to colloids has not been specifically documented in veterinary species, avoiding this class of fluids is recommended in patients with documented kidney injury or those at risk for kidney injury based on the known association in humans. The mechanism associated with acute kidney injury and these products has not been fully delineated though it is suspected to be related to the accumulation of lysosomes in the proximal tubule secondary to pinocytosis of the colloid particles resulting in cellular swelling and interstitial inflammation. Synthetic colloids also decrease renal filtration pressure through their oncotic force. These effects have been documented in canine kidneys in a laboratory setting, though have yet to be documented in a clinical patient. Greater accumulation of hydroxyethyl starch molecules is seen as the dose of the product increases, and a dose dependent risk of mortality has also been documented. This means that higher doses of synthetic colloids have been associated with an increased risk of mortality.[6]

When deciding what fluid to administer, strong consideration should be given to the disease process and composition of the fluid lost from the patient. Underlying acid-base and electrolyte derangements should also be considered when choosing fluid type. A fluid should be chosen that is similar in volume and electrolyte composition to what was lost from the patient. If the patient is showing indications of poor perfusion thought to be responsive to fluids, fluid resuscitation should be initiated. If the patient has low oncotic pressure or a condition where a low-volume resuscitative strategy would be indicated, a synthetic colloid should be considered for resuscitation. If neither of the above situations apply, a balanced crystalloid should be chosen. If there are no clinical signs of hypoperfusion and the heart is expected to be functional normally, the hydration deficit and maintenance needs can be combined and administered over the following 24 hours.

Evaluation of patient electrolytes should always be considered when choosing a fluid (though patients with perfusion deficits will often require and receive fluids prior to

determination of electrolytes). This is most important when choosing a fluid for rehydration and maintenance. Potassium is the electrolyte that most frequently requires supplementation and charts are available to guide the practitioner in potassium supplementation for maintenance fluids. It is a little trickier for patients who are receiving more than maintenance fluids, particularly if the patient is more than mildly hypokalemic. A maintenance rate of potassium is 0.05-0.10 mEq/kg/hr. For patients with a mild deficit, consider adding 0.1-0.2 mEq/kg/hr to the fluids you are administering. If the patient's potassium is 2.7 – 3.0 mmol/L, supplementation of 0.2-0.3 mEq/kg/hr should be considered. For a potassium of 2.2-2.7 mmol/L, supplementation of 0.3-0.4 mEq/kg/hr should be considered. If a patient's potassium is less than 2.2 mmol/L immediate referral should be strongly considered as this patient requires aggressive potassium supplementation that will require intensive monitoring and a continuous ECG. It is important for the clinician to keep in mind that at the doses recommended here, potassium supplementation can be quite aggression in some cases. For example, a 5 kg cat on a fluid rate of 20 ml/hr with a potassium of 2.5 mmol/L would require the addition of 80 mEq/L of KCl to a 1L bag of fluids. The clinician should take care in administering fluids with more than 60 mEq/L of KCl through a peripheral catheter for more than 12-24 hours as phlebitis is a concern. Particularly in patients with moderate to severe hypokalemia correction of the hypokalemia in a relatively fast but safe manner is indicated due to the possible consequences of hypokalemia (severe muscle weakness, ileus, hyperglycemia, arrhythmias including VPCs up to and including cardiac arrest). If more than 40 mEq/L of KCl is added to a 1L bag of fluids, the bag and line should be clearly labelled to prevent any accidental bolusing of fluids; additionally, the catheter should never be flushed, particularly in smaller patients due to the potential to administer a potentially fatal overdose of potassium. All personnel working with the patient should be thoroughly advised of the risks of bolusing and/or flushing the catheter in that particular patient.

When determining the route by which to administer fluids, options include intravenous, subcutaneous, oral, or intramedullary. In extenuating circumstances, intraperitoneal fluids can be considered in certain specific situations.

The intravenous route is preferred when the patient is very ill, if there is notable fluid loss, or when the fluid loss has been acute.[1] Intravenous fluids are also strongly recommended during anesthesia to maintain renal perfusion and to provide vascular access during an emergency. The intravenous route provides rapid dispersion of water and electrolytes while also allowing for precise dosing. Additionally, large volumes can be given rapidly and hypertonic fluids can be given safely using a large vein. Obviously vascular access is required and the catheter should be monitored closely to avoid complications such as overhydration, thrombosis, phlebitis, limb swelling, embolism, infection, or impaired fluid delivery caused by obstruction. IV catheter function and the catheter to skin interface should be monitored regularly (IV catheter function every 4-6 hours, catheter to skin interface at least once daily or immediately if the patient develops a fever) to detect complications. Catheters that remain clean and do not have complications do **not** need to be replaced at a routine interval (i.e. 3 days).

Subcutaneous fluids are convenient for maintenance fluid therapy in small dogs and cats. Potassium can be used in concentrations up to 30-35 mEq/L without irritation. Approximately

10 ml/kg of SQ fluids can generally be administered per site. Unless a patient has cardiac insufficiency volume overload is unlikely to occur and some owners can use SQ fluids to home to nurse chronic disease conditions (such as CKD). The subcutaneous route should never be used for patients with acute and severe losses or extremely dehydrated or hypothermic patients because peripheral vasoconstriction may decrease absorption and dispersion of the fluid in those situations. As the volume given is limited by skin elasticity this route is typically not as useful in larger animals requiring larger fluid volumes. Irritating or hypertonic solutions should never be given SQ and only isotonic fluids are recommended. Isotonic fluids containing bicarbonate precursors other than lactate (i.e. Plasmalyte, Normosol) are generally not recommended as they appear to cause mild local discomfort and are not well tolerated in some veterinary patients. D5W should not be administered subcutaneously because equilibrium of extracellular fluid with a pool of an electrolyte-free solution may lead to temporary worsening of electrolyte imbalance.

Oral fluids can be administered rapidly and with minimal side effects however should not be used in patients with gastrointestinal dysfunction (i.e. vomiting, diarrhea). This route is also inadequate in patients with acute or extensive fluid losses as dispersion of the administered fluids and electrolytes are not sufficiently rapid. If a patient is anorexic but not vomiting or having diarrhea, fluid can be given using any number of appropriate feeding tubes (nasogastric, nasoesophageal, esophagostomy, gastrostomy tube). Oral fluid therapy is useful for giving hypertonic fluids with high caloric density in order to meet the patients' caloric needs.

Intraosseous fluid administration is useful in very young or small animals when venous access is difficult to obtain. The IO route provides rapid vascular access through bone marrow sinusoids and medullary venous channels and allows rapid dispersion of fluid. As the bone marrow does not collapse when hypovolemic, it can be easier to access the marrow than a vein in some hypovolemic patients. The tibial tuberosity, trochanteric fossa of the femur, wing of the ilium and greater tubercle of the humerus are all appropriate for IO fluid administration. The periosteum should be anesthetized using 1% lidocaine to avoid pain during needle placement, though it should be noted that lidocaine toxicity is possible when given IO, especially to cats. An 18 gauge to 30-gauge hypodermic needle is useful in neonates with soft cortical bone and an 18-22-gauge spinal needle is useful in cats, small dogs, and small birds.[7] Additionally, a bone injection gun exists that can rapidly lead facilitate IO placement. A jamshidi bone marrow needle may also be used with a high rate of success.[8] A drill for intraosseous access (EZ-IO) is also available and has been found to be more likely to be successful than the bone injection gun and manual intraosseous needle placement in either the tibia or humerus. The practitioner is referred to an outside source[7] for step by step instructions on IO catheter placement.

Contraindications for intraosseous catheterization is a fracture of the bone being used, infection of the tissues over the bone being used, as well as sepsis or septic shock. If an attempted intraosseous catheterization is unsuccessful but the cortex of the bone has been penetrated the risk of drug or fluid extravasation is increased and use of a different bone is recommended. It is important to note that drugs reach a peak effect when given via the IO route more slowly than with IV administration due to a reduction in blood flow and an increase in vascular resistance in the bone marrow during systemic hypotension. It is recommended that fluids be administered under pressure of 300 mmHg to try to minimize the effect. Even under

pressure however, the maximum rate of fluid delivery is ~29 ml/min through a 20-gauge needle and 47 ml/min through a 14-gauge needle.

Potential risks include osteomyelitis and pain on administration of fluids. Care should also be taken during placement into the femur to avoid sciatic nerve injury. Potential complications include infection, fat embolism, extravasation of fluids, nerve injury, compartment syndrome, and bone fractures. Use of sterile technique is imperative and markedly decreases the risk of infection. If any infiltration into tissues is noted, IO fluid administration should be discontinued immediately and no catheter should be placed into the same bone. Covering of the IO site with antiseptic or antibiotic ointment is recommended as well as application of a protective bandage if possible to prevent damage to the needle. IO lines should be considered temporary with the goal of being replaced by an IV catheter as soon as possible. When an IO catheter is required for more than several hours, the same guidelines used for IV care are recommended. Though data is limited, the risk of IO catheter complications is thought to be low for up to 72 hours following placement with the proper maintenance.

Intraperitoneal fluid administration can allow for moderately rapid absorption of moderate to large volumes of fluids. Only isotonic fluids should be used as hypertonic fluid administration results in further contraction of the extracellular fluid volume (water enters the peritoneal space via osmosis). Peritonitis is a strong possibility for fluids administered via this route which is why it is not recommended unless the circumstances are extenuating. Additives (such as dextrose or KCl) should not be used in fluid administered intraperitoneally as the risk for peritonitis markedly increases and significant complications have been observed. In general, intraperitoneal fluid administration should only be used for peritoneal dialysis.

The volume status of the patient is paramount when deciding how rapidly, or how much fluids should be given. The blood volume of a dog is ~80-90 ml/kg while for a cat it is approximately 50-60 ml/kg. These doses are then considered to be the 'shock' doses of isotonic crystalloids. The shock dose of synthetic colloids is 20 ml/kg in dogs and 10-15 ml/kg in cats. When a patient presents with signs of poor perfusion that is expected to be fluid responsive (and there is no concern for cardiac insufficiency), a ¼ shock dose of fluids is recommended. In dogs this should be administered as fast as possible, while administration over 15-20 minutes is recommended in cats. Care should be taken with administration of boluses in cats, particularly when they are hypothermic; vascular tone is poor in hypothermic cats so they are not nearly as responsive to volume resuscitation. This means that once the cat is rewarmed and their vascular tone has improved, they are predisposed to volume overload if they have received a large amount of fluids. For this reason, generally only ~ 10 ml/kg of crystalloids should be administered prior to the feline patient's temperature being >98^{o}F. After a bolus the patients' perfusion parameters and blood pressure should be reassessed. If the patient still has evidence of hypoperfusion another fluid bolus should be considered (except in the case of a hypothermic cat).

If there is no response or minimal response after 2 boluses, use of another means of resuscitation should be considered. This may include using a colloid or hypertonic saline depending on the status or underlying disease process in your patient. In cases where low volume fluid resuscitation is indicated (such as a patient with a hemoabdomen), hypertonic saline (7.2% NaCl) at 3-5 ml/kg administered over 5-10 minutes can be considered.

Resuscitation of the patient with evidence of head trauma should likely also include hypertonic saline. It is not recommended to administer more than one (or a maximum two) doses of hypertonic saline due to the concern for transient hypernatremia and/or hyperchloremia, though these electrolyte abnormalities typically resolve within several hours. Care should be taken when administering boluses to patients with concern for intracavitary hemorrhage as rapid fluid administration can increase the risk of dislodging any clots the body was trying to form to stop bleeding. For this reason, if there is any concern for intracavitary bleeding, low volume resuscitation should be considered, or the use of 10 ml/kg of crystalloids in dogs (5-10 ml/kg crystalloids in cats). Crystalloids may be repeated until the patient has a systolic blood pressure of 80 mmHg. Resuscitation past this end point may increase the risk of worsening hemorrhage.

If a patient is adequately volume resuscitated and still has evidence of perfusion deficits or hypotension, a vasopressor agent should be considered. There is some evidence to suggest that if a patient still has deficits after 50-60 ml/kg of crystalloids (dogs) or 40 ml/kg (cats) a pressor agent should be started at that time. A potential exception to this rule is the patient in an Addisonian crisis who may be truly that volume depleted. Any patient requiring the use of a pressor should be referred to a facility with 24-hour care if it is at all possible to transport the patient in a safe manner.

Patients with perfusion deficits require intense monitoring with serial physical exams to assess perfusion parameters, as well as serial monitoring of blood pressure, urine output, and lactate levels.[2] In critical patients direct arterial blood pressure monitoring using an arterial catheter is key, otherwise indirect blood pressure monitoring using an oscillometric method (i.e. Cardell monitor) or Doppler blood pressure is appropriate. In hypotensive/poorly perfused patients this can lead to a decrease in renal blood flow, causing decreased urine output and potentially acute kidney injury. This is why monitoring of urine output and ensuring it is greater than 1 ml/kg/hour can be critical. Additionally, lactate is a common marker of anaerobic metabolism and is frequently increased (indicating inadequate tissue perfusion) in states of hypoperfusion/shock. Serial physical exams, indirect blood pressure monitoring, quantification of urine output, and assessment of lactate should be easily accessible to any practitioner dealing with very ill/unstable patients. For invasive monitoring techniques (CVP, direct blood pressure monitoring) should be available at critical care hospitals.

Once the patient is volume resuscitated, consideration is given to replacement of a hydration deficit, maintenance, and ongoing losses. It is very important to estimate your hydration deficit as this should be the basis of your fluid strategy (Fluid rate = % deficit + maintenance + ongoing losses). It is recommended that your fluid deficit be administered during the time frame over which it was lost. In some instances, this may not be known, in which case many practitioners will use 24 hours.

Maintenance can be calculated by many different ways, though 60 ml/kg/day for dogs and 40-45 ml/kg/day for cats are common. These formulas are generally accurate for cats and dogs weighing between 5 and 25 kgs. For dogs weighing less than 5 kg this linear formula may underestimate fluid requirements and for those weighing more than 25 kgs it may overestimate fluid requirements. Another formula for dogs which is based on Resting energy requirements as well as body surface area is:

Daily fluid requirement (dogs) = 132 *(Body weight in kgs)$^{0.75}$

(cats) = 70 *(Body weight in kgs)$^{0.75}$

When thinking about maintenance fluid requirements, this can be further broken down into sensible losses (losses which can be directly measured such as urinary losses) and insensible losses (those not easily measured including those lost from the respiratory tract through panting and losses in stool). Insensible losses are in general, roughly 20-22 ml/kg/day. This is important to consider in situations where there is concern regarding urine output, or kidney function. In general urine production can be fairly accurately measured, either through regular weighing of absorbent pads or directly quantified from a urinary catheter. In cases with concern about kidney function, an accurate assessment of urine output is key as for oliguric patients (those with a urine output of < 1 ml/kg/hr) it can be relatively easy to overhydrate them which can lead to tissue/organ edema and increased mortality. Additionally, in very polyuric patients it can be very easy to otherwise underestimate their fluid losses, leading to further dehydration or lack of correction of their initial hydration deficit. This is why accurately measuring a patient's urine output can be key.

To our hydration deficit and maintenance fluids we add ongoing losses, which in many cases are loss of excessive fluids through vomiting and/or diarrhea. These losses can be estimated roughly through 'guesstimation', though in small to medium dogs it is fairly simple to place absorbent pads in the animals' cage and weigh the pads both before and after they are soiled for a more accurate estimate of losses (0.01 kg = 1 ml of fluid). These fluid losses should be measured at least every 6 hours, though more critical patients may require assessment every 2-4 hours depending on the severity of ongoing losses. The IV fluid rate should be adjusted accordingly depending on changes in losses. If there is concern regarding sodium load in a patient or risk of edema, consideration should be given to administering a maintenance fluid for maintenance fluid requirements (such as 0.45% NaCl + 20 mEq/L KCL + 2.5% dextrose), while concurrently replacing a dehydration deficit and ongoing losses with an isotonic crystalloid (+/- a synthetic colloid depending on the patient's condition).

As certain fluid calculations are somewhat estimated (such as % dehydration), continual reassessment of patient hydration, body weight, and perfusion parameters is necessary (at least 1-2 times/day in all hospitalized patients up to every 2-6 hours in more critical patients).

It is interesting to note that placing a patient on '2X maintenance' is essentially equal to their maintenance + a 5% hydration deficit corrected over 24 hours. Other than that specific instance, however, using a certain maintenance multiplier for calculating fluid rates can lead to marked over or underhydration depending on the specific circumstance.

Determining when it is acceptable to discontinue fluid therapy is likely the simplest step! Once your patient is eating and drinking well enough to maintain adequate hydration without fluid supplementation, fluids should be discontinued. Even if your patient is drinking well, it is important to ensure GI losses are not excessive and the patient can maintain hydration.

In conclusion, fluid therapy can be a challenging, but fun and rewarding, part of clinical practice. A fluid plan should be tailored to each individual patient, and there are many factors to consider when formulating the best fluid plan for your patient.

References

1. DiBartola SP, Bateman S. Chapter 14: Introduction to Fluid Therapy. 4th ed. In: DiBartola SP, editor. Fluid, Electrolyte, and Acid-Base Disorders in Small Animal Practice. St. Louis, Missouri: Elsevier; (2012). p. 331-350.
2. Tonozzi C, Rudloff E, Kirby R. Perfusion vs. Hydration: Impact on the Fluid Therapy Plan. Compendium 2009;31(12):E1-E13.
3. DiBartola, SP. Chapter 3: Disorders of Sodium and Water: Hypernatremia and Hyponatremia. 4th ed. In: DiBartola SP, editor. Fluid, Electrolyte, and Acid-Base Disorders in Small Animal Practice. St. Louis, Missouri: Elsevier; (2012). p. 45-79.
4. Semler MW, Self WH, Wang L, Byrne DW, et al. Balanced crystalloids versus saline in the intensive care unit: study protocol for a cluster-randomized, multiple-crossover trial. Trials 2017;18:129.
5. Mazzaferro E, Powell LL. Fluid therapy for the Emergent Small Animal Patient: Crystalloids, Colloids, and Albumin Products. Vet Clin North Am 2013;43(4):721-734.
6. Hayes G, Benedicenti L, Mathews K. Retrospective cohort study on the incidence of acute kidney injury and death following hydroxyethyl starch (HES 10% 250/0.5/5:1) administration in dogs (2007–2010). J Vet Emerg Crit Care 2016;26(1):35-40.
7 Guinit M, Otto CM. Chapter 194: Intraosseous Catheterization. 2nd ed. In: Silverstein DC, Hopper K, editors. Small Animal Critical Care Medicine. St. Louis, Missouri: Elsevier; (2015). p. 1009-1012.
8 Olson D, Packer BE, Perrett J, Balentine H, et al. Evaluation of the Bone Injection Gun as a Method for Intraosseous Cannula Placement for Fluid Therapy in Adult Dogs. Vet Surg 2002;31(6):533-540.