Dogs and cats frequently present to veterinarians in hypovolemic shock following trauma. Blunt trauma from motor vehicles is by far the most common cause of trauma, and intravenous fluid therapy is one of the most important modalities of shock management in these patients. This lecture will cover fluid therapy options and their indications in patients presenting with a variety of complications from blunt trauma, including head trauma, pulmonary contusions, and hemoabdomen.

Physical Examination of the Trauma Patient
All trauma patients require immediate assessment to determine whether life-threatening injuries have occurred. Initial evaluation should begin with the respiratory and cardiovascular systems, followed rapidly by evaluation of the neurologic system and the abdomen, with completion of a full physical examination once the most important crises have been addressed.

By observing the pattern of respiration, mucous membrane color, and auscultation of the respiratory tract, the clinician can determine whether the animal’s airway is patent, and if inadequate ventilation or oxygenation are occurring. Respiratory rate and effort should be quantitated, and the lungs should be carefully ausculted to assess for pulmonary contusions (crackles or harshness) and pneumothorax or hemothorax (dull lung sounds). To evaluate the cardiovascular system, pulse rate and quality, mucous membrane color, and capillary refill time should be assessed. The heart should be ausculted to determine whether a murmur or arrhythmia is present, as the possibility of preexisting heart disease will affect fluid therapy. The initial examination of these systems provides substantial information about the patient’s intravascular volume status and the degree of compensation that is occurring. Increased heart rate, pale mucous membranes, and bounding pulses in a trauma patient suggest a hypovolemic state that needs to be addressed immediately to prevent progression to the final stage, decompensatory shock.

The neurologic status of the trauma patient must next be rapidly assessed, looking for any suggestion of head trauma, which would influence fluid therapy. Rapid assessment of the abdominal cavity to rule out the presence of a hemoabdomen is also important, as it may influence fluid therapy. Palpation of the abdomen may reveal pain and/or a fluid wave. To confirm the diagnosis, abdominocentesis is needed. The presence of nonclotting blood in the peritoneal cavity, often with a packed cell volume and total protein similar to or higher than that of peripheral blood, is diagnostic for a hemoabdomen. The most common sites of bleeding are the spleen and liver. With appropriate medical therapy consisting of intravenous fluids +/- blood products, surgery is seldom needed to stop the bleeding in a traumatic hemoabdomen. Other abdominal injuries such as a ruptured bladder or urethra may be present, but may not become evident until later.

After these 4 systems have been assessed and life-threatening conditions such as hypovolemic shock have been addressed, the rest of the physical examination should be performed to look for other important traumatic injuries such as appendicular fractures, spinal cord injury, or skin wounds.

Initial Diagnostics and Therapeutics
Oxygen therapy is always indicated during the initial assessment of the trauma patient, using a mask or flow-by oxygen. If the patient is dyspneic and has dull lung sounds, then thoracocentesis should be performed to rule out a pneumothorax. Clinical diagnosis of a pneumothorax is essential, as radiographs may not be tolerated by an unstable patient, and thoracocentesis can be both diagnostic and therapeutic. Venous access should be obtained as soon as possible, usually a large gauge cephalic vein catheter due to ease of placement. In extremely hypovolemic patients, a surgical cut-down on the jugular vein may be necessary for rapid venous access. Regardless of the vein chosen, a short, large bore catheter should be used to maximize flow rates for IV fluid therapy.

While placing a catheter, a small amount of blood should be obtained for the emergency database, consisting of a packed cell volume (PCV), total protein (TP), blood glucose, and dipstick estimation of blood urea nitrogen. The PCV and TP can give insight into the severity and duration of bleeding. Immediately after blood loss in an otherwise healthy animal, the PCV and TP are normal. Then, as fluid is mobilized from the interstitium into the intravascular space, the PCV remains stable because of splenic contraction, while the TP decreases due to dilution. As hemorrhage continues, both the PCV and TP decrease. Measuring the PCV and TP on admission also provides a reference point for comparison when monitoring intravenous fluids. The glucose is usually normal in dogs following...
trauma, with the exception of extremely poorly perfused, almost moribund dogs, when a moderate to marked elevation of glucose can be seen. Hyperglycemia is common in cats following trauma, but also is commonly elevated whenever cats experience any significant stress. Elevation of blood urea nitrogen can imply pre-renal azotemia due to hypovolemia, rupture of the urinary tract, or intraluminal gastrointestinal tract hemorrhage.

**Choice of Fluid Therapy**

Once the need for fluid therapy has been established based on the physical examination findings and vascular access has been attained, the choices of fluid type and rate must be made. Options for intravenous fluid administration include crystalloids, colloids, and blood products. The fluid rate varies considerably based on the type of fluid chosen. Crystalloids are most commonly used in trauma patients due to their relatively low cost and the familiarity of clinicians with this type of fluid. In many cases, crystalloids remain the fluid of choice, but there are some instances in which other fluids are more advantageous.

**Isotonic Crystalloids**

Isotonic crystalloids consist of solutions of ions with an osmolarity similar to that of plasma. They include 0.9% saline (NaCl) and balanced electrolyte solutions such as Lactated Ringer’s solution, Normosol-R, or Plasmalyte 156. These fluids are often used interchangeably, but there are some differences to consider. The trauma patient often has a metabolic acidosis secondary to poor tissue perfusion, anaerobic metabolism, and lactate production. Although alkalinizing solutions may be beneficial for treatment of metabolic acidosis, replacement of intravascular volume and improvement of tissue perfusion are the most important goals of therapy. Ultimately, any of these fluids can achieve this goal. However, 0.9% NaCl is an acidifying solution, which may slow down the resolution of the metabolic acidosis, so more neutral fluids such as Lactated Ringer’s solution, Normosol-R, or Plasmalyte may be preferred.

For management of hypovolemic shock, a bolus dose of isotonic crystalloids is equivalent to one blood volume: 40–60 mls/kg for cats and 60–90 mls/kg for dogs. The patient is usually given ⅔ to ⅖ of the calculated bolus dose based on body weight, over a period of 10–30 minutes depending on the severity of clinical signs. The physical examination parameters are then reassessed. If the animal continues to show signs of poor perfusion, then the remainder of the bolus can be given. After the animal has stabilized, the need for continued fluid therapy must be addressed. Complete withdrawal of fluids after the bolus often results in worsening of clinical parameters. Crystalloid fluids rapidly diffuse out of the blood vessels into the interstitial space. Very little (about 20–25%) of the bolus volume infused will remain in the intravascular space after about an hour. Continued fluid therapy is vital to maintain intravascular volume in the face of rapid redistribution. Trauma patients usually require fluid rates of 4–10 mls/kg/hr, depending on ongoing losses, for at least a few hours after presentation and shock resuscitation.

Careful patient monitoring is extremely important, and clinical parameters must be reassessed frequently to make sure that the fluid rate remains appropriate. Clinical parameters including heart rate, pulse quality, mucous membrane color, and capillary refill time are very helpful for monitoring the success of fluid therapy, as are serial measurements of the PCV, TP, urine output, and blood pressure.

Isotonic crystalloids should be used with caution in trauma patients with possible pulmonary contusions. Fluid therapy of any type can increase the amount of pulmonary parenchymal hemorrhage and create edema in the injured lung tissue, aggravating respiratory distress. In animals with both shock and pulmonary contusions, the severity of shock must be assessed compared with the degree of dyspnea, and the most life-threatening problem prioritized. If there are only mild to moderate changes in the patient’s heart rate and pulse quality, fluids may not be required, and oxygen supplementation may be enough. If the animal is in severe shock, incremental boluses of 10–15 mls/kg can be given until cardiovascular parameters are improved, with careful monitoring of pulmonary function.
**Hypertonic Saline**

Hypertonic saline is a crystalloid with a much higher concentration of NaCl than plasma. Most hypertonic saline solutions are either 5% or 7.5%. These solutions provide effective, extremely rapid, but short-lived expansion of the intravascular volume, due to rapid movement of water into the capillaries from the interstitial space. The short duration of intravascular expansion is due to rapid movement of the sodium and chloride molecules back out through the capillary membrane and equilibration with the interstitial space. Hypertonic saline is often combined with a colloid such as Hetastarch in an attempt to prolong the intravascular volume expansion. A mixture of 17 ml of 23.5% saline and 43 ml of 6% Hetastarch is used to create a final concentration of 7.5% saline.

Because of its efficacy in short-term volume expansion, the dose of hypertonic saline is much lower than that of all the other fluid types: 4–7 ml/kg in dogs and 2–4 ml/kg in cats, given over about 5 minutes. Hypertonic saline should be followed by isotonic crystalloids to maintain the volume expansion. Many trauma patients often need a bolus of isotonic crystalloids with the hypertonic saline, but the bolus dose required is considerably reduced. Hypertonic saline is particularly useful in very large dogs or when there is insufficient time to administer the bolus dose of isotonic crystalloids because the patient is in extremis. Currently, the main indication for hypertonic saline use is in patients with head trauma, as the hypertonic solution may actually draw fluid out of the brain, reducing cerebral edema. Because the severity of cerebral ischemia is related to both increased intracranial pressure and decreased systemic arterial perfusion pressure, it is important to maintain adequate mean arterial pressure without contributing to cerebral edema. Hypertonic saline is the ideal fluid choice in this situation, because only a small volume of intravenous fluid can result in dramatic increases in arterial blood pressure.

Contraindications for the use of hypertonic saline include dehydration, hypernatremia, or severe uncontrolled bleeding that may be worsened by a rapid rise in arterial blood pressure. While hypertonic saline may be thought to be beneficial in treatment of patients with pulmonary contusions because of the very small volume required, it may actually worsen the degree of pulmonary hemorrhage by the rapid increase in arterial pressure.

**Colloids**

Colloids are large molecules that cannot freely diffuse through the capillary membrane. They can be divided into 2 types: natural and synthetic. Albumin is the most important natural colloid, and Hetastarch is the artificial colloid most commonly used. The advantage of colloids is that since they do not rapidly diffuse across the capillary membrane, they act to hold water in the intravascular space and maintain intravascular volume expansion for longer periods of time than crystalloids. Although colloids are helpful in management of many other types of critical illness in small animals, their value has been questioned in trauma patients. In human outcome studies, increased survival has not been documented in trauma patients treated with colloids versus crystalloids. If a large cost differential exists, it may be hard to justify the use of colloids for the average veterinary trauma case.

The dose of colloids is much lower than the dose of crystalloids. Since almost all of the administered colloid is expected to remain in the intravascular space, shock doses of about one-fifth to one-quarter the crystalloid dose are recommended. This corresponds to a colloid shock bolus of 10–20 mls/kg in dogs and 8–12 mls/kg in cats. The length of time that the colloids will remain in the intravascular space depends on the size and distribution of the molecules.

If colloids are being used in conjunction with crystalloids for volume resuscitation, both doses should be adjusted accordingly. In a dog with hypovolemic shock for example, a synthetic colloid bolus of 5–10 mls/kg combined with 30 mls/kg of crystalloid fluids would be reasonable for initial volume expansion. Colloids are also lost from the intravascular space, but at a very much slower rate than crystalloids. Thus, as with crystalloids, clinical experience suggests that colloid therapy should be continued (at rates of 0.5–1 ml/kg/hr) following the shock bolus in animals with severe injury. If colloids are used in a patient with suspected pulmonary contusions, the dose should be reduced. In this case, small boluses of 3–5 ml/kg are given and titrated to effect.

Artificial colloids can cause a coagulopathy due to dilution of coagulation factors and impairment of von Willebrand factor and factor VIII function. This effect becomes particularly evident when doses greater than 20 mls/kg/day are given and may be significant in the hemorrhaging trauma patient, but it can be attenuated by the concurrent administration of fresh or fresh frozen plasma as a source of replacement coagulation factors.
**Blood Products**

Hypovolemic shock following trauma is usually due to internal or external hemorrhage. If the blood loss is significant, the patient may require blood products in addition to colloids or crystalloids. There is no specific “transfusion trigger” such as a set PCV or coagulation time that indicates the need for transfusion of blood products; patients’ needs can vary significantly. Whole blood, packed red blood cells (pRBCs), and fresh frozen plasma (FFP) may all be needed, depending on the individual case. The advantage of freshly collected whole blood is that this is the only source of viable platelets in addition to erythrocytes and coagulation factors. Stored blood components, however, offer immediate availability, selective administration of only the blood component required, and the ability to store the products for longer periods. pRBCs can be stored for up to 35 days, and FFP can be stored for 1 year. Recommended doses of blood products for dogs are whole blood 20–25 ml/kg; pRBCs 15–20 ml/kg; and FFP 10–15 ml/kg. For cats, whole blood should be given at the dose of 10–15 ml/kg. This dose of blood would ideally be given over a 3- to 5-hour time period, although if the animal is in hypovolemic shock, it can be given much more quickly, even as a bolus if required. The dose required by individual animals can vary significantly, especially in those with ongoing blood loss.

In canine transfusion medicine, the major blood type is dog erythrocyte antigen (DEA) 1.1. Both DEA 1.1 positive and negative blood types occur. The DEA 1.1 negative blood type is the universal donor. This is especially important in treatment of the trauma patient, where there may not be time to test the blood type of the recipient before administering blood products. When possible, it is ideal to cross match the patient and potential donor’s blood, but this can be omitted if the patient has not previously received blood products. In cats, there are no universal donors, so a blood type should always be obtained. In contrast to dogs, cats are born with naturally occurring antibodies against the other blood group antigens. The most common feline blood type is A, but 2 other blood types exist: B and AB. If type A blood is given to a type B cat, a severe and usually fatal transfusion reaction occurs. Type B blood can usually be given to a type A cat without such serious side effects, but the cells have a reduced half-life and are usually gone within 2–3 days. Cats with type AB blood are rare.

A stroma-free synthetic hemoglobin (Oxyglobin®, Biopure, Cambridge, MA) is also an option for providing oxygen-carrying capacity in the trauma patient, although it currently has limited availability. Oxyglobin is a potent colloid, and care must be taken not to cause volume overload in veterinary patients, particularly cats. Doses for Oxyglobin are 10–15 mls/kg for dogs and 5–10 mls/kg for cats given over several hours.

**Monitoring Fluid Therapy**

The patient must be closely monitored during fluid administration. Physical examination findings such as mucous membrane color, capillary refill time, pulse quality and rate, heart rate, and respiratory rate and effort should all be monitored. Blood pressure can be measured either via indirect, noninvasive methods or direct methods after placement of an arterial catheter. Central venous pressure (CVP) measurement can be used to determine whether volume replacement is adequate, using a central catheter (usually a long jugular catheter) in the vena cava, which is connected to a three-way stopcock and water manometer. Normal CVP measurements are 0–8 cm H2O, but can vary significantly. Intermittent readings are taken, which provides information about the degree of “filling” of the large capacitance vessels and therefore allows monitoring of volume status. Trends of change in CVP are more important than an absolute number.

Urine output should be closely monitored to ensure that renal perfusion has been maintained (urine output will cease if the mean arterial pressure is below 50–60 mm Hg). The minimum acceptable urine output should be 1–2 ml/kg/hr, but can vary significantly from patient to patient, especially if volume depletion is still present. A urinary catheter with a sterile closed collection system is useful for accurate measurement of urine output. A urinalysis after the animal has been stabilized can be helpful to determine the severity of renal injury by poor perfusion; if renal tubular casts are present, renal tubular necrosis has occurred.

Serial monitoring of blood parameters should also be performed, most importantly including PCV and TP. In addition to ongoing hemorrhage, if large volumes of crystalloid or colloid are needed to resuscitate a patient, further dilution of PCV and TP will occur. If the PCV drops quickly, the animal may not be able to compensate for the diminished oxygen-carrying capacity and may require transfusion with either whole blood or pRBCs. Significant decreases in TP may also be accompanied by a dilutional coagulopathy, and these animals should be treated with either FFP or whole blood. If blood lactate measurement is available, it can be very useful in monitoring the
response to fluid therapy. Animals in hypovolemic shock usually present with an elevated blood lactate concentration, which will return to normal as the animal’s perfusion improves.

**Suggested Reading**

