

# Resuscitating Trauma Patients

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## KEY WORDS

- trauma
- oxygen therapy
- thoracentesis
- tracheostomy
- positive pressure ventilation
- blood volume restoration

The diagnostic/therapeutic challenges of trauma are that it can cause devastating internal damage with minimal external signs; it can cause loss of function to organ systems remote to the site of the actual trauma; and some complications have a delayed onset of clinical manifestation. It is necessary to rapidly triage the patient when it is first presented to recognize and expediently stabilize life-threatening problems. Once stabilized, it is important to conduct a more thorough secondary evaluation to fully characterize the overall status of the patient. Finally, a thorough physical examination should be repeated (maybe hourly in the beginning) to keep abreast of the changing status of the patient and any developing complications. Trauma is a "panbody" experience, and your evaluation process must have commensurate breadth and depth.

## BREATHING

Is the animal attempting to breathe? If not, it should be endotracheally intubated and ventilated. Apnea is a sign of a central or peripheral problem with the neuromuscular axis. If the animal is breathing, is it effective (see box at right)? If it is not effective, is it life-threatening (see box at right)? If the animal has respiratory disease, can it be localized (Table 1)?

## Oxygen Therapy

Oxygen therapy may be beneficial when the predominant cause of hypoxemia is due to the low ventilation-perfusion mechanism or diffusion impairment. Oxygen therapy would not be expected to be substantially beneficial if the predominant cause of hypoxemia is small airway and alveolar collapse (no ventilation-perfusion). The patient's response to oxygen therapy should be evaluated at periodic intervals to assure it is beneficial.

A high inspired oxygen concentration can easily be attained with a face mask. The animal's nose and face should fill the mask as much as possible to reduce the dead space within the mask. The mask does not need

## SIGNS OF RESPIRATORY INSUFFICIENCY AND FAILURE

### Insufficiency

- Very slow or fast breathing rate
- Fast and shallow breathing (restrictive disease)
- Slow and deep breathing (obstructive disease)
- Fast and deep breathing (acidosis, hypotension)
- Arrhythmic breathing patterns (medullary disease)
- Abnormal breathing sounds
  - Low-pitched snoring (big airway obstruction)
  - High-pitched squeaking (very severe, big airway obstruction)
  - Mid-pitched "wheezing" (small airway obstruction)
  - Crepitation (some airway fluid)
  - Fluid rales (lots of airway fluid)
  - Absent sounds (regional—lobar disease; generalized—pleural space disease)
- Increased breathing effort
- Percussion (more resonant—air; less resonant—fluid or tissue)
- Radiographic evidence of pleural or parenchymal lung disease
- Arterial blood gas evidence of poor ventilation ( $\text{PaCO}_2 > 50$  mmHg)
- Arterial blood gas evidence of poor oxygenation
  - $\text{PaO}_2 < 80$  mmHg (21% inspired oxygen at sea level)
  - $\text{SaO}_2 < 95\%$  (21% inspired oxygen at sea level)
  - $\text{PaO}_2/\%$  inspired oxygen  $< 5$  (enriched inspired oxygen)

### Failure

- Severe or extreme variation of any of the above signs
- Apnea
- Restlessness or anxiety
- Open mouth breathing or gasping
- Cyanosis
- $\text{PaCO}_2$  above 60 mmHg
- $\text{PaO}_2$  below 60 mmHg or  $\text{SaO}_2$  below 90% (21% inspired oxygen at sea level) or  $\text{PaO}_2/\%$  inspired oxygen  $< 2$  (enriched inspired oxygen)

**Table 1**  
**Common Causes of Respiratory Difficulties and the Major Differentiating Signs**

Major Presentation	Anatomic Problem	Differentiating Signs	General Treatment	
Decreased effort	Central	Apnea; arrhythmic breathing pattern; significant obtundation	Intubate and ventilate	
	Cervical efferents or myoneural junction	Apnea; shallow breathing; tetraparesis	Intubate and ventilate	
Increased effort	"Look-alikes"	No cyanosis; no difficulty breathing	Treat the underlying problem: sepsis; hypotension; hyperthermia; metabolic acidosis	
	Large airway obstruction	Inspiratory difficulty (extrathoracic); expiratory difficulty (intrathoracic), noise (low-pitched "snoring"; high-pitched "squeaking"; or mid-pitched "wheezing")	Remove it or bypass it	
	Small airway obstruction	Expiratory or both inspiratory and expiratory mid-pitched noise ("musical wheezing")	Oxygen; bronchodilation	
	Chest wall	Open pneumothorax		Close the opening, evacuate the chest or intubate and ventilate
		Flail chest		Intubate and ventilate, internal or external fixation
	Abdominal enlargement	Abdominal enlargement	Reduce it	
	Pleural space filling disorder	Lung sounds not as loud as they should be given the size of the animal and the manner in which it is breathing	Thoracentesis	
	Pulmonary parenchymal disease	Hyperresonant lung sounds; crepitant lung sounds; bubbling lung sounds	Oxygen; if this doesn't work, PPV and then treat underlying disease	
Pulmonary thromboembolism	Cyanotic; tachypneic but no difficulty moving air; cannot document any of the more common pulmonary diseases; suitable underlying disease	Oxygen; treat underlying disease		

to form an airtight seal around the animal's muzzle. Dyspneic patients often do not tolerate a tight-fitting face mask, and trying to force them to accept it causes undue stress and excitement. The best that can be done is to blow a high volume of oxygen at the patient's face.

Veterinary oxygen cages, which control oxygen and carbon dioxide concentrations, temperature, and humidity, are commercially available but are expensive (\$15,000–\$20,000). Oxygen-enriched chambers are available from several commercial suppliers or can be fashioned from human oxygen tents, infant incubators, cardboard boxes, or fish aquariums, but these systems do not regulate temperature and humidity. This can be a problem when a relatively large animal is placed in a relatively small chamber. High humidity is acceptable as long as the temperature is controlled at a comfortable level. All oxygen chambers have the disadvantage of the patient being "in there" while the caregiver is "out here" when perhaps the two of you

should be together. Oxygen concentrations also take some time to accumulate and then drop precipitously every time you open the door. Oxygen chambers are not intended for use during the initial, labor-intensive stabilization of a critically ill patient but rather should be used in the maintenance phase when caregiver interventions can be minimized and patient rest can be maximized.

Oxygen can also be administered by insufflation. A soft, flexible catheter can be inserted into the nasal cavity to the level of the medial canthus of the eye. The catheter should exit the nose via the lateral alar notch and should be sutured at this point; it should also be sutured at points on the side of the face or on top of the head to keep the catheter out of the patient's view. Nasal oxygen will not be effective if the patient is breathing through its mouth.

A long intravenous catheter can also be placed transtracheally through the cricothyroid membrane or between tracheal rings. The catheter should be long

enough so that it will not accidentally slip out of the tracheal lumen and into the subcutaneous tissues; serious subcutaneous emphysema, pneumomediastinum, and pneumothorax can develop very rapidly. Locate the cricoid cartilage by palpating the ventral surface of the trachea in a rostral direction from a midcervical starting point. The first very large ring of cartilage palpated will be the caudal edge of the cricoid cartilage; slide over this cartilage to the cricothyroid interspace. The catheter should be sutured and bandaged to the patient's neck. This is a more effective route of oxygen therapy compared to nasal insufflation because a larger portion of the anatomic dead space is filled with oxygen between breaths. An oxygen flow rate of 50 to 100 ml/kg effectively maximizes the inspired oxygen concentration; flow rates should be subsequently adjusted to the needs of the patient. Medical oxygen is anhydrous and should be bubbled through water so that it will be at least partially humidified by the time it reaches the patient.

### Thoracentesis

A diagnostic thoracentesis should be performed if the respiratory distress is life-threatening (i.e., when it is not safe to perform thoracic radiography) and the physical examination does not rule out a pleural space filling disorder. A therapeutic thoracentesis is indicated if the diagnostic thoracentesis is positive or if a chest radiograph reveals a pleural space filling disorder. A diagnostic thoracentesis is usually performed with a 22 g, 1 inch needle and a 3 ml syringe. A therapeutic thoracentesis is usually performed with a 20 to 16 g, 2 to 5 inch outside-the-needle catheter attached to a 60 ml syringe via a length of extension tubing and a three-way stopcock.

For either procedure, introduction of the needle or catheter into the pleural space is the same. The procedure is performed in an aseptic manner. A convenient, mid-point location on the chest wall is selected. The anterior edge of a rib is palpated with one hand, and the needle or catheter is slid underneath the anterior edge of the rib in a caudal direction, staying as flat to the pleural surface as possible. Once the end of the needle passes under the anterior edge of the rib, you have entered the pleural space. For a diagnostic thoracentesis, aspirate now. For a therapeutic thoracentesis, hold the needle steady with one hand and advance the catheter into the pleural space, then remove the needle, attach the extension tubing, and aspirate.

### Chest Drainage

Thoracentesis is indicated if fluid or air has accumulated in the pleural space in sufficient quantities to

cause clinical respiratory distress. An indwelling chest drain is indicated whenever frequently repeated thoracentesis of fluid or air is necessary. Indwelling chest tubes should be soft and nonirritating to the tissues and must be noncollapsible. Tubes with small internal lumens (Foley urinary catheters, intravenous catheters, urinary catheters, and feeding catheters) may be suitable for short-term drainage but are associated with a high incidence of occlusion when used long term; tubes must be large enough to allow the passage of cellular debris and fibrin. The tube should have several large holes toward its tip to maximize the opportunity for fluid drainage. The holes should not be so large as to weaken the wall of the tube, and the edges of the holes should be smooth so that they will not catch on tissues when the tube is removed.

The dorsal/caudal quadrant of the thorax is clipped and prepared with antiseptic solution. Sterile gloves and drapes must be used; and sedation is often helpful. The skin incision is made approximately at interspace 10 to 12; deposit a small volume of 1% to 2% lidocaine subcutaneously, and make a small incision one-and-a-half to two times the diameter of the tube. Slide the skin incision forward and downward as far as possible (at least two intercostal spaces), or have someone else pull the skin in this direction. This is essential to provide a subcutaneous tunnel between tube's point of entry in the skin and its point of entry into the chest, which will help prevent leakage of atmospheric air into the chest once the tube is placed. A midintercostal point is selected for tube insertion. A small volume of 1% to 2% lidocaine is deposited and a small relief incision is made partially through the intercostal musculature but not through the pleura. The tip of the tube is placed into the relief incision and held firmly there with the right hand; the left hand is moved to grasp the trocar introducer or forceps a couple of centimeters above the chest wall. The left hand provides some of the force to push the tube into the chest, but, most importantly, it acts as a stop to make sure that the trocar or forceps are not introduced too far into the chest, which can damage the underlying lung parenchyma. The tube is then inserted into the pleural space so that the end of the tube is placed near the fourth intercostal space. The trocar or a similar tube could be used on the outside of the chest to estimate the location of the tip of the tube on the inside of the chest. Care must be taken not to introduce the chest tube into the apex of the thoracic cavity as it will be occluded by the mediastinal tissues. The skin is then allowed to slide back to its normal resting position. The skin incision is closed around the chest tube, and the tube is sutured securely to the skin using

one of several techniques: (1) Place a tag of tape around the cannula close to the skin incision so that a wing of tape extends from each side, suture the tape to the catheter, and suture the wings of the tape to the skin; (2) place a snug suture at the incision site and tie around the tube several times in a finger-locking pattern; or (3) secure the tube with a suture that has been placed through the periosteum of an underlying rib.

The chest tube is then attached to the drainage tubing, which is taped to the tail (or hind leg) in a manner that allows full range of motion without applying traction to the skin sutures. A loose stockinette fishnet "sweater" can be used to help hold these, and other tubes and wires, in place. The skin incision is covered with an antibiotic-antifungal ointment and a sterile gauze pad. The wound should be cleaned and rebandaged once daily.

There are many ways to drain a chest. The chest tube can be fitted with a self-sealing injection cap, allowing the chest to be periodically drained using a large syringe. The force of aspiration should be very mild since extremely low subatmospheric pressures can be easily generated and can be very damaging to thoracic tissues. This is a good way to quantitate the volume of air or fluid accumulating in the chest but is somewhat labor intensive. One-way Heimlich valves do not work well for long-term drainage because secretions drying in the tube will cause it to stick shut. The chest tube can be attached to a wound drainage apparatus, but these appliances tend to have rather small volume and may need to be recharged frequently.

Several systems allow automatic, continuous drainage (Figure 1). The chest tube can be attached to a two-bottle water-trapped chest drainage system (Figure 1A). The suction control is provided by the depth of the tube under water; the cm H<sub>2</sub>O of subatmospheric pressure applied to the pleural space is equivalent to the depth of the tip of the tube under the water (in centimeters). Care must be taken to clamp this system whenever it is disconnected from the suction source as there is nothing to prevent the aspiration of air through the apparatus and into the pleural space. A third bottle can be added to act as a water trap (Figure 1B) so that the system can be disconnected from the suction source without clamping.

The chest tube can be also attached to a passive, single-bottle water-trapped chest drainage system (Figure 1C). The bottle is attached to the patient with a tube that is under water; this bottle acts both as a collection bottle and a water trap. The water trap is necessary because the other port of the bottle must be open to atmosphere to allow air to vent out as fluid accumulates in the bottle. These systems are passive

and depend on gravity for proper drainage. They must be placed below the patient to work properly; if they are placed above the patient, fluid may drain back into the pleural space. An expandable, closed, sterile, empty fluid bag or urine collection bag can be used to drain fluid from the chest and, because it is expandable, does not need to be vented to atmosphere. This would not work for a pneumothorax because a non-vented collection device simply represents an extended pneumothorax.

Fluid and air will cease to drain if the chest is empty of material or if the cannula is plugged. Thoracic radiography should be repeated periodically to assess the adequacy of the chest drainage and to distinguish a plugged tube from other problems. The tube may have been inserted too far into the chest so that its tip is occluded in the apex of the chest (withdraw the tube slightly). The tube may be occluded with plugs of fibrin or cellular debris. The collection tubing should be "stripped" or aspirated with a syringe. To strip the tube, (1) grasp the tube between the thumb and forefinger with both hands close together, (2) while holding the tube with the hand closest to the patient, slide the other hand away from the patient, holding the fingers tightly so that the tube remains collapsed between the two hands, (3) release the hand closest to the patient first (as the collapsed tube expands, enhanced suction is applied to the chest tube), and (4) release the other hand an instant later. The procedure may be repeated several times.

Tube occlusion may also result if plugs of mediastinum or lung are sucked into the holes at the end of the chest tube. Try stripping the collection tubing toward, rather than away from, the animal. The fluid might be pocketed (chronic inflammatory exudates), and placement of bilateral or even multiple lateral chest drains might be necessary.

### Tracheostomy

Dogs and cats tolerate tracheostomy tubes very well. Tracheostomy tubes are indicated when: (1) A laryngeal or upper airway obstruction needs to be bypassed; (2) positive pressure ventilation is needed for an extended period; or (3) frequent access to the lower airway is needed for more effective treatment of a respiratory infection.

The insertion of a tracheostomy tube should be a well-controlled, aseptic surgical procedure except when performed as a life-saving emergency. Animals may need to be orotracheally intubated first and maintained under a well-controlled anesthetic. The animal should be positioned in exact dorsal recumbency so that the head, neck, and thorax are not rotat-

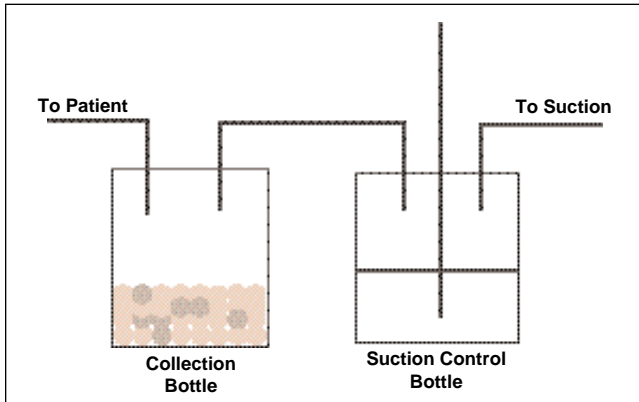


Figure 1A

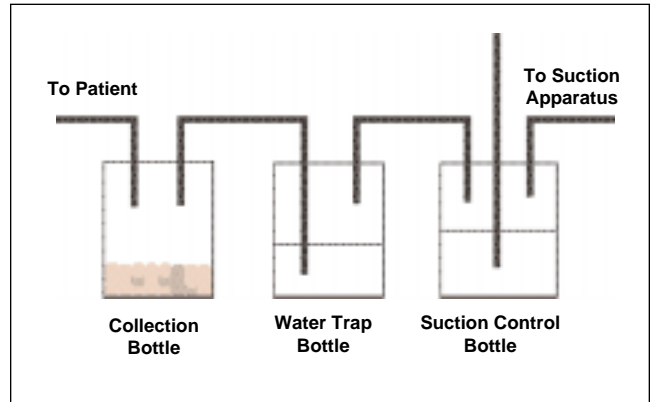


Figure 1B

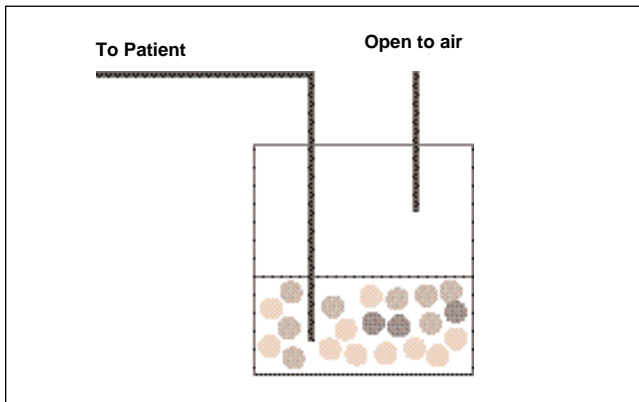


Figure 1C

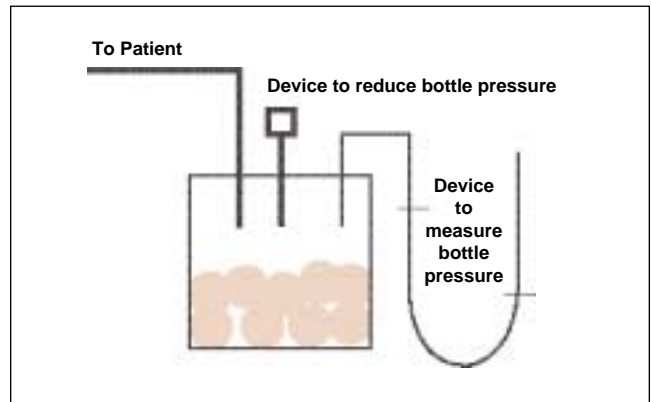


Figure 1D

**Figure 1.** (A) Two-bottle, active chest drainage system. (B) Three-bottle, water-trapped active chest drainage system. (C) Single-bottle, passive drainage system. (D) Homemade active drainage device.

ed laterally. A longitudinal skin incision, two times the diameter of the tube to be inserted, is made caudally from the cricoid cartilage. The muscles are divided exactly on the midline, and the fascia is completely cleaned away from the trachea over a length of three to four tracheal rings. The trachea may be stabilized by grasping it with forceps; alternately, a suture may be passed around a tracheal ring. A longitudinal incision starting from tracheal ring two is made exactly on the midline of the trachea. Small transverse incisions can be made at one or both ends of the longitudinal incision if it facilitates the introduction of the tube. Alternately, a transverse incision large enough to accommodate the tracheal tube can be made between tracheal rings two and three or three and four. The tracheostomy tube is inserted so that the tube rests comfortably within the lumen of the trachea. The majority of the skin incision is closed, but an airtight closure around the tube should be avoided. Air will escape from the tracheal incision and must be allowed to vent to the outside. If trapped, the air will accumulate subcutaneously and migrate along the loose connective

tissue planes of the neck into the chest, resulting in pneumomediastinum and pneumothorax. The tube should be double-tied firmly around the animal's neck. The skin incision should be covered with a sterile gauze sponge that has been cut so that it fits comfortably around the tube.

A tracheostomy tube should be soft, pliable, and nonirritating to the tissues. It should have an inner cannula that can be removed for easy cleaning. It should have a high-volume, low-pressure cuff to minimize cuff-induced trauma to the trachea. The cuff should not be inflated unless positive pressure ventilation is intended. When inflating the cuff, introduce just enough volume to prevent most of the backleak of air during positive pressure inflation of the lungs. The pilot balloon is not a reliable indicator of the amount of pressure that the cuff is applying to the tracheal wall. The volume of air instilled should be recorded—increasing volumes over time indicate the development of tracheomalacia. Tracheal tube trauma associated with excessive cuff inflation, tube malpositioning, and tube torque or traction should be avoided because

it predisposes to tracheal necrosis, ulceration, hemorrhage, fistulation, and stenosis.

Airway humidity (by nebulization or direct saline instillation) should be provided continuously or at regular intervals (hourly). Every 4 hours the inner cannula should be cleaned and the trachea and tube should be aseptically suctioned.

### Positive Pressure Ventilation

Positive pressure ventilation (PPV) is indicated when:

- An animal cannot ventilate adequately (usually defined as a  $\text{PaCO}_2 > 60$  mmHg) due to neuromuscular disease or pulmonary parenchymal disease
- Pulmonary parenchymal disease is sufficiently serious so that oxygen therapy alone does not adequately oxygenate the patient (usually defined as a  $\text{PaO}_2 < 60$  mmHg).
- The animal is having to work excessively hard to breathe and may soon become exhausted.

Since ventilator therapy is a labor- and cost-intensive endeavor, there is a common tendency to wait too long to apply it. Instituting PPV as the animal is dying of its respiratory disease is usually of little value.

The goals of PPV are to restore oxygenation (a normal  $\text{PaO}_2$  of 80 to 100 mmHg is optimal, but a range of 60 to 250 is acceptable) and ventilation (a  $\text{PaCO}_2$  of 35 to 45 mmHg is optimal, but a range of 30 to 60 is acceptable) with inspired oxygen concentrations of less than 60% while minimizing the deleterious effects of the technique.

The general guidelines for PPV of animals with relatively normal lungs (regardless of the method or brand of ventilator utilized) are:

- Proximal airway pressure of 10 to 15 cm  $\text{H}_2\text{O}$
- Inspiratory time of about 0.5 to 1 second (just long enough to achieve a full tidal volume)
- Tidal volume of 8 to 15 ml/kg
- Ventilatory rate of 10 to 20 times per minute
- Minute ventilation of 150 to 250 ml/kg/min
- Zero (atmospheric) end-expiratory pressure

Diseased lungs are often stiffer (less compliant) than normal lungs and are therefore more difficult to ventilate. It is common for the guidelines recommended above to be insufficient to adequately oxygenate or ventilate a patient with diffuse pulmonary parenchymal disease. Whenever ventilator settings do not seem to meet the needs of the patient or the aforementioned goals, first make sure that the ventilator settings are as planned (including the oxygen supply); that there is patient synchrony with the ventilator; and that other

untoward problems (hyperthermia, pneumothorax) have not developed. Then adjust the ventilator settings. There is no algorithm for this—make progressive changes that seem appropriate for the situation. To improve ventilation you could increase the ventilatory rate, proximal airway pressure/tidal volume, or inspiratory time/inspiratory plateau. To improve oxygenation you could increase ventilation, inspired oxygen concentration, or end-expiratory pressure. A positive airway pressure, applied between breaths, increases the transpulmonary pressure and the functional residual capacity, keeps small airways and alveoli open during the expiratory phase, and improves oxygenation. Lung units are also easier to ventilate when they are kept open after the last breath rather than having to start from a collapsed position. Positive end-expiratory pressure (PEEP) is available on most ventilators via an adjustable knob. PEEP can also be achieved by attaching a corrugated breathing tube to the exhalation port of any ventilator and placing the other end under water. The depth to which the end of the tube is submerged determines the PEEP. PEEP can also be applied by commercially available weighted expiratory valves.

Several ventilator-induced problems warrant attention:

*Impairment of intrathoracic blood flow* may be the result of increasing pleural pressure, which impedes venous return to both the right and the left side of the heart. The degree of impairment of stroke volume, cardiac output, and arterial blood pressure is proportional to the magnitude of the increase in airway/pleural pressure, the length of time that the pressure is applied per breath (the inspiratory time), and the length of time that the pressure is applied per minute (ventilatory rate). Circulatory impairment is assessed by the magnitude of pulse quality or arterial blood pressure diminution associated with each breath. Diseased lungs are often poorly compliant; while they may require higher airway pressures to ventilate them, less of the pressure is transmitted to the pleural space and there is less tendency to impair circulation.

*Barotrauma, alveolar septal rupture resulting in pneumomediastinum, pneumothorax, pulmonary hemorrhage, and air embolism* may be associated with high airway pressures/volumes in normal lungs and normal airway pressures in abnormal lungs. Airway pressures/volumes should be only as high as necessary to achieve acceptable ventilation and oxygenation.

*A more subtle mechanism of ventilator-induced lung injury (VILI) results in a permeability pulmonary edema that is histologically very similar to the disease for*

which the patient was ventilated in the first place. There are two possible mechanisms for this: (1) Repetitive collapse of regional small airways and alveoli (between breaths) and their reopening (during inspiration) causes shear injury, and (2) collapse of some regional alveoli exposes neighboring alveoli to overdistention, even with recommended tidal volumes. Overdistention of alveoli and small airways causes tangential wall stress as well as "tethered expansion" of extra-alveolar vessels that causes "stress failure" (the stretched pore phenomenon) of epithelial and endothelial cell layers. PEEP helps prevent airway/alveolar collapse between breaths as long as it is above the lower inflection point of the pressure-volume curve. Minimize peak airway pressures so that they are below the upper inflection point of the pressure-volume curve. The idea is to remain on the steep part of the pressure-volume curve for the entire tidal volume. Sometimes this translates into some small tidal volumes (e.g., 5 ml/kg).

Once set up, the animal's response should be evaluated by clinical and available laboratory analyses to determine the efficacy of the ventilator settings. The management of a patient receiving continuous ventilatory support is an endeavor requiring trained personnel to always be within audible range of the ventilator and patient so that immediate attention can be rendered when necessary.

### **Patient-Ventilator Synchrony**

Few animals will allow themselves to be ventilated unless they are significantly obtunded by their disease or are quadriplegic. When a patient attempts to breathe out of synchrony with the ventilator, ventilation and oxygenation deteriorate rapidly. Patient synchrony can be accomplished by matching the ventilator settings to the patient's breathing effort, but this is very labor intensive. Consequently, patient synchrony is usually enforced with anesthetic drugs administered in quantities sufficient to achieve a light level of anesthesia. We most frequently use pentobarbital (1–2 mg/kg/hr).

### **Trauma Avoidance**

The ventilator circuitry must be supported so that it does not pull or torque the tracheal tube. The animal should always be positioned so that the tracheal tube is not pressured in any way.

### **Preventing Tube Lumen Occlusion**

The inner lumen of the tracheal tube must be cleaned regularly. If a tracheostomy tube with an inner cannula is used, it can be removed for easy cleaning. If a tracheostomy tube or an endotracheal tube

without an inner cannula is used, cleaning must be accomplished by careful, aseptic tracheal suctioning at regular intervals (every 4 hours). Patient hydration must be maintained, and airway humidity must be provided at regular intervals.

### **Fluid Ins and Outs**

Animals on ventilators may retain sodium and water; daily weighing and the careful monitoring of fluid therapy "ins and outs" are important. The urinary bladder should be expressed every 4 hours, and volumes should be recorded to make sure that fluid input and fluid output are in reasonable balance. Urinalysis should be done every few days to evaluate renal function and for the presence of cystitis.

### **Repositioning**

Repositioning the animal at approximately 4 hour intervals and using heavy padding over pressure points are very important to prevent pressure sores and decubital ulcers. Repositioning, postural drainage, chest coupage, or vibration is also important in the prevention of dependent pulmonary atelectasis and to help mobilize secretions from the periphery of the airways to the central airways where they can be removed by suctioning. Passive range of motion of all appendages should also be done every 4 hours.

### **Mouth Care**

The mouth and pharynx accumulate some very nasty secretions in these patients and should be flushed with saline and gently suctioned every 4 hours and flushed with a dilute chlorhexidine solution every 8 to 12 hours. The tongue rapidly develops pressure-induced ulcers if pressure is inadvertently placed on it by endotracheal tubes or if it is simply draped across the teeth. The tongue should be wrapped in a glycerin-soaked gauze sponge and placed wholly within the mouth cavity.

### **Eye Care**

The corneas must be protected from physical abrasion and excessive drying. Approximately every 4 hours the conjunctival sacs should be flushed with sterile saline, and then a sterile ophthalmic ointment should be instilled to prevent corneal drying. The eyelids must be kept completely closed so that the cornea is not exposed between treatments. Ophthalmic antibiotics may be indicated if conjunctivitis or corneal ulcers develop.

### **Minimizing Nosocomial Infection**

All patient circuits and nebulization equipment

should be sterile when first connected and should be changed every 48 hours. All tracheal suctioning must be accomplished aseptically.

### **Nutrition**

Nutrition is important in prolonged procedures. Ventilated animals can be fed via a nasogastric tube or gastrostomy tube if the stomach is motile or via intravenous nutrition if it is not. Gut stasis, the accumulation of residual feedings in the stomach and of feces in the colon, may be a problem in the sedated, ventilated patient. Residuals must be checked prior to each gastric tube feeding and must not be allowed to accumulate (to more than about 5 ml/kg). This usually does not require the removal of volume as much as it dictates that additional volume not be instilled. Gastric motility may require augmentation by metoclopramide, cisapride, or bethanechol. The colon should be palpated daily to make sure that it is not accumulating feces; an enema may be required.

### **Being Prepared for Emergencies**

Emergency intubation (tubes become obstructed or are accidentally dislodged), ventilation (pneumatic in case the power goes out; manual in case the compressed gas supply becomes depleted), and suction equipment should be readily available for the inevitable and unforeseen complications. Ventilator function and the animal's condition should be evaluated frequently.

### **BEATING**

Is the heart beating? If not, cardiopulmonary resuscitation should be instituted (see box at right). If the heart is beating, how is its electrical activity? Is it beating too slowly (<50 to 60 beats per minute [bpm])? This is an unexpected finding in a stressed emergency patient, and its cause should be identified and treated (see box on left on p. 15). Is the heart beating too fast (>200 bpm in a large-breed dog; >240 bpm in a small-breed dog; >280 bpm in a cat)? Tachycardia in critically ill patients is common and may be attributed to hypovolemia, pain, hypoxemia or hypercapnia, hyperthermia, sepsis, hyperthyroidism, pheochromocytoma, or drugs (ketamine, anticholinergics, sympathomimetics). Therapy is usually directed to the underlying cause; however, if you think that the rate is so fast that diastolic fill time and cardiac output are being jeopardized, the heart rate may be slowed by vagal maneuvers (eyeball or carotid sinus pressure) or beta-adrenergic blocking agents (esmolol, propranolol).

An irregular heart beat associated with pulse

deficits may represent an atrial or ventricular arrhythmia and should be identified electrocardiographically. The underlying cause should be corrected when possible (see box on top right on p. 15). Ventricular arrhythmias are a sign of the underlying disease process and should not always be treated just because they are present; they should be treated when:

- The rate exceeds 180 to 200 bpm (or would if a paroxysmal rhythm continued for a minute).
- The arrhythmia is multiform in nature.
- The incidence or severity is increasing.

### **CARDIOPULMONARY RESUSCITATION CHECKLIST**

- I. Endotracheally intubate
- II. Commence PPV (1 breath every 3–5 chest compressions)
- III. Commence external chest compression (80–120/min)
  - A. Evaluate effectiveness; if ineffective:
    1. Change the compression technique
    2. Apply an augmenting technique
    3. Administer epinephrine
    4. Rapidly administer fluids
  - B. If external technique proves ineffective after 5 minutes or if heart has not resumed a spontaneous rhythm in 10 minutes, perform a thoracotomy for internal cardiac compression
- IV. Administer drugs
  - A. Oxygen (100%)
  - B. Fluids
    1. Isotonic crystalloid: 40 ml/kg (dog); 20 ml/kg (cat per aliquot)
    2. Hypertonic crystalloid: 5 ml/kg 7.5% NaCl; 10 ml/kg 25% mannitol
    3. Colloid: 10 ml/kg (dog); 5 ml/kg (cat)
  - C. Epinephrine (0.02 to 0.2 mg/kg)
  - D. Atropine (0.04 mg/kg)
  - E. Sodium bicarbonate (0.5 mEq/kg after first 5 minutes)
- V. Evaluate electrical activity of the heart
  - A. None (asystole): epinephrine (0.02 to 0.2 mg)
  - B. Chaotic (ventricular fibrillation): defibrillate
  - C. Rhythmic but bizarre ventricular pattern with no generated pulse (electromechanical dissociation): epinephrine; dexamethasone; calcium
- VI. Follow-up monitoring and support
  - A. Cardiovascular
  - B. Pulmonary
  - C. Cerebral

- The ectopic foci fires during the T wave of the preceding complex.
- There is evidence of inadequate cardiac output.

Symptomatic treatment starts with lidocaine (1–5 mg/kg IV; 50–100 µg/kg/min). If this does not satisfactorily tame the problem, procainamide (same dose as for lidocaine) or a beta-receptor blocker (esmolol: 0.5 mg/kg IV; 50–200 µg/kg/min; propranolol: 0.04–0.06 mg/kg IV; 0.2–1.0 mg/kg PO q8h) can be administered. Total elimination of the arrhythmia is not necessarily the objective of therapy because the adverse effects of the antiarrhythmic drug often occur prior to reversion of the arrhythmia to a normal sinus rhythm. A simple decrease in the rate or severity of the arrhythmia may be a suitable end point to the titration of the antiarrhythmic drugs.

Assess the heart's mechanical function. Does the heart sound loud and robust or distant and wimpy? Does the pulse quality feel strong, full, and wide, or is

### CAUSES AND GENERIC TREATMENT OF BRADYCARDIA

#### Causes

- Excessive vagal tone
  - Opioids
  - Pain
  - Vagovagal reflex secondary to visceral stimulation
  - Oculovagal reflex secondary to eyeball pressure
- Atrioventricular conduction disturbances
- Hyperkalemia
- Severe hypothermia
- Terminal hypoxia
- Drugs
  - Opioids
  - Xylazine
  - Cholinergics
- Organophosphate or carbamate poisoning

#### Treatment

- Correct the underlying disease process if it can be found
- Anticholinergic
  - Atropine: 0.02–0.04 mg/kg IV, IM
  - Glycopyrrolate: 0.01–0.02 mg/kg IV, IM
- Sympathomimetic
  - Dopamine: 3–7 µg/kg/min
  - Dobutamine: 5–10 µg/kg/min
  - Epinephrine: 0.05–0.1 µg/kg/min
- Pacemaker

### CAUSES OF ATRIAL OR VENTRICULAR ECTOPIC PACEMAKER ACTIVITY

- Endogenous release of catecholamines secondary to any stress
- Exogenous catecholamine therapy
- Hypoxia or hypercapnia
- Hypovolemia
- Digitalis toxicity (potentiated by hypokalemia and hypercalcemia)
- Hypokalemia (potentiated by respiratory or metabolic alkalosis; glucose or insulin therapy)
- Hyperkalemia (potentiated by acidosis, hypocalcemia, succinylcholine; may be iatrogenic)
- Certain anesthetics (halothane, xylazine, thiopental) lower the threshold to endogenous or exogenous catecholamines
- Myocardial inflammation, disease, or stimulation (intracardiac catheters, pleural tubes)
- Thoracic and nonthoracic trauma
- Dilative or hypertrophic cardiomyopathy
- Visceral organ disease (gastric volvulus/torsion)
- Intracranial disorders (increased pressure, hypoxia)
- Pheochromocytoma

### CAUSES OF HYPOTENSION

#### Hypovolemia

- Blood loss
- Dehydration secondary to vomiting, diarrhea, diuresis
- Maldistribution of extracellular fluid
  - Back-pressure edema
  - Hypoproteinemia edema
  - Vasculitis edema

#### Reduced Cardiac Output

- Poor venous return (other than hypovolemia)
- Poor diastolic performance (hypertrophic cardiomyopathy)
- Poor systolic performance
  - Dilative cardiomyopathy
  - Arrhythmias
  - Anesthetic drugs
- Bradycardia
- High afterload (aortic stenosis)

#### Peripheral Vasodilation

- Vasodilator drugs
- Vasomotor tone failure (end-stage shock)
- Large arteriovenous shunts (patent ductus arteriosus)

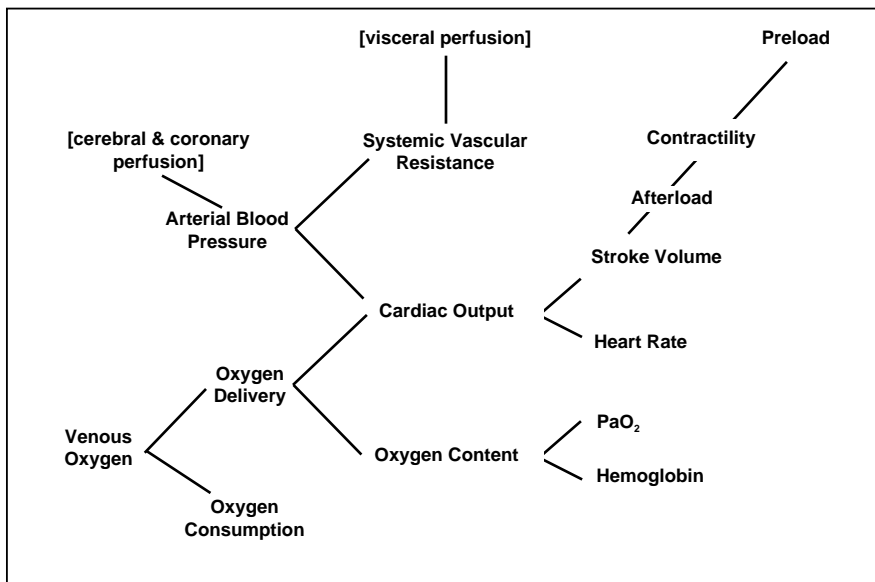


Figure 2. Interrelationships of important cardiovascular parameters.

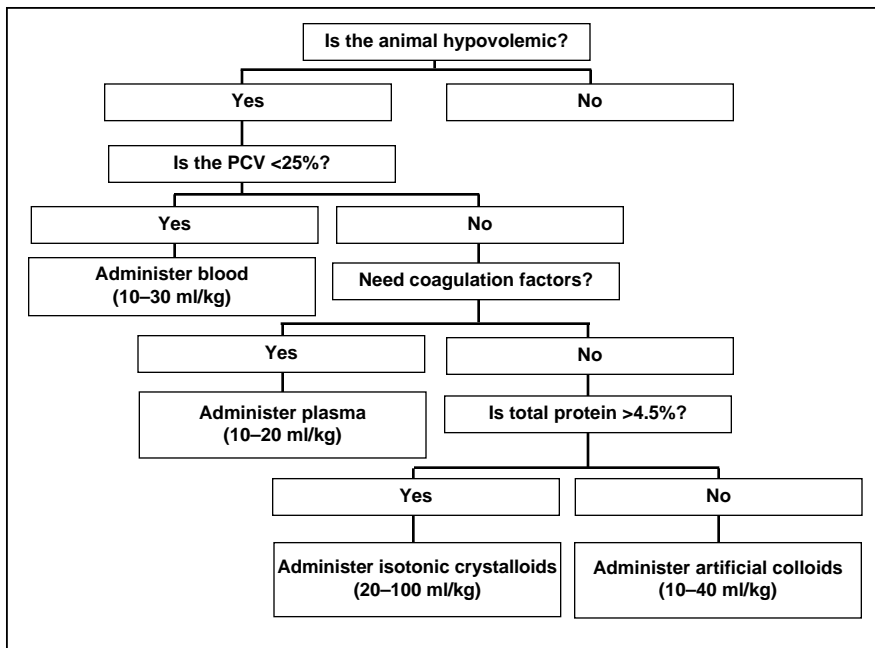


Figure 3. Deciding which fluids to administer.

it weak and thready? Based on echocardiographic evaluation of diastolic and systolic performance, is the arterial blood pressure adequate (at least 60–80 mmHg mean or 80–100 mmHg systolic; see box on bottom right on p. 15)? Arterial blood pressure is an important determinant of cerebral and coronary perfusion.

What is the status of vasomotor tone and peripheral tissue perfusion (Figure 2)? Arteriolar vasomotor tone is the predominant regulator of perfusion to tissues other than the brain and heart; excessive vasoconstriction impairs peripheral (visceral) perfusion. Excessive vasodilation causes hypotension, which in turn results

in poor cerebral and myocardial perfusion. Vasomotor tone is assessed by mucous membrane color (pale to white mucous membrane color indicates serious vasoconstriction), capillary refill time (>3 seconds indicates serious vasoconstriction), appendage temperature (palpably cool appendages or a toe web/core temperature gradient >8°F [4°C] indicates serious vasoconstriction), or urine output (anuria indicates serious vasoconstriction). Vasoconstriction is due to an increase in sympathetic tone (hypovolemia, poor cardiac output, hypothermia, exogenous vasoconstrictor therapy, pain, hypoxia, or hypercapnia). Vasoconstriction does not define the presence of hypotension or hypovolemia because there are several other causes for it. Vasodilation may be caused by hyperthermia, sepsis, and vasodilator therapy.

### Initial Blood Volume Restoration

An isotonic, polyionic solution with approximately normal extracellular concentrations of sodium, potassium, chloride, and a "bicarbonate-like" anion (bicarbonate, lactate, gluconate, or acetate) is a good fluid to use to begin blood volume restoration therapy (Figure 3). These solutions can be safely administered in large volumes to normal animals. Crystalloid fluids may need to be administered in quantities of 40 to 90 ml/kg or more (in the dog) to achieve

adequate blood volume restoration. The cat has a smaller blood volume than the dog (50 to 55 ml/kg versus 80 to 90 ml/kg) and should receive a proportionately smaller dose of fluids. Fluid administration should be conservative in animals that have preexisting pulmonary edema, cerebral edema, or congestive heart failure or that have suffered traumatic hemorrhage within the last 2 hours. In these animals, fluid therapy should be sufficient to achieve adequate, but not necessarily complete, blood volume restoration.

Only about 20% of a crystalloid fluid remains within the vascular fluid compartment 30 minutes following administration; the remainder redistributes to the

**Table 2**  
**Characteristics of Common Colloid Solutions**

Colloid	m.w. (range)	m.w. (average)	m.w. (numerically weighted average)	COP (mmHg)	Osmolarity (mOsm/L)
Albumin 5%	66–69	69	69	24	290
Plasma	66–400	119	88	22	285
Dextran 40	10–80	40	26	82	310
Dextran 70	15–160	70	41	62	310
Hetastarch	10–1000	450	69	32	310
Pentastarch	150–350	264	35	—	310
Gelatins	5–100	35	6	—	—
Saline	0	0	0	0	310

m.w. = molecular weight in Daltons; COP = colloid oncotic pressure.

interstitial fluid compartment. The volume restoration achieved by crystalloid fluids may be fleeting; if hypotension or vasoconstriction recur (fluid redistribution or continued bleeding may be the cause), further fluid administration, perhaps in the form of colloids or whole blood, is indicated.

Excessive hemodilution is a common limitation to crystalloid fluid administration. Excessive hemodilution is defined as a packed cell volume below 15% to 30% (depending on the systemic status of the patient), hemoglobin below 5 to 10 g/dl, total protein below 3.5 g/dl, or albumin below 1.5 g/dl.

Hypertonic saline (volume for volume compared to isotonic solutions) provides better volume expansion and higher cardiac output, blood pressure, and tissue perfusion with less volume of infusate. Hypertonic saline also causes prominent vasodilation. The commonly recommended dose of 7.5% hypertonic saline is 4 to 6 ml/kg. The deleterious effects of hypertonic saline include an increase in sodium and chloride concentrations and osmolality and a decrease in potassium and bicarbonate concentrations. Changes are moderate and of minimal clinical importance unless the patient has preexisting electrolyte abnormalities or if repeated doses are administered (not recommended).

If the total protein is below about 3.5 g/dl or is likely to be reduced below this level with crystalloid therapy, plasma or a plasma substitute (dextran, hetastarch) should be administered as a part of the fluid therapy program. The colloids are more effective blood volume expanders than are the crystalloid fluids and should be considered when the patient does not appear to be responding appropriately to the crystalloid fluid infusion or when edema develops prior to adequate blood volume restoration. Colloids, although more expensive than crystalloids on a per bottle cost, provide a better blood volume expansion effect and

less interstitial expansion compared to crystalloids and maintain a higher colloid oncotic pressure; they are cost effective. Commercial colloidal solutions are generally isoosmotic and hyperoncotic in the bottle (Table 2) and are approximately equally efficacious with regard to their plasma volume expansion.

The artificial colloids produce a dose-related defect of primary hemostasis that is somewhat greater than that due to simple dilution. Prolongation of activated partial thromboplastin time is attributed to a reduction of coagulation factor VIII:C factor activity. Prolonged bleeding time and decreased platelet adhesiveness are attributed to inhibition of the von Willebrand's factor. While it is not expected that even large doses would induce bleeding in normal patients, perhaps they should not be used in patients with von Willebrand's disease. The artificial colloids are considered therapeutic for the hypercoagulable phase of disseminated intravascular coagulation (DIC).

It is commonly presumed that hetastarch has a longer half-life due to its larger-sized molecules compared to dextran 70, but the residual differences over time may be clinically unimportant. It is also commonly presumed that hetastarch has less tendency to cause bleeding, but, again, the differences are minimal.

Albumin comprises 50% of the total plasma protein and 80% of the plasma colloid oncotic pressure. There are approximately 5 g of albumin per kilogram of body weight in the extracellular fluid: 40% in the intravascular space and 60% in the interstitial space. The plasma albumin concentration is about 2.5 to 3.5 g/dl, whereas interstitial albumin is about 1 to 1.5 g/dl. Albumin maintains intravascular colloid oncotic pressure and is an important carrier of certain drugs, hormones, metals, enzymes, and chemicals and toxins such as cations, anions, toxic oxygen radicals, and toxic inflammatory substances. Plasma also contains coagulation factors, depending on how it is stored. Fresh plasma, of course, has everything and therefore is good for the treatment of all coagulation disorders. Fresh plasma should be used within 6 hours after collecting it from the donor. Freezing destroys the platelets, and thus fresh frozen plasma would not be good for the treatment of thrombocytopenia or DIC. Refrigerator storage is associated with the loss of both platelets and labile coagulation factors V and VIII and von Willebrand's factor and hence would not be good for the treatment of these deficiencies but could still be used for the stable factors for vitamin K-antagonist rodenticide-induced bleeding.

If the packed cell volume is below 15% to 25% or is likely to be reduced below this value with crystalloid fluid therapy, packed red cells or whole blood should

be administered as part of the fluid therapy. The incidence of first-time transfusion reactions in dogs is minimal because of the paucity of naturally occurring alloantibodies. Clinically significant transfusion reactions are likely to occur following the second transfusion of dog erythrocytic antigen (DEA) 1.1, DEA 1.2, and, to a lesser extent, DEA 7. In vitro crossmatching is recommended to check out the intended transfusion if the recipient has received a previous transfusion or if the recipient suffers immune-mediated hemolytic anemia. Domestic "mongrel" cats are virtually all Type A. Type B populations are more likely to occur in breeds such as Scottish Fold, Berman, Himalayan, Abyssinian, Somali, Persian, Cornish and Devon Rex, and British shorthair. Type A cats have low titers of naturally occurring anti-B antibodies; transfusion of Type B blood into Type A cats is associated with a reduced red blood cell survival time (2 days) and minor transfusion reactions. Type B cats have high titers of strong, naturally occurring anti-A antibodies; transfusion of Type A blood into Type B cats is associated with a red blood cell survival time of 1 hour and marked transfusion reactions. In vitro crossmatching may be very important in specialty breed cats.

The amount of whole blood to administer can be calculated as 2 ml/kg (1 ml/lb) per 1% of change in the measured packed cell volume. For example, a 10 kg dog with a packed cell volume of 10% would require 200 ml of whole blood to raise the PCV to 20%. The calculated volume is usually rounded up to the nearest whole unit of blood. This amount should be halved if packed red blood cells are being infused. The amount of blood to administer usually ranges between 10 and 30 ml/kg, and this represents another easy method to calculate a small to a large transfusion, respectively. The rate of whole blood and plasma administration should be conservative (5 ml/kg/hr) to minimize the clinical manifestations of transfusion or foreign protein histamine-mediated reactions.

The product Oxyglobin<sup>®a</sup> has recently been approved for clinical use in veterinary medicine. It is a sterile, ultrapurified, stroma-free, polymerized bovine hemoglobin solution. There is no potential for the transmission of infectious disease. It is nonantigenic and does not require blood-typing or crossmatching prior to administration. Oxyglobin<sup>®</sup> is supplied in packages of two 125 ml single-dose bags. It is more expensive than whole blood. It is deep purple in color. It can be stored at room temperature for up to 2 years. Once administered, it has a half-life of approximately 2 days. It is a plasma-phase, oxygen-carrying solution; the plasma will appear red when the blood is centrifuged,

<sup>a</sup>Biopure, Cambridge, MA.

but it does not represent hemolysis. The red urine is simply due to the excretion of the smaller hemoglobin moieties and is not indicative of hemolysis nor has it been associated with any renal complications. Because it is carried in the plasma, it will not affect packed cell volume measurements but will directly and proportionately affect hemoglobin concentration measurements. Because it is carried in the plasma, it may improve oxygenation of tissues in which vessel pathology does not permit passage of whole red blood cells.

### Sympathomimetic Therapy

Sympathomimetic therapy is indicated when fluid therapy alone has failed to restore acceptable tissue perfusion, pulse quality, arterial blood pressure, or cardiac output in the face of high central venous or pulmonary occlusion pressures (Tables 3 and 4).

**Dopamine** causes renal and visceral perfusion at dosages of 1 to 3 µg/kg/min and provides some cardiovascular support. Higher doses (3 to 10 µg/kg/min) produce greater cardiotoxic and blood pressure support. Dopamine is preferable to dobutamine if an increase in arterial blood pressure is the desired end point. Higher doses of dopamine may cause excessive vasoconstriction and no further increase in cardiac output or oxygen delivery.

**Dobutamine** improves cardiac output, oxygen delivery, and oxygen consumption more reliably than dopamine; it is usually associated with a decrease in systemic vascular resistance.

**Epinephrine** is associated with an increase in cardiac output with minimal changes in systemic vascular resistance at lower dosages; higher dosages are associated with increases in systemic vascular resistance and arterial blood pressure with no further improvement in cardiac output. Epinephrine is indicated if the animal is not responsive to dobutamine or dopamine.

**Norepinephrine** and **phenylephrine** are used for arterial blood pressure stabilization.

### BLEEDING

External bleeding should be controlled with direct digital pressure. Internal bleeding should be suspected if there is gross enlargement in the area of a trauma or fracture (apply a pressure wrap). Abdominal bleeding may be associated with abdominal enlargement. Removal of the blood from the abdomen is generally not recommended—40% will be reabsorbed (red cells intact) in 24 hours. The indications to remove blood from the abdomen are when the accumulation is sufficient to cause respiratory impairment, when it is necessary that the patient receive a blood transfusion and the abdominal blood is the only available source, and

**Table 3**  
**Receptor Activity of Inotropic and Vasoactive Agents**

	Alpha <sub>1</sub>	Alpha <sub>2</sub>	Beta <sub>1</sub>	Beta <sub>2</sub>	Dopaminergic
Isoproterenol	0	0	++++	++++	0
Dopexamine			+	+++	++++
Dobutamine	++/+++	?	++++	++	0
Dopamine	+	+	++++	++	++++
Ephedrine	+	?	++	+	
Epinephrine	++++	++++	++++	+++	0
Norepinephrine	+++	+++	+/+	+/+	0
Phenylephrine	++/+++	+	?	0	0

when it is necessary during laparotomy to clear the field for visualization. Intrathoracic bleeding may be associated with respiratory distress (hemothorax—blood should be removed to alleviate the respiratory distress; intrapulmonary hemorrhage). Intracranial bleeding can cause rapidly deteriorating neurologic status. Not all internal bleeding is readily apparent from the outside but should be suspected when an animal is resistant to blood volume restoration therapy.

Does the animal have a coagulopathy? Coagulopathies may be unifocal or multifocal. Petechiae/ecchymoses are suggestive of a platelet problem or a vasculitis. The intrinsic and common pathways of the coagulation cascade can be easily checked:

- Whole blood clotting time (in a red-topped tube)
- Activated coagulation time (ACT tube)
- Activated partial thromboplastin time (APTT)

Platelet counts and platelet function (buccal mucosal bleeding time) should be evaluated. Other tests that could be conducted to more fully characterize the coagulopathy include prothrombin time (PT), proteins induced by vitamin K antagonism (PIVKA) to assess vitamin K-antagonist poisoning, fibrin degradation products (FDP) to assess fibrinolysis (which is extensive in DIC), antithrombin III assay (it is low in protein-losing glomerulopathies and DIC; low values predispose to thrombosis), von Willebrand's factor (especially in the bleeding Doberman, German shepherd, standard poodle, Golden retriever, and Shetland sheepdog [or any dog]), and specific factor deficiencies.

## BRAIN

What is the mental status of the patient (alert, mildly obtunded but spontaneously aware, moderately obtunded and responsive only to external stimulation, severely obtunded and responsive only to deep pain stimulation,

**Table 4**  
**Dosages of Inotropic and Vasoactive Agents<sup>a</sup>**

	Dosage (μg/kg/min)	Comments
Isoproterenol	0.05–0.5	Potent hypotensive agent
Dopexamine	5–20	
Dobutamine	5–20	
Dopamine	2–10	
Ephedrine	0.1–0.5 mg/kg per dose IV, IM	Central nervous system stimulation
Epinephrine	0.05–1.0	
Norepinephrine	0.1–2.0	
Phenylephrine	1–10	
Hydralazine	0.5–3 mg/kg per dose IM, PO q8–12	Vomiting/diarrhea
Nitroprusside	1–5	Cyanogen, thiocyanate toxicity

<sup>a</sup>For cardiovascular support exclusive of cardiac arrest.

or comatose and unresponsive)? Is there external evidence of head trauma (abrasions/lacerations, fractures, bleeding from the nose, blood or cerebrospinal fluid in the external ear canal)? Is there neurologic evidence of intracranial disease (obtundation/coma; mydriasis/miosis or anisocoria; depressed/absent menace, palpebral, corneal, or nasal reflexes; spontaneous/positional nystagmus; seizure activity)? Light-reactive, mydriatic pupils are sympathetically mediated and suggest noncranial disease; light reactive miotic or unequal pupils, which exhibit physiologic nystagmus, are suggestive of cerebral disease. Animals with evidence of intracranial involvement at presentation should be monitored frequently for decreasing mental acuity over time. Brainstem involvement (unconsciousness; bilaterally unresponsive miotic or mydriatic pupils; absent gag; swallow, and laryngeal reflexes; strabismus, absent physiologic nystagmus; spontaneous or positional nystagmus; irregular breathing rhythms/apnea; decerebrate rigidity) carries a very poor prognosis.

Unconscious patients should be endotracheally intubated to assure an open airway, to protect the airway should the animal vomit or regurgitate, and to provide a means of PPV should the need arise. Mannitol (0.5 g/kg over 20 minutes, repeated up to four times) should be considered to reduce cerebral edema and lower intracranial pressure. Computed tomography or magnetic resonance imaging scans, if possible, will help characterize the nature and extent of the intracranial abnormalities and help identify the surgical candidates.

What is the extracranial nerve status of the patient? Regional paresis/paralysis and pain perception and specific spinal cord reflexes should be carefully assessed to identify and localize extracranial neurologic deficits.

## CAUSES OF ABDOMINAL PAIN

### Hepatobiliary Disease

**Medical conditions:** hepatitis, cholecystitis, cholangiohepatitis, neoplasia, trauma

**Surgical conditions:** hepatic abscess, bile duct obstruction, liver, gallbladder or bile duct rupture, neoplasia, trauma

### Gastrointestinal Disease

**Medical conditions:** hemorrhagic gastroenteritis, viral enteritides (parvovirus, panleukopenia, coronavirus), gastric/duodenal ulcers/perforation, garbage intoxication/dietary indiscretion, obstipation, neoplasia, trauma

**Surgical conditions:** gastric dilation volvulus, intestinal obstruction, intussusception, perforated gastric/duodenal ulcer, herniation/incarcerated bowel, mesenteric volvulus, neoplasia, trauma

### Pancreatic Disease

**Medical conditions:** acute pancreatitis, chronic pancreatitis, neoplasia

**Surgical conditions:** necrotizing or hemorrhagic pancreatitis, pancreatic abscess, neoplasia

### Splenic Disease

**Medical conditions:** neoplasia

**Surgical conditions:** torsion, abscess, ruptured neoplasia, trauma

### Urogenital Disease

**Medical conditions:** urethral obstruction, acute nephritis, dystocia, metritis, prostatitis, neoplasia, trauma

**Surgical conditions:** renal, ureteral, cystic or urethral calculi, pyometra, uterine torsion, prostatic abscess, testicular torsion, testicular infection, neoplasia, trauma

### Peritonitis

**Medical conditions:** bile, blood, urine, pancreatic enzyme induced

**Surgical conditions:** septic, ruptured viscus, ruptured abscess (sources as above), penetrating wounds

### Other Problems Causing Referred Pain in the Abdomen

Myositis (lumbar, abdominal)

Spinal lesions/intervertebral disc disease

Vertebral malformations

## BELLY

Is there abdominal distention or pain (see box, above)? Abdominal radiographs and ultrasound, paracentesis, or diagnostic peritoneal lavage may be helpful diagnostically. Surgical intervention is indicated when:

- The specific conditions listed in the box above are confirmed
- The hemorrhage cannot be controlled
- There is free gas in the abdomen
- The abdominal fluid contains intracellular bacteria, bile staining, toxic neutrophils, fecal, or plant material
- There is a penetrating wound (bite, gun, knife, stick, etc.)
- There is evisceration or hernia
- There is complete intestinal obstruction

## BODY TEMPERATURE

Fever (up to 104°F [40°C]) could be appropriate in response to an infection and should not be treated specifically. Hyperthermia (over 106°F [41°C]) must be treated by active cooling since temperature-driven hypermetabolism will spiral body temperature relentlessly upward. Excessive temperatures (over 108°F [42°C]) may be associated with activation of systemic inflammatory cascades, protein denaturation, and multiple organ failure. Cooling techniques include iced, sterile isotonic crystalloids (intravenously, rectal/gastric/open body cavity), ice water bath, cool water "wet down" (evaporative

cooling enhanced by alcohol), fan, and ice packs over large-vessel areas (neck, inguina, axilla). Antipyretic drugs (antiprostaglandins, dipyron, dantrolene) could be helpful in keeping the temperature down.

Hypothermia has no adverse effects down to about 96°F (36°C). Below 94°F (34°C), there is cerebral obtundation and active rewarming is necessary; below 82°F (28°C), there may be arrhythmias and coagulopathies. Surface rewarming techniques (do not exceed 2°F [1°C] per hour) include warm water bath, forced air warming units, heat lamps, circulating warm water blankets, and hot water bottle "heat tents." Warm, sterile isotonic crystalloid solutions administered intravenously or by rectal/gastric/open body cavity lavage may also be useful.

## BLOOD

Many of the abnormalities of the "blood organ system" have been discussed in the framework of other considerations (hemoglobin, colloids, coagulation). However, the blood also contains indices of other organ (dys)functions that are important considerations: acid-base balance, glucose, electrolytes, white blood cell counts, urea nitrogen, and liver enzymes.

## BONES

Are there fractures or skin lacerations?