Anesthesia for the Acute Abdomen Patient

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Patients with acute abdomen often have marked physiologic and pathologic changes, making anesthesia both challenging and potentially hazardous for the patient. A thorough understanding of the pathophysiologic mechanisms of cardiovascular function under anesthesia and selection of appropriate anesthetic protocols are critical to a successful anesthetic outcome. The goal is to produce anesthesia while minimizing depression of the cardiovascular system. Monitoring and management of acid-base and cardiovascular function serve to ensure appropriate oxygen delivery to the tissues during anesthesia. Postoperative management can significantly influence patient outcome following anesthetic recovery, and must therefore be considered in the anesthetic plan. Finally, pain management in all patients is an important aspect of case management, and should not be overlooked. This article serves to educate the clinician in the above-described areas in regard to the acute abdomen patient.

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Anesthesia for the patient with an acute abdomen is one of the greatest challenges for the veterinary anesthetist. Patients presenting with acute surgical diseases of the abdomen are frequently unstable, have marked physiologic derangements, and can respond variably to different drugs. Because of these significant changes, the veterinary anesthetist of these patients must be delicate, precise, and, perhaps most importantly, attentive. Furthermore, preoperative stabilization and postoperative supportive care are critical to a successful anesthetic episode and recovery. Several intraoperative challenges may arise that require special attention. Pain control in these patients is frequently difficult to obtain, causing further debilitation. The purpose of this article is to educate the veterinary anesthetist about various difficulties and challenges in the management of the veterinary patient with acute abdomen.

Physiology Considerations

Patients with acute abdominal diseases that require surgery often have hematologic, biochemical, electrolyte, and acid-base disturbances. Knowledge of the physiologic significance of these abnormalities to anesthesia is critical to understanding the methods of anesthetic management. One of the most critical goals of the veterinary anesthetist is to provide appropriate oxygen delivery (DO2) to tissues while a patient is under anesthesia. Oxygen delivery to tissues depends on several factors, including the oxyhemoglobin dissociation curve, the oxygen content of blood, and blood flow. Various changes in the acute abdomen patient, such as acidosis, hypothermia, and others, will affect the oxyhemoglobin dissociation curve (Table 1). Factors that contribute to blood oxygen content include hemoglobin concentration, hemoglobin saturation, and the partial pressure of oxygen. The oxygen content of blood depends largely on the hemoglobin concentration (Table 2). Hemoglobin concentration can be estimated to be approximately one-third the packed cell volume. In the anemic patient, the oxygen content of blood is markedly reduced because of decreased circulating hemoglobin, making this a priority for management to assure appropriate oxygen delivery to tissues. Finally, blood flow is largely determined by cardiac output to the whole body and the vessel diameter of vascular beds of specific organs. Decreases in cardiac output caused by drugs, circulating cytokines including myocardial depressant factor, cardiac dysrhythmias, and endotoxemia, can markedly decrease DO2 to tissues. Similarly, vasoconstriction, which may occur with shock, hypothermia, pain, and drugs, can decrease blood flow to key organs. Maintenance of cardiac output and prevention of marked vasoconstriction must occur to assure appropriate blood flow and, hence, DO2.

Biochemical markers of systemic disease are important to consider, as they will affect drug selection and management. A patient with marked alterations of liver enzyme activity, for example, may not be capable of processing/metabolizing certain drugs. Patients that are septic and hypoglycemic will require glucose supplementation to help prevent a markedly hypoglycemic and catabolic state under anesthesia. Azotemic patients may be dehydrated, necessitating fluid therapy before or during anesthesia to help maintain cardiac output and renal perfusion.

Electrolyte and acid-base disturbances are the second greatest challenge for the veterinary anesthetist managing a patient with acute abdomen. Hyperkalemia caused by urinary leakage, urinary tract obstruction, or anuric renal failure must be stabilized before anesthetizing the patient, as hyperkalemia may cause arrhythmias and decrease cardiac output. Patients that are acidic will have a decreased cardiac output and may have difficulty with hemoglobin saturation. Every attempt should be made to prevent or treat electrolyte and acid-base derangements before anesthesia of the patient. The greater the number of abnormalities, the more difficult anesthetic management will be, and thus, greater morbidity and mortality that result from anesthesia.

Management

The triad of anesthetic goals for the patient with acute abdomen is to produce analgesia, narcosis, and muscle relaxation while maintaining tissue DO2. To this end, the use of balanced anesthetic techniques that decrease the dose of drugs used is recom-
mended. Additionally, the drugs used work synergistically, targeting specific aspects of the anesthetic triad, taking advantage of the desirable effects of each drug while preventing or eliminating any undesirable effects. A variety of premedication, induction, and maintenance techniques is listed in Table 3.

Opioids, including morphine, hydromorphone, oxymorphone, fentanyl, butorphanol, and buprenorphine, have minimal negative effects on the cardiovascular system. They provide potent analgesia, some narcosis, and no muscle relaxation. Use of opioids as part of a balanced anesthetic protocol markedly reduces the amount of inhalant anesthetic required to maintain general anesthesia. Although opioids may produce respiratory depression in some animals under anesthesia, this potentially dangerous side effect is readily managed by use of positive-pressure ventilation. Also, the respiratory depressant effects of opioids may be overstated, and may not be as clinically significant as once thought. Opioids should unquestionably form a significant cornerstone for the anesthetic management of any patient with acute abdomen. Butorphanol, a κ receptor agonist/μ receptor antagonist, has relatively less analgesic potency and much shorter duration of action than morphine, hydromorphone, or oxymorphone. Additionally, butorphanol is more expensive than the other drugs listed. For these reasons, butorphanol is not recommended for anesthetic management, except in unusual cases such as gallbladder obstruction. Opioid drugs with μ receptor specificity can cause contraction of the sphincter of Oddi and potentially can cause gallbladder rupture. Butorphanol can provide some analgesia without causing sphincter contraction. Buprenorphine, a partial μ agonist, is slow in onset and has a long duration of action because of its tight binding to the μ receptor. This same quality makes it relatively difficult to antagonize buprenorphine with naloxone or naltrexone. Buprenorphine’s prolonged duration of action and the challenge of reversal may be disadvantageous during anesthesia, when cardiovascular effects must be carefully titrated with the amount of opioid given. Because of long duration of action and difficulty in reversing buprenorphine, use of this agent is not recommended during the pre- and intraoperative management of patients with acute abdomen.

Intravenous (IV) morphine can cause significant vasodilatation with a subsequent drop in blood pressure; therefore, IV use of this agent is not recommended in the critically ill patient.

Benzodiazepines, like opioids, cause minimal cardiovascular depression. They provide some narcosis, good muscle relaxation, and no analgesia. Similar to opioids, use of a benzodiazepine for premedication and induction reduces the dosage of other drugs required for induction and maintenance of general anesthesia. Both diazepam and midazolam are available for use in clinical practice and should be considered for part of any balanced anesthetic plan for veterinary patients with acute abdomen. When a tranquilizer and an opioid are combined, neuroleptanalgesia is produced. Neuroleptanalgesia is characterized by a cataleptic immobility with an externally tranquil patient who is dissociated to the environment. Analgesia is intense during this state. When combined with an opioid such as fentanyl, a benzodiazepine can often induce anesthesia and allow endotracheal intubation in the critically ill animal.

Halothane, isoflurane, and sevoflurane are inhalant agents commonly used in clinical practice. Inhaled anesthetics provide good narcosis with minimal analgesia; however, muscle relaxation occurs only at higher doses, usually doses that also cause vasodilatation with subsequent hypotension. All inhalant anesthetic agents produce a dose-dependent cardiorespiratory depression. Most also cause vasodilatation, which causes decreased blood pressure, but may improve tissue perfusion. Potency and solubility are two characteristics that are inherent to the inhalant anesthetic being used. The more potent an agent is, the lower concentration is required to maintain anesthesia. Solubility of the agent is one of the key factors in determining the rapidity of uptake of the agent; less soluble agents allow for more rapid changes in anesthetic depth. Halothane is the most potent of the inhalant anesthetics commonly used. As such, it is relatively more difficult to titrate halothane to effect. Also, because of its greater solubility characteristics, changes in anes-
etheric depth occur slowly after a change to the circuit concentration is made. Isoflurane, being less soluble and less potent than halothane, makes it a more appropriate choice for the patient with acute abdomen. Changes in anesthetic depth can be titrated more rapidly with isoflurane than halothane because of lower solubility. Sevoflurane is essentially similar to isoflurane with regard to cardiovascular and respiratory depression. It has the same benefits over isoflurane as isoflurane does over halothane (ie, less solubility, less potency). Additionally, because sevoflurane is extremely insoluble, changes in cardiac output do not affect the rapidity of sevoflurane uptake as much as the more soluble agents. Concern has been raised in the past about sevoflurane causing or exacerbating renal disease. Recently, this concern has been laid to rest with numerous studies in human medicine that demonstrated no adverse effects on the renal system when using sevoflurane. Both isoflurane and sevoflurane produce less cardiovascular depression than halothane. Therefore, use of either isoflurane or sevoflurane is preferred over halothane in the patient with acute abdomen. This author prefers using sevoflurane for the reasons mentioned above.

Etomidate is a general anesthetic that is unrelated to any other anesthetic drug. It has minimal cardiovascular effects, and can be used for induction of general anesthesia. Myoclonus can also result from its use. Administration of a benzodiazepine concurrent with the etomidate lowers the total dose of etomidate used and may prevent myoclonus. Etomidate is relatively expensive, but should be considered a valuable option in the anesthetic induction of the debilitated patient. Ketamine is a dissociative anesthetic used for induction of anesthesia. It has mild sympathomimetic effects and maintains cardiac output relatively well in a healthy patient. Chronically debilitated patients may have maximized sympathetic tone, and thus, ketamine can also have direct cardiodepressant effects. When used without diazepam, ketamine has the potential to increase intracranial pressure. Hence, its use is contraindicated in a patient with head trauma or any suspected cause of increased intracranial pressure. A benzodiazepine should be used with ketamine induction, as ketamine alone will produce muscle rigidity and will often be insufficient for intubation. An anticholinergic may be recommended before ketamine induction, as ketamine-induced salivary secretions can make induction difficult.

Anticholinergic agents, such as atropine and glycopyrrolate, prevent bradycardia and occasionally induce tachycardia. Atropine tends to cause greater increases in heart rate and lasts for a shorter period of time compared with glycopyrrolate. However, the onset of effects of atropine are more rapid than glycopyrrolate. Glycopyrrolate is recommended if an anticholinergic is to be used, unless an immediate and rapid change in heart rate is required, in which case atropine would be the drug of choice. Anticholinergics can occasionally cause second degree atrioventricular block. This arises as a result of the parasympatholytic effects of the anticholinergic affecting the sinoatrial node before lower conduction pathways are affected. Therefore, the sinoatrial node fires, but impulses cannot be transmitted because of continued vagal tone on lower conduction pathways. The second degree atrioventricular block resolves with time and should not be a clinical concern.

Acepromazine, an α receptor antagonist, has been reported to cause hypotension secondary to vasodilation. Because this vasodilation cannot be reversed or readily controlled, use of acepromazine is contraindicated in the patient with acute abdomen. Xylazine and medetomidine are both α-2 receptor agonists. Xylazine produces marked depression of cardiac output, and its use has been associated with significantly greater morbidity and mortality in dogs. Medetomidine causes vasoconstriction, which may decrease blood flow to vital organs. Moreover, it increases myocardial work and decreases cardiac output. Therefore, use of an α-2 agonist is strictly contraindicated in any compromised patient, including those with acute abdomen.

Propofol is a sedative-hypnotic frequently used for anesthetic induction in veterinary patients. Use of this agent can cause peripheral vasodilation and decreased cardiac output, both of which can contribute to hypotension. Therefore, its use is relatively contraindicated in unstable patients with acute abdomen unless other alternatives are unavailable.

Thiopental is a barbiturate that produces rapid anesthetic induction following IV injection. Like propofol, it causes a dose-dependent peripheral vasodilation and decreases cardiac output. Thiopental has also been shown to be arrhythmogenic. In critically ill patients who may have already had ischemic insult to their myocardium, thiopental may create a hemodynamically significant arrhythmia. Its use is not recommended for induction of a debilitated patient.

Hemoabdomen

Patients presenting with hemoabdomen are typically anemic. Hemoglobin concentrations in these patients can be markedly low, causing decreased blood oxygen content with subsequent compromised tissue DO2. Because of this, whenever possible, hemoglobin should be supplied to these patients before induction of anesthesia. This can take the form of fresh whole blood, packed red blood cells, or a commercial hemoglobin-based oxygen carrier product (Oxyglobin; Biopure, Cambridge, MA). Failure to provide appropriate oxygen-carrying capacity in the form of additional hemoglobin can result in profound tissue ischemia, possibly leading to myocardial or cerebral death. As a general guideline, any patient with a hemoglobin concentration lower than 7 g/dL (21% packed cell volume [PCV]) should be transfused before surgery. In other cases, pre-emptive transfusion is sometimes advocated if rapid hemorrhage is anticipated.

Patients with abdominal distension from any etiology (uroabdomen, peritonitis, etc.) may experience profound hypotension during surgical decompression. Surgical decompression causes a rush of blood into previously compressed splanchnic vascular beds, subsequently decreasing venous return. Aggressive fluid support, possibly including hypertonic saline (2 to 4 mL/kg IV over 10 minutes), hetastarch (>20 mL/kg IV), and/or Oxyglobin (30 mL/kg IV @ 10 mL/kg/h in dogs; 15 mL/kg IV @ 5 mL/kg/h in cats), is necessary in these cases. A mild vasoconstrictor, such as dopamine (5 to 10 µg/kg/min IV), may also help to improve venous return.

Uroabdomen/Upper Urinary Tract Obstruction

Animals with uroabdomen or ureter obstruction are azotemic and can have marked electrolyte imbalances, most notably with hyperkalemia and metabolic acidosis. These patients should be stabilized with IV crystalloid imbalances, and the abdomen should be drained of as much urine as possible. Fluid therapy should be aimed at treating shock or dehydration, if present. Otherwise, a
double maintenance rate should be used. Maintenance rates differ, but the author uses: (body weight in kg \times 30) + 70 \times 1.5 = \text{ml/d}. If the patient is extremely unstable, peritoneal dialysis may be necessary to restore electrolyte and acid-base balance before anesthesia.14

**Gastric Dilation-Volvulus**

Anesthetic management of patients with gastric dilation-volvulus (GDV) has been covered in depth previously.15 Generally, decompression and treatment of shock must occur before induction of anesthesia. Any acid-base abnormalities and dysrhythmias should also be addressed before anesthesia. Ventricular dysrhythmias are common in the patient with GDV. Lidocaine 1 to 5 mg/kg IV bolus over 5 minutes, followed by constant rate IV infusion (50 to 100 \mu g/kg/min), can be used for treatment of ventricular tachycardia before and during anesthesia. Maintenance of serum potassium is also important in the pre-emptive treatment of dysrhythmias.

**Gastrointestinal Foreign Body**

Pure \(\mu\) agonist opioids, such as morphine, hydromorphone, oxymorphone, and fentanyl, increase segmental contractions, but decrease propulsive contractions of the gastrointestinal tract. If a complete obstruction or string foreign body is suspected, the veterinary anesthetist should avoid these drugs and use a \(\kappa\) agonist opioid such as butorphanol until the lesion is surgically corrected. The \(\mu\) receptor opioid agonists also increase urinary and bile duct sphincter contractions. If a lower urinary tract or bile duct obstruction is suspected, use of a pure \(\mu\) receptor agonist is relatively contraindicated, and butorphanol may be the better choice until the obstruction is relieved.16

**Peritonitis**

Animals with peritonitis are often the most difficult patients to anesthetize. Patients with peritonitis typically have minimal cardiovascular and sympathetic reserves, and may have endotoxemia with markedly decreased cardiac output. Often, these patients respond more profoundly to the negative effects of some anesthetics than healthier animals. Attempts at cardiovascular and metabolic stabilization of patients with peritonitis often have already occurred by the time anesthesia and surgery become necessary. If anemia is present, supplementing the patient with hemoglobin from some source will improve oxygen delivery to the tissues. A colloid, such as hetastarch or Oxglobin, may help improve tissue blood flow and oxygenation and may help maintain blood pressure. Positive inotropes, such as dobutamine (5 to 20 \mu g/kg/min), are frequently necessary for management of hypotension. An algorithm for managing hypotension in septic patients is presented in Fig 1. When applying this algorithm, it is important to give each step appropriate time to work and to recheck previous steps on a regular basis to make sure a change that should have been made has not been overlooked. If all the steps before an epinephrine infusion have been attempted and hypotension does not correct, it may be preferable to tolerate moderate hypotension rather than risk increasing myocardial work and causing vasoconstriction with the epinephrine infusion. Generally, a patient with a mean blood pressure consistently below 40 mm Hg should be considered for treatment with an epinephrine infusion.
be in either a hyperdynamic or hypodynamic cardiovascular state. The hyperdynamic state is characterized by hyperthermia, tachycardia, tachypnea, normal cardiac output, hyperemia, and marked vasodilatation. These responses are secondary to the direct effects of endotoxin, which causes indiscriminate vasodilatation of tissue vascular beds. The body's normal response to shock is to maintain blood flow to important organs such as the brain and heart. With endotoxemia, however, blood flow is shunted inappropriately, leading to poor perfusion of critical organs. The hypodynamic state is characterized by hyperthermia, tachycardia, depression, tachypnea, low cardiac output, pale mucous membranes, and marked vasopressor response. While this is more characteristic of a hemorrhagic shock state, it may occur in septic shock. Aggressive fluid therapy to treat for septic shock is necessary before anesthesia. End points for therapy may include return to normal heart rate, improvement of mucous membrane color, increased blood pressure, and improvement in awareness of external stimuli. Failure to appropriately treat septic shock before anesthesia may result in profound refractory hypotension with subsequent cardiac arrest.

### Monitoring

Monitoring of the patient under general anesthesia should include assessment of the patient's anesthetic depth, tissue oxygenation, acid-base balance, carbon dioxide, and glucose. Patient depth can be monitored by assessing jaw tone, eye position, and physiologic responses to external stimuli (Table 4). Tissue oxygenation cannot be directly measured, so we must use the parameters described earlier, notably oxygen content of blood and blood flow (Fig 3). Oxygen content of blood can be obtained by knowing the hemoglobin concentration, hemoglobin saturation (SaO₂), and partial pressure of oxygen in the plasma. Since dissolved oxygen contributes so little to the total oxygen content, it can usually be ignored. Hemoglobin concentration can be estimated from the PCV unless Oxyglobin has been administered, in which case it must be measured directly. Oxyhemoglobin saturation can be measured with a pulse oximeter. Direct measurement of cardiac output is difficult without using lithium dilution or placement of a pulmonary artery catheter and use of thermodilution. However, cardiac output can be estimated or extrapolated from the blood pressure. When blood pressure is low, cardiac output is probably low. Mean blood pressure must be maintained above 60 mm Hg to insure adequate blood flow to the kidneys and brain. Diastolic blood pressure must be maintained above 40 mm Hg to insure adequate blood flow to the heart, because the coronary arteries fill in diastole. The gold standard for arterial blood pressure measurement is with use of a direct arterial line that provides beat-to-beat information about the patient's blood pressure. Indirect methods, such as with Doppler flow or oscillometric methods using an automated inflatable cuff (such as a Dinamap), can also be used. However, they are less reliable than direct arterial measurement, particularly at lower blood pressures, or high heart rates often seen in patients with acute abdomen, and do not provide beat-to-beat information. Because of wide variability in the accuracy of indirect methods of blood pressure monitoring, it is recommended that trends are monitored rather than absolute values. In cats, the measurement obtained by Doppler may be more consistent with the mean arterial pressure, rather than the systolic arterial pressure.

Vessel diameter can be estimated based on mucous membrane color and capillary refill time. If the patient is anemic, is not saturating hemoglobin well, is hypotensive, or is pale under anesthesia, tissue oxygenation may be compromised. It is possible for a septic patient to have normal to hyperemic mucous membrane color while other vascular beds are vasoconstricted. Also, at least 5 g/dL of deoxyhemoglobin must be present for cyanosis to be clinically appreciable. It is therefore possible for a patient to be markedly anemic, but not be cyanotic because all of the hemoglobin is saturated with oxygen (oxyhemoglobin).

Acid-base balance should be monitored before, during, and after anesthesia for any patient with acute abdomen. While this can be done either by arterial or venous sampling, arterial sampling is preferred. The appropriateness of ventilation, as determined by the partial pressure of CO₂ in arterial plasma (PₐCO₂), can also be monitored when the blood gas sample is obtained. Acid-base disturbances should be corrected either by changing ventilation (to bring PₐCO₂ to between 35 and 45 mm Hg) or by addition of bicarbonate to the patient. Bicarbonate can be added according to the following formula: body weight in kg × 0.3 × base deficit = miliequivalents of bicarbonate to correct acidosis.

Serum/Plasma glucose concentration should be monitored periodically (usually once per hour is sufficient), particularly in patients with apparent sepsis. If hypoglycemia is present preoperatively or develops intraoperatively, dextrose can be added to the fluids to make a 2.5% or 5% solution. A 2.5% solution of dextrose can be made by first removing 50 mL from 1 L of a commercial fluid solution (LRs, saline, Normosol-R, etc.) and replacing it with 50 mL of 50% dextrose. A 5% solution can be made in the same way by removing and replacing 100 mL.

### Postoperative Management

Following recovery from anesthesia, the principles described above should continue. Critically ill patients often have decreased oxygen delivery to tissues similar to patients under anesthesia. The kidneys are among the most sensitive organs to hypotension; acute renal failure can result from intraoperative hypotension. In those patients who have sustained hypotension during anesthesia, or in which oxygen delivery to tissues was questionable, an indwelling urinary catheter should be placed to monitor urinary output. Patients with adequate circulating...
volume producing less than 1 mL/kg/h should be evaluated for acute renal failure. A central venous catheter, such as a long jugular catheter or, in smaller animals, a long catheter started in a peripheral vein (ie, lateral saphenous) with the tip entering the vena cava, also aids in postoperative management for easily accessible blood sampling and measurement of central venous pressure. Central venous pressure can be monitored to help guide fluid therapy and prevent volume overload. Maintenance of a direct arterial catheter during the postoperative period may also be beneficial in alerting the clinician to sudden changes in blood pressure, as well as direct arterial blood sampling for measurement of arterial oxygenation. Arterial blood pressure measurements can be made continuously, or on an intermittent basis, as needed. Causes of hypotension during the postoperative period include hypovolemia, endotoxemia, drugs such as antibiotics, and decreased cardiac output as a result of the disease process. Appropriate management of hypotension has been described in detail elsewhere. Patients may also be hypertensive. Causes of hypertension during the postoperative period include pain, anxiety, hypoxia, hypercarbia, anemia, hypodynamic shock, and drugs such as positive inotropes, anticholinergics, and medetomidine. These etiologies need to be investigated, as they can have detrimental consequences to the patient.

**Analgesia**

Management of pain is one of the most important aspects of anesthesia for the patient with acute abdomen. Pain before, during, or after anesthesia can result in increased morbidity, a stress response, a catabolic state, and other negative consequences that adversely affect patient outcome. Analgesia can be provided by local and regional strategies, systemic opioids, anti-inflammatory agents, α-2 receptor agonists, and ketamine.

Pain is difficult to recognize in veterinary patients because of their inability to verbally communicate with us. However, there are some responses that are suggestive of pain. Dogs in pain may have sympathetic stimulation, resulting in tachycardia and/or tachypnea and pupillary dilation. They may appear hunched, depressed, and uninterested in interacting with observers. Painful dogs may vocalize, but this is typically a late-stage clinical manifestation, and the absence of vocalization should not rule out the presence of pain. Anxious dogs often have many of the same characteristics as painful dogs. Anxious dogs may bark, whine, or yip, may have sympathetic responses, do not hunch up or protect an area, and usually quiet when handled. Animals with a full bladder may also appear very similar to animals in pain. An algorithm for identifying pain in dogs is presented in Fig 2. Identifying pain in cats is even harder than doing so in dogs, since the only marker that has been shown to be successful in identifying pain is behavior.20 Cats should be observed before surgery to determine their presurgical behavior. Cats should be handled and interacted with to try and determine whether their behavior has changed from their behavior before surgery. A change in behavior such as disinterest in interaction, crouching in the back of the cage, or appearing disinterested in their environment may suggest that pain is present.

Local anesthetics block the transmission of the sensation of pain to the spinal cord. All other analgesic modalities merely...
modulate the sensation of pain. Therefore, when possible, a local anesthetic should be used in the analgesic regimen. Bupivacaine (0.1 mL/kg) can be used epidurally with morphine (0.1 mg/kg) to provide 4 to 6 hours of complete pain relief in addition to the 12 to 24 hours usually obtained by the morphine. Lidocaine can be used as a line block of the linea before skin incision. Anecdotally, local anesthetics have been infused into the thoracic cavity to provide analgesia to the cranial abdomen (1 mg/kg lidocaine, 1 mg/kg bupivacaine).

Systemic opioids include those drugs listed above. Selection of the appropriate opioid should depend on the level of pain the animal is experiencing, the cost of the drug, and the ease of delivery. Ideally, a constant rate infusion of a pure μ agonist such as hydromorphone, oxymorphone, or fentanyl is used. This allows close and accurate titration of dose according to amount of pain the animal is experiencing, avoids peak and trough concentrations, and provides the most potent analgesia. Respiratory depression is a theoretical concern with systemic opioids, largely because respiratory depression occurs in human patients given systemic opioids. However, respiratory depression has not been proven to occur in animals, and there is some evidence to suggest it does not occur in animals.5 Other adverse effects, such as inappetance, nausea, and ileus, are more commonly observed. Should nausea occur with a cros-reactive idiootype of a pure μ agonist, the dose can be decreased or the patient can be switched to a partial μ agonist, such as buprenorphine. Buprenorphine is a good choice for patients who have reached a steady state of pain (ie, out of the postoperative period) because it is potent and has a prolonged duration of effect.

Anti-inflammatory drugs, such as non-steroidal anti-inflammatory drugs (NSAIDs) and steroids, can profoundly decrease the amount of pain an animal experiences.21 This is accomplished by decreasing inflammation at the site of injury and also by decreasing the activity of cyclo-oxygenase in the central nervous system, which centrally modulates the intensity of pain. Few options exist in the United States for parenteral NSAIDs. Presently, ketoprofen (2 mg/kg IV/intramuscular (IM)/subcutaneous (SQ) once, then 1 mg/kg IV/IM/SQ daily; Ketofen; Fort Dodge, Overland Park, KS) is the most readily available parenteral NSAID. However, ketoprofen has been associated with significant gastrointestinal irritation, particularly if used chronically. NSAIDs also have the potential risk of decreasing renal perfusion, leading to renal ischemia, particularly in volume-depleted patients or patients with pre-existing renal disease. Other NSAIDs that can be given orally include carprofen (2.2 mg/kg orally q12 hour; Rimadyl; Pfizer, New York, NY) and etodolac (10 to 15 mg/kg orally q24 hour; EtoGesic; Fort Dodge). These NSAIDs should be given with food, so cannot be used in the anorexic patient. Combined with an opioid, carprofen and etodolac provide excellent analgesia with minimal side effects.

The α-2 receptor agonists, such as xylazine and medetomidine, have profound analgesic properties.22 Xylazine, as previously mentioned, profoundly decreases cardiac output and has been associated with greater morbidity and mortality in dogs, so should not be used to provide analgesia for these patients. Medetomidine, however, may be used if a patient is cardiovascularly stable and is no longer profoundly ill. A very small dose (0.005 mg/kg IM) combined with an opioid can result in marked analgesia. The primary drawback with the use of medetomidine, aside from its potentially adverse effects on the cardiovascular system, is its relatively short duration of action. A constant rate infusion of medetomidine is not recommended for analgesia because of the marked vasconstriction with potential decreased blood flow that accompanies its use. In patients that remain significantly painful and are refractory to opioids, medetomidine may be a valuable option.

Ketamine is a dissociative anesthetic that blocks the N-methyl-D-aspartate (NMDA) receptor in the central nervous system. The NMDA receptor is partly responsible for dorsal-horn windup, which causes an increase in sensitivity to pain and the intensity of the response to pain. Blocking the NMDA receptor and thus preventing windup should decrease overall pain over time.23 Ketamine is not effective in treating acute, severe pain. It should instead be used as an adjunct to analgesia. The protocol

![Diagram](image-url)

**Fig 3. Factors affecting oxygen delivery to tissues.**

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is to give 0.5 mg/kg IV bolus, then 0.5 mg/kg/h for the duration of surgery and into recovery, up to 18 hours post-surgery. The doses of ketamine used for prevention of windup are too low to cause the dissociative effects.

Epidural administration of analgesics can be of significant benefit to both the patient and the anesthetist. Because a drug within the epidural space is placed very close to the proposed site of action, a significantly lower dose can be used, thereby minimizing any adverse systemic effects of the drug. Preservative-free morphine (0.1 mg/kg; Astramorph; Astra, Sodertalje, Sweden), buprenorphine (0.006 mg/kg; Buprenex, Reckitt & Colman, Richmond, VA), lidocaine (1 mL/5 kg; Xylocaine; Astra), and bupivicaine (1 mL/5 kg; Marcaine; Sanofi Winthrop Pharmaceuticals, Morrisville, PA) can all be used to provide epidural analgesia. Preservative-free morphine is the most frequently used epidural analgesic because of its relatively long duration of action (12 to 24 hours) and sufficient analgesic effect. Bupivicaine can be mixed with epidural morphine on a 1:1 volume basis to provide complete anesthesia to the hind limbs and perineum in addition to the 12 to 24 hours of analgesia provided by the morphine. Contraindications for epidural injections include local skin infection over the site of injection and coagulopathies. A relative contraindication for the use of epidurals is sepsis, as traumatic technique can introduce blood into the epidural space. Epidural analgesia significantly reduces the amount of inhalant anesthetic required to maintain anesthesia. Any patient with acute abdomen without the above-listed contraindications should be considered a strong candidate for epidural analgesia. An epidural catheter can be placed for those patients expected to be in chronic pain, and is discussed elsewhere. Potential complications of epidural and epidural catheter placement include introduction of infection into the spinal canal and hemorrhage into the spinal canal if a relative contraindication for the use of epidurals is sepsis, as traumatic technique can introduce blood into the epidural space. Epidural analgesia significantly reduces the amount of inhalant anesthetic required to maintain anesthesia. Any patient with acute abdomen without the above-listed contraindications should be considered a strong candidate for epidural analgesia. An epidural catheter can be placed for those patients expected to be in chronic pain, and is discussed elsewhere. Potential complications of epidural and epidural catheter placement include introduction of infection into the spinal canal and hemorrhage into the spinal canal if a venous sinus is inadvertently lacerated.

Occasionally, animals vocalize or struggle, and it is difficult to determine whether the patient is painful, anxious, or having a dysphoric reaction to a drug (such as an opioid). Because animals cannot verbally communicate, it is this author's opinion that they should be treated first and foremost for pain. This may require high doses of opioids to accomplish, but the differential of pain must first be ruled out by aggressively treating the patient. If the patient continues to cry despite high doses of opioids, an anxiolytic agent such as a benzodiazepine (diazepam 0.25 to 0.5 mg/kg IV) can be given to help decrease anxiety. Only if the patient continues to vocalize despite these steps should reversal of the opioid, preferably with a partial agonist-antagonist such as butorphanol, be pursued. It is this author's opinion that the vast majority of these patients are, in fact, in pain and not dysphoric due to opioids. Reversal of the opioids should only be a last resort, as true opioid dysphoria is likely to be extremely uncommon.

Conclusions

Anesthetic management of the patient with acute abdomen is one of the greatest challenges for the veterinary anesthetist. A solid knowledge of physiology is important to understanding and managing complications as they arise during the perianesthetic period. Oxygenation of the tissues, largely modulated by oxygen content of the blood and blood flow, is one of the most important variables to maintain during anesthesia. Anesthetic protocols should provide sufficient analgesia, narcosis, and muscle relaxation while minimizing cardiovascular depression. Monitoring the anesthetized patient is necessary to identify and treat threats to the patient's overall well-being. Pain control is another important aspect of anesthetic management, and appropriate anesthetic regimens should be considered for any patient undergoing anesthesia and surgery.

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