Use and Misuse of Crystalloids, Colloids and Blood Products

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Many fluids are available to the clinician including maintenance and replacement crystalloids, colloids such as tetrastarch, and blood products. This session will discuss the properties as well as the pros and cons of the different fluids and how to ensure your patients are getting what they need.

Crystalloids

Crystalloids are fluids containing sodium chloride and other solutes that are capable of distributing to all body fluid compartments. Since approximately 80% of extracellular fluid is in the interstitial space crystalloids will rapidly redistribute and after as short a period of time as 20 minutes there will be only 20% to 30% of the administered volume remaining in the circulation. On a short-term basis crystalloids certainly will expand the intravascular space, but this effect will be short-lived. Thus, crystalloids should be thought of as interstitial dehydrators, not intravascular volume expanders. This increase in interstitial fluid can lead to tissue edema (thus decreasing the ability of oxygen to diffuse to the cells). Interstitial edema may be extremely detrimental in cases of cerebral edema and pulmonary edema.

Replacement fluids have electrolyte concentrations that resemble extracellular fluid whereas maintenance fluids contain much less sodium (40-60 mEq/l) and more potassium (15-30 mEq/l). Maintenance fluids should be used in patients who have ongoing losses other than normal losses through urine and feces, and in those who will not tolerate a sodium load. The latter typically includes patients with heart failure or severe liver or kidney disease.

The most commonly used replacement fluids are 0.9% saline, lactated Ringer's solution and Normosol-R, Plasmalyte 148 or Plasmalyte-A. Normal saline has a pH of approximately 5 so it can be very acidifying. It is primarily indicated in patients with gastric outflow obstructions, hypoadrenocorticism and hypercalcemia. Buffered solutions are usually indicated for resuscitating patients in shock since administration of a highly acidotic solution may worsen a preexisting metabolic acidosis. Buffered solutions are also an ideal choice for all patients requiring a replacement-type fluid. Buffered solutions usually contain lactate, gluconate or acetate. The liver must metabolize lactate whereas many cells in the body metabolize acetate and gluconate; however, end-stage liver disease must be present before the patient will have problems metabolizing the lactate. Plasmalyte-A is the only prebuffered solution; the pH is 7.4. All other buffered solutions have a pH of about 6.8; the metabolism of the buffer leads to increase in the pH to normal. Lactated Ringer's solution is no longer recommended by many due to the adverse effects of the lactate. These include neutrophil priming and worsening of cellular apoptosis. Calcium-containing fluids (i.e., lactated Ringer's solution) should not be administered concurrently through the same line as blood products anticoagulated with citrate since the resultant precipitate may be detrimental to the patient. Crystalloids are generally isoosmolar; however, they become hyperosmolar once other medications or supplements are added to the fluids. This may be important to patient therapy.

Hypertonic saline is a hyperosmolar crystalloid fluid used for resuscitation of hypovolemia. It is usually given as a 7.5% solution (2600 mOsm/L). The hyperosmolarity leads to rapid intravascular volume expansion by drawing fluids from the interstitial and intracellular space into the intravascular space. Its major benefit is that it can produce an equivalent intravascular volume expansion to colloids but at one-fourth the volume. Caution should be exercised when infusing this fluid in patients with uncontrolled internal hemorrhage since the rapid rise in volume, and; therefore, blood pressure, can worsen the hemorrhage. Because it is a crystalloid it will rapidly redistribute similar to all other sodium chloride-based solutions; however, its effects can be prolonged by concurrent administration of a colloid. It also appears to have an immunomodulatory effect including decreasing mesenteric lymph production and eliminating neutrophil priming, which decreases susceptibility to sepsis following hemorrhagic shock.

Colloids
Colloids are fluids containing large molecular weight substances that generally are not able to pass through capillary membranes and as such they can be considered intravascular volume expanders. Examples include synthetic colloids such as the, dextrans, hydroxyethyl starch (tetrastarch), and biologic colloids such as whole blood, plasma, and albumin. Colloids are usually isoosmolar. All synthetic colloids have the potential to cause a dilutional coagulopathy.

Since most patients in shock require sustained intravascular volume expansion, colloids are indicated frequently during fluid resuscitation. Patients with SIRS (systemic inflammatory response syndrome) or sepsis frequently have increased vascular permeability which leads to leakage of albumin and other small proteins out of the intravascular space ('third-spacing'). Synthetic colloids that have a larger molecular weight than albumin (69,000 Daltons) usually remain in the intravascular space.

Boluses typically are given to improve the blood volume and blood pressure to the desired end point. A constant rate infusion of 20 ml/kg/day can be given in patients with hypoalbuminemia less than 20 mg/dL or in those with ongoing albumin losses in an attempt to maintain oncotic pressure.

The use of colloids in the face of increased pulmonary vascular permeability seems to still be a matter of individual clinical decision. It has been proposed that larger molecules might block the open pores in the capillary membranes thus decreasing pulmonary edema; however, there is a concern that smaller molecules will pass through the open pores and lead to a worsening of the edema. Most synthetic colloidal fluids contain molecules that vary dramatically in size with some small enough to easily pass through pores along with particles far too large to pass through the pores. Once small colloid particles are in the pulmonary interstitium clearance has been shown in research situations to be very slow.

Hydroxyethyl starch is a molecule made from maize or sorghum and is primarily an amylopectin. Hetastarch expands the volume by about 1.4 times the volume infused. It has an average molecular weight of 450,000 Daltons. Doses greater than 20 ml/kg/day have been associated with an increased incidence of bleeding problems. Pentastarch has an average molecular weight of 260,000 Daltons. Tetrastarch has an average molecular weight of 130,000 Daltons. Much higher doses – up to 50 ml/kg - can be given on a daily basis. In cats the dose of hydroxyethyl starch should be infused slowly – over 15 to 20 minutes - as hypotension (related to histamine release??) may result with boluses. Due to the negative impact on renal function as well as an increase in mortality seen with hydroxyethyl starches they have been removed from the human market in Europe. Similar effects have not been documented in dogs or cats.

Human Albumin
Human albumin made from pooled human plasma is a concentrated source of albumin. At a 25% concentration the COP is 100 mm Hg, making it a very potent colloid that is able to expand the intravascular volume by 5 times the volume infused. It is also hyperosmolar at 1500 mOsm/L. For both of these reasons the patient must be monitored closely for signs of fluid overload when it is being infused. It provides all the beneficial effects of albumin (see below). The half life is approximately 16 hours. Doses of 2.5-5.0 mL/kg have been recommended with a maximum dose of 2 g/kg. Because it is human albumin allergic reactions are possible. This may manifest as facial swelling, vomiting or fever. Delayed reactions several weeks after administration have been documented.

Transfusion Medicine
Transfusion medicine involves the infusion of blood products. Ideally blood should be used when patients have lost whole blood. The lower the hematocrit becomes the more important hemoglobin replacement is to ensure adequate oxygen delivery to the cells. Packed red blood cells, which contain up to 80% packed red cells, should be used for patients with hemolytic anemia (loss of red cells but normal plasma components). Some packed red blood cells come with an extender making the packed cell volume only 45%. It is important to know what the packed cell volume of the blood product is in order to calculate the desired volume to be administered and to gain

an understanding of how fast the red cells are being destroyed in the case of a hemolytic anemia. Platelets are only found in fresh whole blood (administered within 6-8 hours) and in platelet-rich plasma.

If the patient has lost clotting factors then clotting factors should be replaced. This means administering fresh whole blood or fresh frozen plasma. Fresh frozen plasma is considered fresh frozen for 1 year and then frozen for another 4 years although there is some published information suggesting the clotting factors maintain their integrity for much longer than 1 year. Fresh frozen plasma contains coagulation factors, albumin and immunoglobulins. Frozen plasma contains Factors II, VII, IX, X, albumin and immunoglobulins. Cryoprecipitate contains 50% Factor VIII/vWf from the original unit, 20-40% fibrinogen and some Factor XIII. Cryopoor plasma contains the remaining clotting factors, albumin and immunoglobulins.

If the patient has a low albumin but normal clotting factors then fresh frozen plasma is not necessary and frozen plasma or human albumin can be given. Two-thirds of the albumin is in the interstitial space so replenishing albumin levels often requires significant volumes of plasma, especially in large dogs. For this reason plasma usually is used to replenish clotting factors and not restore albumin levels (except in small patients) and synthetic colloids are used to ensure adequate oncotic pressure is maintained.

Plasma not only is an important contributor to oncotic pressure but albumin also is important as a free radical scavenger. Albumin may improve microcirculatory flow and is important as a carrier of drugs. Plasma also provides a source of α–macroglobulin, which binds the activated and liberated proteases in patients with pancreatitis.

Unless the blood type of the recipient and donor are known all transfusion recipients should have a major and minor crossmatch. Dogs who are in danger of dying and have never received a transfusion usually can be transfused without a crossmatch but the clinician should watch carefully for any reaction including delayed reactions that may not show up for several weeks. Since cats have naturally occurring alloantibodies they must be crossmatched prior to transfusing since even a few drops of type A blood given to a type B cat can cause death.

References available on request.