

# Fluid therapy in the trauma patient

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## KEY POINTS

- Small companion animals are frequently presented to veterinarians in hypovolemic shock following trauma.
- Traumatic accidents involving animals and motor vehicles are by far the most common cause of trauma.
- Intravenous fluid therapy is one of the most important shock management techniques in these patients.
- In order fully to understand the indications, doses, and monitoring of fluid therapy, it is first necessary to understand hypovolemic shock.

## STAGES OF HYPOVOLEMIC SHOCK

Shock is defined as hemodynamic perfusion that is inadequate to meet the metabolic requirements of the tissues. There are several different types of shock based upon the etiology, including hypovolemic, cardiogenic and septic, or distributive shock. Hypovolemic shock is common following trauma, as a consequence of internal or external hemorrhage.

Hypovolemic shock can be divided into three stages:

- The earliest, compensatory, stage manifests clinically as increased heart rate, peripheral vasoconstriction, and increased cardiac output, all of which help maintain normal blood pressures and perfusion. This stage usually has an excellent prognosis if treated appropriately with adequate fluids to restore the intravascular volume.
- The middle stage of hypovolemic shock occurs if volume loss continues. It is characterized by tachycardia, hypothermia, decreased blood pressure, prolonged capillary refill time, poor peripheral pulses, and, eventually, decreased urine output. Blood is shunted away from the abdominal organs in an effort to maintain perfusion to the brain, heart, and lungs.
- The final stage is the decompensatory stage, which is often irreversible. As hypovolemia reaches the end stage, blood vessels begin to dilate, allowing blood to pool in the peripheral tissues. Decreased myocardial perfusion can lead to arrhythmias and further reductions in cardiac output. Poor cerebral perfusion causes progressive central nervous system depression. Pulmonary edema and respiratory failure can develop following the onset of the Systemic Inflammatory Response Syndrome. Severe, refractory hypotension often leads to cardiopulmonary arrest. Despite aggressive treatment, decompensatory shock is often fatal.

The most important treatment for hypovolemic shock is re-expansion of the intravascular volume by intravenous fluid therapy. Expansion of the blood volume results in improved tissue perfusion and improvement in such clinical parameters as heart rate, pulse quality, and vasoconstriction.

## PHYSICAL EXAMINATION OF THE TRAUMA PATIENT

All trauma patients require immediate assessment to determine whether life-threatening injuries have occurred (Table 1). Initial evaluation should begin with the respiratory and cardiovascular systems, followed rapidly by evaluation of the central and peripheral nervous system and the abdomen. A complete physical examination should be performed once the most important crises have been addressed.



By observing the pattern of respiration and assessing mucous membrane color, the clinician can determine whether the animal's airway is patent and whether adequate ventilation and oxygenation are occurring. Respiratory rate and effort should be quantified. The lungs should be carefully auscultated to check for pulmonary contusions (crackles or harshness) and pneumothorax or hemothorax (dull lung sounds).

To evaluate the cardiovascular system, pulse quality should be determined, and mucous membrane color and capillary refill time assessed. The heart should be carefully auscultated to determine whether a murmur or arrhythmia is present. This is important as the possibility of pre-existing heart disease must be considered before a fluid rate is chosen. In dogs, the absence of a murmur or arrhythmia on auscultation is usually sufficient to determine that there is no significant cardiac disease. The finding of a murmur or arrhythmia does not always imply the presence of intrinsic heart disease in the trauma patient. However flow murmurs may result from anemia and ventricular arrhythmias may result from poor myocardial perfusion. Unfortunately, feline patients can be more difficult to assess since their cardiac disease is usually myocardial rather than valvular. As such, murmurs and arrhythmias may be absent or intermittent in cats with cardiomyopathy.

The initial examination of these two vital 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 a bounding pulse in a trauma patient suggest a hypovolemic state that needs to be addressed immediately to prevent progression to the final stage of decompensatory shock.

The neurological status of the trauma patient must then be rapidly assessed, looking closely for any suggestion of head trauma, which would also influence the choice and rate of fluid therapy. Signs of head trauma can include anisocoria, conjunctival hemorrhage, palpable skull fractures, epistaxis, bleeding in the aural canals, or abrasions or lacerations on the skin of the face and head. An inappropriate mental state (dullness or delirium) may also be seen.

Rapid assessment of the abdominal cavity is important. The clinician must rule out the presence of a hemoabdomen prior to making decisions about fluid therapy. Palpation of the abdomen may be sufficient if pain and/or a fluid wave are detected. Usually, however, abdominocentesis is necessary. The presence of non-clotting 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 – intravenous fluid resuscitation and placement of an abdominal pressure bandage – 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 four systems have been assessed and life-threatening conditions such as hypovolemic shock have been dealt with, further physical examination should 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 (Table 2). It may be supplied by using a mask or by providing flow-by oxygen (Figure 1). Once it is determined that the patient does not have respiratory compromise, oxygen supplementation may be discontinued. The use of a nasal oxygen

**Table 1**  
**Initial assessment of the trauma patient**

- Respiratory – rate, effort, mucous membrane color, auscultation
- Cardiovascular – heart rate, pulse rate and quality, mucous membrane color, capillary refill time, auscultation
- Nervous – mental state, pupil size and responsiveness, motor function, proprioception, pain
- Abdomen – abdominal pain, effusion

**Table 2**  
**Initial diagnostics/therapeutics in the trauma patient**

- O<sub>2</sub> therapy
- Intravenous catheter, initial database (PCV, TS, glucose, BUN)
- Fluid therapy – fluid and rate?
- Thoracocentesis and/or abdominocentesis
- Blood pressure, pulse oximetry



**Figure 1** Flow-by oxygen is being provided to this cat via oxygen tubing. This is a very nonstressful way to increase the inspired oxygen concentration while retaining access to perform additional diagnostics and therapies.

catheter is not recommended initially, as placement of the catheter can be stressful, and it is often unclear how long the patient will actually need oxygen therapy. If the patient is dyspneic and, on auscultation, the lung sounds are difficult to hear, thoracocentesis should be performed immediately. Radiographs are often postponed until after the patient has been stabilized, so clinical assessment of a pneumothorax is essential. A large syringe, needle, extension set, and three-way stopcock are all that is needed to perform thoracocentesis, a potentially life-saving procedure.

Venous access is of immediate concern in the hypovolemic trauma patient. A large gauge cephalic vein catheter is usually preferred as it is comparatively easy to place. However, in extremely hypovolemic patients, a surgical cut-down on the jugular vein may be necessary for rapid venous access. Regardless of the vein chosen, the catheter length should be as short as possible. Fluid flow through a catheter depends on the radius of the catheter to the fourth power and is directly proportional to the catheter's length. Long, small diameter catheters will therefore not allow rapid infusion of fluid boluses.

During the process of catheterization a small amount of blood should be obtained for the emergency database. This will consist of a packed cell volume (PCV), total protein (TP), dipstick blood glucose,

**Table 3**  
**Shock fluid boluses**

		Dog	Cat
Isotonic crystalloid		60–90 ml/kg	40–60 ml/kg
Hypertonic saline		4–7 ml/kg	2–4 ml/kg
Colloids (dextrans, starches, gelatins)		10–20 ml/kg	8–12 ml/kg
Blood products	whole blood	20–25 ml/kg	10–15 ml/kg
	pRBCs	15–20 ml/kg	
Fresh frozen plasma		10–15 ml/kg	

and dipstick estimation of blood urea nitrogen. The PCV and TP can give insight into the severity and duration of bleeding. For example, immediately after blood loss, in an otherwise healthy animal, the PCV and TP are normal. However, as fluid is mobilized from the interstitial spaces into the intravascular space, the PCV remains stable because of splenic contraction (which releases additional red blood cells in to the circulation), while the TP decreases due to dilution. As hemorrhaging 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. Glucose is usually normal in dogs following trauma, unlike cats, which often have an exaggerated stress response accompanied by hyperglycemia. An exception occurs in extremely poorly perfused, almost moribund dogs when a moderate to marked elevation of glucose can be seen. Elevation of blood urea nitrogen can imply pre-renal azotemia due to hypovolemia, rupture of the urinary tract, or intraluminal gastrointestinal tract hemorrhage.

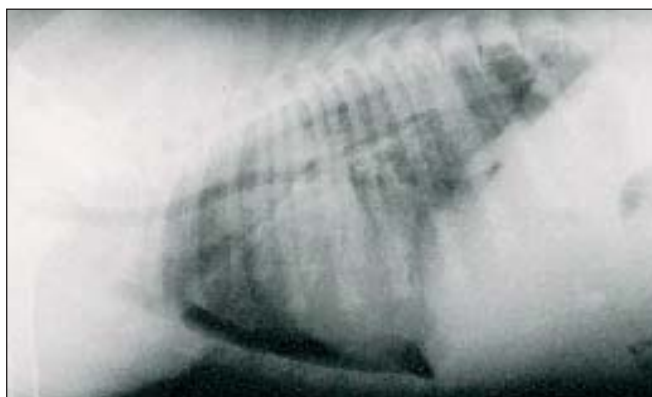
## CHOICE OF FLUID THERAPY

Once the need for fluid therapy has been established, as outlined above, the choices of fluid type and rate must be made (**Table 3**). Options for intravenous fluid administration include crystalloids, colloids, and blood products. The rate at which intravenous fluids are administered varies considerably and is influenced by 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 have been available for longer than any other type of fluid and 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 Ringer's or Hartmann's (lactated Ringer's) solution. 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 alkalizing solutions may be beneficial for the treatment of metabolic acidosis, the most important treatment is the replacement of intravascular volume and the improvement of tissue perfusion. Both 0.9% NaCl and Ringer's are acidifying solutions and may slow down the resolution of the metabolic acidosis. Thus, a slightly less acidifying fluid (such as Hartmann's) may be beneficial. In cases of hyperkalemia due to uroperitoneum, 0.9% NaCl is the best choice.

For the management of hypovolemic shock, a bolus dose of isotonic crystalloids is equivalent to one blood volume – i.e., 40–60 ml/kg for cats and 60–90 ml/kg for dogs. The patient is usually



**Figure 2**  
*Lateral and ventrodorsal radiographs of a four-month-old American Pit Bull Terrier after a road traffic accident. There are marked pulmonary contusions on the left side, a small pneumothorax, and fractured ribs 9 and 10 on the right.*

given  $\frac{1}{3}$  to  $\frac{1}{2}$  of the calculated bolus dose (based on bodyweight) 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 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 the worsening of clinical parameters. This is because crystalloid fluids rapidly diffuse out of the blood vessels into the interstitial space. For example, very little of the initial bolus dose (about 20–25%) will remain in the intravascular space after about one hour. Continued fluid therapy is therefore essential if the intravascular volume is to be maintained in the face of rapid redistribution. Trauma patients usually require fluid rates of 4–10 ml/kg/hr 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 (**Figure 2**). 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 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 small boluses of 10–15 ml/kg can be given until the desired perfusion parameters are obtained, with careful monitoring of pulmonary function.

### *Hypertonic saline*

Hypertonic saline is also a crystalloid, with a much higher concentration of sodium chloride 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 Dextran 70 in an attempt to prolong the intravascular volume expansion. A mixture of 17 ml of 23.5% saline and 43 ml of 6% Dextran 70 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. Only 4–7 ml/kg in dogs and 2–4 ml/kg in cats are required, given over a five-minute period. Hypertonic saline administration should be followed by isotonic crystalloids to maintain the volume expansion. Many trauma patients often need a bolus of isotonic crystalloid with the hypertonic saline, but the bolus dose required is usually considerably reduced in comparison to that required if hypertonic fluids have not been previously administered.

Hypertonic saline is particularly useful in very large animals 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 a small volume of intravenous fluid can dramatically increase the arterial blood pressure.

Contraindications for the use of hypertonic saline include dehydration (there is insufficient water in the interstitial space to move into the intravascular space and dilute the hypertonic saline), 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 treating patients with pulmonary contusions (because of the very small volume required), it may actually worsen the degree of pulmonary hemorrhage by rapidly increasing arterial pressure.

### **Colloids**

Colloids are large molecules that cannot freely diffuse through the capillary membrane. They can be divided into two types: natural and synthetic. Albumin is the most important natural colloid, which in veterinary medicine can only be given via whole plasma transfusion. It has a molecular weight of 69,000 daltons. There are several different types of synthetic colloids, including gelatins,

starches, and dextrans (see below). 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 the expansion of intravascular volume for longer than crystalloids. Although colloids are helpful in managing 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 there is a large cost differential, it may be hard to justify the use of colloids for the average veterinary trauma case.

The dose of colloid is much lower than that of crystalloids (Table 3). Since almost all of the administered colloid is expected to remain in the intravascular space, shock doses of about 1/3 to 1/2 the crystalloid dose are recommended. This corresponds to a colloid shock bolus of 10–20 ml/kg in dogs and 8–12 ml/kg in cats. The length of time that the colloids remain in the intravascular space depends on the size and distribution of the molecules. Smaller molecules are eliminated more quickly, especially if they are below the renal threshold of 55,000 daltons, when they are lost into the urine. Larger molecules may require hydrolysis before they can be eliminated, although some are also phagocytosed by the monocyte-macrophage system. The specific rates of elimination for individual colloids are discussed below.

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, synthetic colloid boluses of 10 ml/kg combined with 30 ml/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 0.5–2 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.

All of the colloids can cause a coagulopathy, due to dilution and precipitation of coagulation factors, and impairment of von Willebrand factor function. This coagulopathic effect becomes particularly evident when doses greater than 20 ml/kg/day are given, and may be significant in the hemorrhaging trauma patient. The coagulopathic effect can be attenuated by the concurrent administration of plasma as a source of replacement coagulation factors. Refractometric measurement of TP is also affected by the administration of synthetic colloids. The refractometer reading of hetastarch and dextrans is 4.5 mg/dl, so synthetic colloids usually dilute the patient's TP measurement, unless the TP is below 4.5 mg/dl prior to colloid administration. Despite the decrease in measured TP, synthetic colloids effectively increase the patient's colloid osmotic pressure.

### *Gelatins*

Many different gelatin solutions are available, all of which are chemically modified versions of naturally occurring gelatins. These solutions have an average molecular weight of 30,000–35,000 daltons, resulting in rapid excretion by the kidneys. Although they cause rapid volume expansion, they have an intravascular half-life of only about 2.5 hours. Since other synthetic colloids (below) have a longer duration of action, they offer significant advantages over gelatins. Because they are eliminated by the kidneys, gelatins are not recommended for use in patients with renal failure or insufficiency, although they have not been documented to cause renal failure. Of all the synthetic colloids, the gelatins have the highest incidence of anaphylactic reactions. It is possible that animals may have antibodies to gelatins from previous exposure to them in food.



**Figure 3** This five-year-old male neutered Greyhound developed a hemoabdomen after a road traffic accident. An abdominal compression wrap was placed to increase intra-abdominal pressure and reduce bleeding. He became anemic, requiring the administration of a unit of pRBCs. A urinary catheter was placed so that urine output could be measured.

Photo courtesy of Dr. Ken Drobatz, University of Pennsylvania.

### Dextrans

These are glucose polymers that are synthesised by the bacteria *Leuconostoc mesenteroides* growing in a sucrose medium. The synthetic dextrans are fractionated into solutions containing two different sized molecules, which are commercially available as Dextran 40 and Dextran 70, both packaged in isotonic saline. Dextran 40 has an average molecular weight of 40,000 daltons and is a 10% solution, while Dextran 70 has an average molecular weight of 70,000 daltons and is a 6% solution. Dextran 70 has a much longer half-life (12–24 hours) than Dextran 40 (2–4 hours) because the smaller molecules are more rapidly eliminated by the kidneys. Both dextrans rapidly expand the intravascular volume, with Dextran 40 causing a larger increase initially but persisting for a shorter time. Dextran 40 also has a rheologic effect; it improves microcirculation by reducing blood viscosity. Dextran 40 can result in acute renal failure because it can precipitate in the renal tubules of dehydrated patients, but this effect is not seen with Dextran 70. Because of the significant risk of renal failure, Dextran 40 is not commonly used in veterinary patients.

Anaphylactic reactions have been reported with both dextrans and are thought to result from histamine release. In addition, naturally occurring antibodies may occur, as dextrans are found in sugars and other foods. Dextrans also result in the most severe coagulopathy. In addition to causing a dilutional coagulopathy, dextrans reduce platelet adhesion and aggregation by inhibiting Factor VIII and Von Willebrand factor. Despite these drawbacks, their relatively low cost compared with starches have made dextrans popular in veterinary clinical use.

### Starches

Hetastarch is a hydrolyzed synthetic polymer of amylopectin, which is a highly branched polysaccharide resembling glycogen. Hetastarch is packaged as a 6% solution in isotonic saline. It has a very large molecular weight range, from 10,000 to greater than 1,000,000 daltons, with a number average molecular weight of 71,000 daltons (note: the average molecular weight, which is a less clinically relevant value, is approximately 450,000 daltons). The half-life of hetastarch is greater than 24 hours, with rapid clearance of the smallest molecules by the kidneys. Glucose moieties must be cleaved from the large polymer molecules by plasma amylase before the hetastarch molecules are small enough to be excreted in the urine. This often causes a 2–3 fold increase in serum amylase which is not

associated with pancreatitis. In addition, large hetastarch molecules are also ingested by macrophages, thereby being cleared from the circulation. The starches have a very low incidence of anaphylactic reactions (lowest of all the synthetic colloids). They also cause inhibition of Factor VIII and Von Willebrand factor in addition to the dilutional coagulopathy, but to a lesser extent than dextrans. Pentastarch is similar to hetastarch except that the molecular weights are larger, with a narrower distribution range, including more of the molecules that are of therapeutic size. Because of their low toxicity, large molecular weights, and duration of action, the starches are the preferred synthetic colloid for veterinary clinical use.

## 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. Whole blood, packed red blood cells (pRBCs), and fresh frozen plasma (FFP) may all be needed. 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 relatively long periods. Canine 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 3–5 hour 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 the presence of ongoing blood loss. Every attempt should be made to stop ongoing bleeding as soon as possible. This may include placement of an abdominal pressure bandage if a hemoabdomen is present (**Figure 3**), or ligation of a peripheral artery if possible.

In canine transfusion medicine, the major blood type of concern is dog erythrocyte antigen (DEA) 1.1. There are DEA 1.1 positive and negative blood types. The DEA 1.1 negative blood type is the universal donor, so canine donors with this blood type are preferred. This is especially important in treating 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's and potential donor's blood, but this is of minor concern in the trauma setting when the canine patient has not previously received blood products. In cats, there are no universal donors, so it is always important to obtain a blood type immediately. 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 there are two others: 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 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. Because there is no closed collection system for blood donation by cats, long-term storage and separation of feline blood into component products has not been possible. Cat blood can be stored for up to a week as whole blood, but should not be kept any longer for fear of bacterial contamination.

A stroma-free synthetic hemoglobin is commercially available in the USA, and may soon become available in the UK. This product effectively increases plasma oxygen-carrying capacity, and offers the potential advantages of easy availability and long shelf-life for use in the emergency situation. Problems such as its short half-life *in vivo*,





**Figure 4**  
Central venous pressure can be used to determine the degree of volume replacement. This Great Dane has a jugular catheter that is attached to a manometer via a three-way stopcock. Heparinized saline colored with B vitamins is used to fill the manometer, then the stopcock is turned, connecting the patient to the manometer. The level at which the fluid column settles is the CVP reading.

tissue discoloration and volume overload mean that red blood cell transfusion remains the ideal management choice for the foreseeable future.

## 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 (Doppler technique or oscillometry) or direct methods after placement of an arterial catheter. Central venous pressure (CVP) measurement can be used to determine whether volume replacement is adequate. CVP can be measured using a central catheter (usually a long jugular catheter) in the vena cava, which is connected to a three-way stopcock and water manometer (**Figure 4**). Normal CVP measurements are 0–8 cm H<sub>2</sub>O, but can vary significantly. Intermittent readings are taken to provide information about the degree of 'filling' of the large capacitance vessels, and therefore allow monitoring of volume status.

Trends of change in CVP are more important than an absolute number. CVP provides an estimate of right atrial pressure and right ventricular end-diastolic pressure. With regard to fluid overload, particularly in relation to lung function, left atrial and ventricular end-diastolic pressure would actually be a more accurate measure. These parameters are estimated by measuring the pulmonary capillary wedge pressure (PCWP), which requires placement of a balloon-tipped Swan-Ganz catheter from the jugular vein, through the right heart, and out into a pulmonary artery. Normal PCWP is 6–12 mmHg, so volume replacement should continue until the PCWP rises back into this range. Unfortunately, the time it takes to place this catheter and the equipment needed to calculate PCWP do not make it practical for use in most clinical situations.

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 mmHg). The minimum acceptable urine output should be 1–2 ml/kg/hr, but can vary significantly from patient to patient, especially if there is still volume depletion. A urinary catheter with a sterile closed collection system is very useful so that accurate measurement of the urine output can be performed.

A urinalysis should be performed after the animal has been stabilized 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 tends to 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.

## FURTHER READING

- Griot-Wenk, M. E., Giger, U. Feline transfusion medicine: blood types and their clinical importance. *Veterinary Clinics of North America* 1995; **25**: 1302–1322.
- Hackner, S. G. Emergency management of traumatic pulmonary contusions. *Compendium on Continuing Education* 1995; **17**: 677–686.
- Hughes, D. Fluid Therapy. In: Hammond, R., King, L. G. (eds). *BSAVA Manual of Canine and Feline Emergency and Critical Care*. Cheltenham: BSAVA Publications, 1999.
- Kristensen, A. T., Feldman, B. F. Canine and feline transfusion medicine. *The Veterinary Clinics of North America* 1995; **25**: 1277–1291.
- Mandell, D. C., King, L. G. Fluid therapy in shock. *The Veterinary Clinics of North America* 1998; **28**: 623–644.
- Matthews, K. A. The various types of parenteral fluids and their indications. *The Veterinary Clinics of North America* 1998; **28**: 483–510.
- Tobias, T. A., Schertal, E. R. Shock: Concepts and Management. In: Dibartola, S. P. (ed). *Fluid Therapy in Small Animal Practice*. Philadelphia: Saunders, 1992: 436–470.