Analgesia, Anesthesia, and Chemical Restraint in the Emergent Small Animal Patient

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INTRODUCTION

The emergent veterinary patient needs a thorough preoperative assessment to define what type of trauma or compromise the patient is undergoing. The critically ill patient has altered physiology and decreased reserves that will affect the pharmacokinetic and pharmacodynamic behavior of analgesic and anesthetic drugs. These patients benefit from minimizing stress levels and optimizing oxygen delivery.

Stabilization of the critically ill patient before anesthetic drug exposure is ideal, because the risk of anesthesia in an unstable patient increases the risk of anesthetic complications. In some of these patients analgesia and chemical restraint may be required to facilitate handling and stabilization. The administration of analgesics may not result in complete pain relief; however, the goal is to achieve a state whereby the pain is bearable and some of the protective aspects of pain, such as inhibiting the use of a fractured leg, remain. It is vital that the underlying disease process be addressed at the same time while pain relief is provided.

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**STABILIZATION**

Venous access is imperative in the critically ill patient because it will allow administration of intravenous (IV) fluids and analgesics. A dehydrated or hypovolemic state, along with fluid, acid-base, and electrolyte deficits should be corrected, if possible, before anesthesia. Once the patient has been stabilized, thorough diagnostics, such as serial physical examinations, radiographs, blood chemistry, complete blood count, coagulation profile, acid-base status, and blood glucose and lactate levels, should be performed before anesthesia.

The emergent patient often benefits from having more than one IV catheter, either peripherally or centrally, to administer multiple agents and fluids during and after the anesthetic period. If a central venous catheter is to be used for drug administration, the drug should be titrated carefully to avoid a sudden delivery of drug to the brain, causing a profound depressive effect on the animal.

**Chemical Restraint**

Because of pain, fear, or an ill-natured temperament, some trauma patients cannot be safely examined or handled without some form of chemical restraint, and using chemical restraint may be safest to avoid further injury to the animal or personnel. In animals that can be handled but need analgesia to facilitate radiography or other diagnostics, a physical examination and blood work before drug administration is recommended if possible. In patients that are unable to be handled, choosing the appropriate agents may be difficult, because blood work or a complete physical examination may not be possible. Restraint drugs usually include a combination of a dissociative, alpha-2 agonist, an opioid and possibly a tranquilizer. These agents can be mixed in the same syringe, which will improve ease of administration. If a benzodiazepine is chosen, midazolam may be the preferred drug as it is compatible with other agents and has better intramuscular (IM) absorption than does diazepam. In the extremely painful or vicious animal, a mu-agonist narcotic combined with the alpha-2 agonist (eg, dexmedetomidine) given IM will provide analgesia, sedation, and restraint.

In cats, various combinations of drugs have been used for restraint and sedation, and to ease handling. Midazolam combined with butorphanol IM may not be effective in aggressive or responsive cats, because it has been shown to create anxiousness and difficulty in restraint, and may lead to aggressive behavior. This combination, therefore, should ideally be limited to geriatric cats or cats that are very ill. The addition of ketamine or dexmedetomidine to midazolam and butorphanol improves sedation and restraint. The use of ketamine and dexmedetomidine will also provide excellent sedation, but this combination may induce vomiting. The use of dexmedetomidine can result in bradycardia and increased blood glucose concentrations, which are known side effects of alpha-2 agonists.

**Premedication**

Premedication may not be necessary unless the animal is fractious or extremely painful. Premedication can calm and quiet the patient, and therefore decrease the amount of induction drugs needed. Analgesic premedication can decrease the amount of inhalant anesthesia that will be required, and provide preemptive, preventive, analgesia before surgery.

**Opioids**

If it is decided that patients who are critically ill would benefit from premedication, opioids such as morphine, hydromorphone, or oxymorphone in combination with a tranquilizer (eg, midazolam) can be administered IM to provide analgesia and sedation.
Opioids are the preferred agents in the critically ill because of their minimal effect on cardiac output, systemic blood pressure, and oxygen delivery.3 Opioids provide analgesia and sedative effects and can be reversed with naloxone if necessary. The mu-agonist opioids are used for their significant analgesic effects. The mu-antagonist/kappa-agonist opioid butorphanol does not provide sufficient analgesia for severe pain; however, it does have antiemetic properties, and is the preferred analgesic in the vomiting patient.3 The partial mu-agonist buprenorphine can be used to treat moderate pain but is difficult to reverse if adverse clinical events occur.3 Finally, significant histamine release and profound vasodilation can be seen when certain opioids (eg, morphine, meperidine) are given as a rapid IV injection.3

**Tranquilizers**

Benzodiazepines are unreliable anxiolytics when given alone unless the animal has central nervous system (CNS) depression; however, they are can provide improved sedation when given in combination with opioids and dissociatives.3,4 Likewise, the use of acepromazine should be used cautiously (if at all) in critically ill patients because of its hypotensive effect. One indication for the use of acepromazine would be for the patient with upper airway obstruction (eg, laryngeal paralysis) because of its sedative and antianxiety effects. Acepromazine has minimal respiratory depressant effects, making it an ideal sedative for this population of patients. Sufficient time must be allowed for complete drug effect (even when administered IV), because it can take up to 30 minutes to exhibit its full effect.4 Oxygen supplementation should also be provided to these patients while sedation is being achieved.3

**Anticholinergics**

Anticholinergics are not routinely administered unless the patient is bradycardic. Anticholinergics may increase myocardial oxygen consumption because of induced tachycardia, and can decrease the threshold for cardiac dysrhythmias.5

**Dissociative medications**

Dissociatives are N-methyl-D-aspartate (NMDA) receptor agonists, and work by providing analgesia peripherally and somatically.4 The most common dissociative used in veterinary medicine is ketamine, which can be easily included in the premedication protocol as an IM or IV analgesic. As a single agent, ketamine causes muscle rigidity, and is best combined with a benzodiazepine or alpha-2 agonist to provide muscle relaxation. Ketamine causes tachycardia, increases blood pressure, and has some respiratory depression properties.3,4 Ketamine will have a prolonged effect in cats with renal disease, because excretion is impaired, and should be used cautiously in azotemic patients.3,4 In addition, ketamine will increase intracranial and intraocular pressure, and is therefore not recommended for use in patients that have sustained traumatic brain injury.3,4

**Alpha-2 agonist**

Alpha-2 agonists can be used to provide sedation and analgesia in extremely painful or fractious animals. Alpha-2 agonists work primarily by decreasing norepinephrine release centrally and peripherally and reducing nociceptive transmission; a decrease in CNS sympathetic outflow and circulating catecholamines also occurs. They can be safely combined with dissociatives, opioids, and tranquilizers for analgesia and anesthesia. Dexmedetomidine, a potent alpha-2 agonist, is commonly used to provide restraint, sedation, analgesia, and muscle relaxation. It can be used IM and IV, and as a constant rate infusion (CRI). Potential side effects of dexmedetomidine include vomiting, peripheral vasoconstriction, and hypertension; a reflex bradycardia may then
be seen secondary to hypertension. Adding ketamine to the dexmedetomidine can help to modulate this response.\textsuperscript{6} Anticholinergics (eg, atropine) are not recommended to treat the dexmedetomidine-induced bradycardia, because increased heart rate in combination with the peripheral vasoconstriction can worsen cardiac performance and exacerbate hypertension.\textsuperscript{4} If the bradycardia induced by administration of dexmedetomidine is significant or clinically relevant, IM reversal with atipamezole is the preferred treatment.\textsuperscript{4} In cats, dexmedetomidine has been safely used to provide analgesia and sedation, and helps to decrease the amount of anesthetic inhalant that is required.\textsuperscript{6,7} Potential side effects of dexmedetomidine include polyuria and interference with insulin production, contributing to hyperglycemia. Because of this, dexmedetomidine is not recommended for use in patients with urinary obstruction or in animals with diabetes mellitus.\textsuperscript{4}

\textbf{Reversal}

The reversal of either opioids with naloxone or alpha-2 agonists with atipamezole results in loss of analgesic and sedative effects, which may lead to excitement, pain, and distress for the animal. To minimize these potential side effects, only one reversal agent should be used; for example, if both an opioid and alpha-2 agonist are used in combination, only the alpha-2 agonist should be reversed, leaving the analgesic effects of the opioid active. If a mu-agonist opioid (eg, fentanyl, hydromorphone, or morphine) requires reversal, it is advisable to use a kappa-agonist/mu-antagonist, such as butorphanol or nalbuphine, to reverse the sedative effect of the opioid, because this retains some of the analgesic effects of the kappa-agonist.\textsuperscript{4}

The other drug class that can be reversed is the benzodiazepines. If reversal of benzodiazepines is necessary (eg, diazepam, midazolam), the antagonist flumazenil can be administered intravenously.\textsuperscript{4}

\textbf{INDUCTION}

Critically ill patients are often depressed and lethargic, and require minimal drug therapy for induction. In the compromised, critically ill patient, anesthetic drug doses can often be reduced to as much as half of the dose used in more stable patients. Induction drugs should be slowly titrated IV to effect, and the minimal amount of drug necessary to intubate the patient should be used. In addition, a balanced anesthetic technique (eg, the use of multiple drug classes) will help minimize the side effects from the use of a single agent or drug class. The use of local anesthesia and epidural analgesia should be used, if appropriate, to decrease the amount of general anesthesia that is required. Intubation should always be performed to control the airway, provide the ability to ventilate the patient, and protect the airway from aspiration of gastric contents into the lungs. The critically ill animal that presents emergently should be considered to have a full stomach, and therefore at risk for aspiration.

Protocols should be implemented to minimize the amount of time the animal is under anesthesia; therefore, techniques such as preclipping the surgical site with the animal awake should be performed if possible. Preoxygenation of the animal before induction will allow for additional time that may be needed to intubate the animal; this is especially helpful in animals in respiratory distress or with an airway that may be difficult to intubate. Finally, electrocardiography and blood pressure monitoring should be in place before induction to detect evidence of arrhythmias, hypotension, or cardiovascular collapse that may occur during induction of the critically ill animal.

Ideally a slow transition to general anesthesia should occur that would allow time for the cardiovascular and nervous system to appropriately respond to and accommodate the medications.\textsuperscript{9} However, the critically ill patient may not be able to respond
appropriately, and therapeutic intervention must be available to prevent clinical dete-
rioration of the patient. For example, the patient in respiratory distress will require a
rapid-sequence intubation to gain control of the airway and provide ventilation with
an inspired oxygen concentration of 100%.

**Thiopental and Propofol**

A rapid-sequence induction can be accomplished with agents that have a short onset
time, such as thiopental or propofol. These agents have an onset time of approxi-
mately 30 seconds and must be given IV. The duration of action is also short, with
thiopental lasting 10 to 15 minutes and propofol lasting 5 to 10 minutes. Propofol
may be the preferred agent because of its shorter duration of action. Both of these
drugs can be used in combination with a benzodiazepine (eg, diazepam or midazolam)
to improve relaxation and decrease the overall dose of thiopental or propofol needed.
Both thiopental and propofol are capable of creating cardiac arrhythmias, hypoten-
sion, and apnea; hence, intermittent positive pressure ventilation (IPPV) may be
necessary. Neither agent will provide analgesia, and therefore additional analgesics
must be given before the surgical procedure. Thiopental and propofol decrease intra-
cranial and intraocular pressure and would be indicated for induction of the patient
with a traumatic brain injury.

The new formulation of propofol, PropoFol 28, is not labeled for use in cats. The new
formulation contains the preservative benzyl alcohol, which can be toxic to cats when
administered in large doses. Although PropoFol 28 has been safely used in healthy
cats with no indications of toxicity (and normal recoveries have been reported), propo-
fol is less well tolerated in cats compared with dogs because of slower metabolism
and excretion. Cats have a low capacity for glucuronic acid conjugation, and there-
fore have limited ability to metabolize benzoic acid. Repeated doses or infusions can
lead to prolonged anesthetic recoveries. Propofol has been reported to increase the
presence of Heinz bodies in cats, potentially leading to hemolytic anemia. PropoFol
should be avoided in cats that are significantly debilitated or that have or are sus-
pected to have liver impairment.

**Alfaxalone**

A new induction agent, alfaxalone, may be useful for induction of the critically ill ani-
mal. Alfaxalone is a synthetic neuroactive steroid that is rapidly metabolized and elim-
inated from the body. Alfaxalone, like thiopental and propofol, has dose-dependent
changes such as hypoventilation and apnea, but has a wide margin of safety. Alfax-
alone has a short duration of action, reported as 14 to 50 minutes. It can also be used
as a CRI with good muscle relaxation and rapid recovery. Because excitement on
recovery can occur (seen as paddling, muscle twitching, or even violent movements),
the administration of sedative drugs in combination with alfaxalone will improve recov-
ery. In dogs that were considered a poor anesthetic risk, alfaxalone administered at
a dose of 1 to 2 mg/kg IV over 60 seconds was shown to be an acceptable induction
agent with a smooth recovery. It can also be safely combined with a fentanyl CRI. Cats
recovering from alfaxalone may be more disoriented and nervous compared with
those recovering from propofol.

**Opioids**

In the critically ill patient that is more cardiovascularly stable, a more gradual induction
technique can be performed, such as neuroleptanalgesic techniques, such as hydro-
morphone, oxymorphone, or fentanyl and diazepam or midazolam, with the addition of
either propofol or ketamine to facilitate induction. In dogs and cats with severe liver
compromise, remifentanil can also be considered for analgesia. Remifentanil is a synthetic opioid with direct action on the mu-receptors with an ultra-short duration of action. Remifentanil is a synthetic opioid with direct action on the mu-receptors with an ultra-short duration of action.14 The elimination of remifentanil is independent of hepatic or renal function, which makes it an attractive agent for use in animals with hepatic or renal compromise.14 It is metabolized by nonspecific esterases in the blood and tissues.14 Recovery from remifentanil is rapid, even after long-term IV infusions.14 It has been used in dogs at an initial IV dose of 3 μg/kg IV, followed by a CRI of 0.1 to 0.3 μg/kg/min, with the drug diluted in normal saline.14,15 Because of the drug’s short duration of action, an additional analgesic should be administered on termination of the remifentanil if the painful condition persists. The clinical effects of remifentanil are rapidly dissipated on discontinuation of the infusion, with dogs recovering in 5 to 20 minutes regardless of the duration of the infusion.14,15 Remifentanil, like other opioids administered as a CRI, is a potent respiratory depressant. IPPV may be required with severe cases; however, this respiratory depression does not persist after discontinuation of the drug.15 Remifentanil has been used in cats; however, at doses greater than 1 μg/kg/min, dysphoric behavior and frenetic locomotor activity was reported.16

**Etomidate**

The use of etomidate for induction of critically ill patients that are cardiovascularly unstable is appealing because of its minimal cardiovascular effect. Etomidate should not be used as the sole induction agent, because it may lead to retching and myoclonus.5 Giving a benzodiazepine or opioid IV before administering etomidate minimizes these adverse effects.5 Repeated use of etomidate in cats may lead to hemolysis secondary to the propylene glycol vehicle.5 The use of etomidate in the critically ill human patient is controversial because of its ability to lead to adrenal dysfunction, which may lead to an increase in morbidity and mortality.17 The duration of the adrenal dysfunction can range from 24 to 48 hours in the critically ill patient.17 The use of hydrocortisone to treat the etomidate-induced adrenal insufficiency had no effect on outcome.18 The recommendation in human medicine is to use etomidate cautiously in septic shock patients who may have relative adrenal insufficiency secondary to their disease.17,18 In addition, etomidate should not be used in patients who have or are suspected of having hypoadrenocorticism.

**Ketamine**

Ketamine can be safely used in the critically ill patient as part of induction (IV). It is commonly used in combination with a benzodiazepine. Ketamine increases heart rate, blood pressure, and cardiac output via a centrally mediated sympathetic response and endogenous catecholamine release.4 Because of the potential for increased cardiac contractility, it should be used cautiously in animals with hypertrophic cardiomyopathy.4 Ketamine can have direct myocardial depressant effects, and in debilitated patients with a decreased endogenous catecholamine response, hypotension and cardiovascular instability may result.4 Ketamine also has the potential to induce seizures when given as a sole agent.3,4

**Multiple Agents**

The use of multiple agents (eg, hydromorphone, diazepam, ketamine, lidocaine, propofol) is an example of balanced anesthesia. Using these drugs in combination results in a slower onset of action, but provides superior analgesia and is more cardiovascularly sparing.19 Ketamine may be used to enhance analgesia and will increase heart rate and blood pressure.20 Lidocaine is often beneficial in the critically ill patient because of its free radical scavenging abilities, analgesic effects, and antiarrhythmic properties,
which may help minimize the effects of compromised viscera, reperfusion injury, or ventricular arrhythmias. In cats, the use of lidocaine is not recommended because of its cardiovascular depressive effects. Using some of these medications as a combination CRI results in a slower onset of action; therefore, loading doses before starting the CRI is required. The CRI doses of these medications in one study were morphine at 3.3 μg/kg/min, lidocaine at 50 μg/kg/min, and ketamine at 10 μg/kg/min.

Propofol is not recommended for use as a single agent for major surgical procedures because it does not prevent hemodynamic responses to noxious stimulation. It can be used in combination with other agents such as lidocaine and ketamine in the dog for total IV anesthesia. Propofol has negative chronotropic and inotropic effects, and causes venodilation, which can lead to significant hypotension.

In animals with splenic disease, using an induction agent that does not result in splenomegaly is recommended, because splenomegaly/splenic congestion can lead to worsening of splenic hemorrhage. The administration of acepromazine, thiopental, and propofol has been reported to cause splenomegaly. In addition, a reduction in packed cell volume was reported in dogs receiving acepromazine, thiopental, and propofol, which may be of concern in the anemic patient. Therefore, avoiding these agents in animals with splenic disease or if laparoscopy is planned is recommended. Two alternative drugs to consider are hydromorphone and dexmedetomidine, which do not result in splenomegaly.

MAINTENANCE

Once the animal is intubated and stabilized, anesthesia can be maintained via an inhalant agent such as isoflurane or sevoflurane. These agents are the most commonly used, but both create dose-dependent myocardial depression, hypotension, and respiratory depression. Both agents have a rapid onset and recovery time, allowing for rapid change in anesthetic concentration. Alternatively, maintenance can also be performed with a CRI of anesthetic agents if the patient cannot tolerate the hypotensive effects of inhalant anesthesia. Ketamine/propofol and ketamine/propofol/dexmedetomidine infusions have been used in cats for ovariectomy. Cats were given one of the combinations IV and then maintained on a ketamine/propofol infusion for the surgical procedure. No adverse effects were seen with either group; however, sedation was more profound in the group receiving dexmedetomidine.

Morphine, lidocaine, and ketamine can be used in dogs as a CRI to provide analgesia and to decrease the amount of inhalant required. Additional mu-agonists that can be used as a CRI include fentanyl, oxymorphone, and hydromorphone. Alpha-2 agonists can also be used as a CRI to enhance analgesia and minimize the level of inhalant needed. These CRIs can then be administered postoperatively at lower doses to provide continued analgesia as needed.

Maintenance anesthesia requires careful and constant monitoring to avoid excessive anesthetic depth and preserve cardiovascular function. The electrocardiogram should be monitored closely for changes in heart rate and rhythm, and for the presence of malignant arrhythmias, which may be more prevalent in animals with trauma, splenic disease, septic peritonitis, or hypoxia, or dogs with gastric dilatation volvulus. Additional monitoring during the maintenance phase of anesthesia includes keeping the mean arterial blood pressure (MAP) at greater than 60 mm Hg to maintain renal perfusion. Physical examination findings for perfusion, such as the capillary refill time, mucous membrane color, heart rate, and pulse quality, should also be monitored continuously. Depth of anesthesia should be frequently assessed through monitoring eye position, pupil size, jaw tone, response to stimulus, heart rate, blood pressure, and
respiratory rate during the duration of anesthesia. Other monitoring techniques should be implemented, both during and after anesthesia, to enhance the quality of care and decrease morbidity and mortality. The use of pulse oximetry helps to continually assess hemoglobin saturation (Hb) and, therefore, blood oxygenation. Arterial blood gas monitoring may be necessary as the gold standard in some critically ill patients while under anesthesia to assess oxygenation, ventilation, Hb saturation, electrolyte abnormalities, and overall acid-base status. Capnography allows monitoring of the adequacy of ventilatory function and provides an indication of sufficient cardiac output. Capnography will also monitor for signs of esophageal intubation, breathing circuit disconnection, and cardiac arrest; in these situations, carbon dioxide levels become unreadable.

**INTRAOPERATIVE HYPOTENSION**

Because critically ill patient are often hypotensive during anesthesia, an MAP of less than 60 mm Hg or a systolic blood pressure less than 90 mm Hg requires prompt treatment to maintain appropriate organ perfusion. The initial step should be to decrease the administration of inhalant anesthetic agents because of their depressant and vasodilatory properties. Next, a fluid bolus should be administered. A crystalloid at a rate of 10 to 20 mL/kg IV over 15 to 20 minutes or an artificial colloid bolus of 5 to 10 mL/kg IV over 10 to 20 minutes should be implemented. If no effect occurs, multiple small boluses can be attempted, keeping in mind the total volume of fluids that have been administered. If the hypotension persists during fluid therapy, inotropic support may be needed through administering dopamine or dobutamine. These agents are given as an IV CRI because of their short half-life, at a dose of 2 to 10 μg/kg/min. Dopamine and dobutamine can be used concurrently. Patients on inotropes and vasopressors should be monitored carefully for tachycardia; if this occurs, the rate of the infusion should be decreased or the addition of another inotrope should be considered. Other agents that may be used include ephedrine (0.05–0.5 mg/kg IV as a single bolus), norepinephrine (0.1–1 μg/kg/min IV as a CRI), and vasopressin (0.01–0.04 U/kg/h IV as a CRI). If the initial inotrope is not successful in correcting the hypotension, a second agent is added while continuing administration of the first agent. For example, norepinephrine is most often used in combination with dopamine or dobutamine, and vasopressin can also be used in combination with these agents.

If the patient has persistent hypotension after appropriate fluid therapy and inotropic support, discontinuation of the inhalant anesthetic should be considered, and injectable anesthetic drug therapy should be instituted. An example of an injectable anesthetic regimen used in this situation includes a CRI of fentanyl in combination with ketamine and lidocaine. Some very critical patients may only need fentanyl as an intermittent IV bolus or as a CRI. The use of multiple agents to maintain injectable anesthesia can be considered; however, in cats, recent research suggests that the use of a lidocaine CRI should be avoided because of the cardiovascular depressant effects it produces.

**RECOVERY**

In critically ill patients, continuous cardiovascular support, monitoring, supportive care, and analgesia are imperative during the recovery period. The recovering patient may still require inotropic support, which should be continued in the intensive care unit during recovery, if necessary. Patients should be kept dry and warm, and should recover in a quiet, stress-free environment where they can be continuously and carefully monitored. A shivering animal has greatly increased demands for glucose and
oxygen, and oxygen supplementation and heat support should be provided until clinical signs resolve.\textsuperscript{31} Acid-base, electrolyte, and blood glucose levels should also be monitored in the recovering and shivering animal. The use of forced warm air heating blankets will help in the treatment of postoperative hypothermia. Finally, the use of analgesics is imperative in these critically ill patients experiencing pain. Although these patients may not exhibit classic pain response symptoms because of their debilitated state, they should be carefully but appropriately treated with analgesics. Pain can lead to catabolism and complications such as delayed wound healing, sepsis, and nosocomial disease.\textsuperscript{32}

**SUMMARY**

Critically ill patients that need to be sedated or anesthetized should be stabilized before drug administration. Appropriate monitoring should be performed at all times to ensure that these patients survive sedation or emergent surgery. Postoperative care includes continued vasopressor and inotropic support, aggressive colloid and/or crystalloid therapy, analgesic support, antibiotic therapy, oxygen therapy, blood pressure monitoring, and nursing care to improve the survivability in this critically ill patient population.

<table>
<thead>
<tr>
<th>Drugs dosages</th>
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<tbody>
<tr>
<td><strong>Anticholinergics</strong></td>
</tr>
<tr>
<td>Atropine, 0.04 mg/kg IM, 0.02 mg/kg IV</td>
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<tr>
<td>Glycopyrrolate, 0.01 mg/kg IM, IV</td>
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<tr>
<td>May make secretions more viscous</td>
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<tr>
<td>Increase heart rate and can increase myocardial work and oxygen consumption</td>
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<tr>
<td>Glycopyrrolate does not cross the blood brain barrier or the placenta</td>
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<tr>
<td><strong>Opioids, mu-agonists</strong></td>
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<tr>
<td>Morphine, 0.2 to 2.0 mg/kg IM, subcutaneous (SC)</td>
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<tr>
<td>CRI, 0.1 to 0.3 mg/kg loading dose, then 0.1 to 0.3 mg/kg/h</td>
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<tr>
<td>Oxymorphone, 0.05 to 0.20 mg/kg IM, IV, SC</td>
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<tr>
<td>Meperidine, 2 to 11 mg/kg IM, SC</td>
</tr>
<tr>
<td>Hydromorphone, 0.1 to 0.2 mg/kg IV, IM, SC</td>
</tr>
<tr>
<td>CRI, 0.025 to 0.050 mg/kg IV loading dose, then 0.01 to 0.04 mg/kg/h</td>
</tr>
<tr>
<td>Fentanyl, 0.005 to 0.08 mg/kg IM, IV, SC</td>
</tr>
<tr>
<td>CRI loading dose for dog, 5 to 10 µg/kg, then 0.7 to 1.0 µg/kg/min</td>
</tr>
<tr>
<td>CRI loading dose for cat, 5 µg/kg, then 0.3 to 0.4 µg/kg/min. May need to give anticholinergic before CRI if bradycardic</td>
</tr>
<tr>
<td>Remifentanil, 3 µg/kg IV, then CRI, 0.1 to 0.3 µg/kg/min</td>
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<tr>
<td>Complete reversal with naloxone</td>
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<tr>
<td><strong>Analgesic</strong></td>
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<tr>
<td><strong>Respiratory depression</strong></td>
</tr>
<tr>
<td><strong>Bradycardia</strong></td>
</tr>
<tr>
<td><strong>Minimal effect on cardiovascular performance</strong></td>
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Partial mu-agonist
- Buprenorphine, 0.005 to 0.020 mg/kg IM, IV
  - Slow onset, difficult to reverse
  - Good for moderate pain

Kappa-agonist/mu-antagonist
- Butorphanol, 0.1 to 0.8 mg/kg intramuscularly, IV, SC
  - CRI, 0.1 to 0.2 mg/kg IV loading dose, then 0.1 to 0.2 mg/kg/h
  - Minimal cardiovascular effects, not good for severe pain
  - Can be used for partial reversal of mu-agonist opioids

Antagonist
- Naloxone, 0.002 to 0.02 mg/kg IM, IV
  - Used for reversal of opioids

Dissociatives
- Ketamine, 4 to 11 mg/kg IV, IM
  - CRI, 0.5 mg/kg IV loading dose, then 0.1 to 1.2 mg/kg/h
- Telazol, 2 to 4 mg/kg IM, 2 mg/kg IV (tiletamine and zolazepam)
- Salivation
- Increases heart rate
- Increases intracranial and intraocular pressure
- Analgesic effects

Benzodiazepines
- Diazepam, 0.2 to 0.5 mg/kg IM, IV
- Midazolam, 0.07 to 0.4 mg/kg IM, IV
  - CRI, 0.1 to 0.5 mg/kg/h
- Can decrease other drug doses
- Mild sedation and muscle relaxation
- Treat seizures
- Not analgesic
- Diazepam has propylene glycol

Antagonist
- Flumazenil, 0.08 to 0.2 mg/kg IV

Phenothiazines
- Acepromazine, 0.01 to 0.2 mg/kg intramuscularly, intravenously
  - No more than 3 mg total dose
  - Vasodilation
  - Long duration
  - Not analgesic

Barbiturates
- Thiopental, 4 to 20 mg/kg IV
  - Cardiovascular and respiratory depression
  - Rapid induction
Decreases intracranial and intraocular pressure
Effects may be potentiated by concurrent acidosis or hypoproteinemia

**Propofol**
- Propofol, 2 to 8 mg/kg intravenously
- CRI, 0.1 to 0.4 mg/kg/min
- Rapid-acting with short duration
- Respiratory depression
- Decreases intracranial and intraocular pressure
- Peripheral vasodilation
- Myocardial depressant

**Etomidate**
- Etomidate, 0.5 to 4 mg/kg IV
  - Maintains cardiovascular stability
  - Not used as a single agent; commonly combined with a benzodiazepine
  - Suppresses adrenocortical function

**Alpha-2 agonists**
- Dexmedetomidine, 3 to 40 µg/kg IM, IV
  - CRI, 1 µg/kg intravenous loading dose, then 1 to 3 µg/kg/h
  - Cardiovascular depression
  - Vomiting
  - Good sedation and analgesia
  - Can combine with opioid or dissociative

**Antagonist**
- Atipamazole, 0.04 to 0.5 mg/kg IM, IV

**Lidocaine**
- Loading dose, 1 to 2 mg/kg IV, then CRI, 1–3 mg/kg/h
  - CRI not recommended for use in cat

**Alfaxalone**
- Alfaxalone, 2 to 5 mg/kg intravenously.
  - May need sedation to improve recovery

**Neuroleptanalgesics**
- Combination of an opioid with a tranquilizer or sedative
  - Analgesic
  - Noise-sensitive
  - Maintain cardiovascular stability

**Inhalants**
- Isoflurane, sevoflurane
  - All inhalants will produce a dose-dependent cardiovascular depression
  - Cause peripheral vasodilation
  - Anesthetic depth is rapidly adjusted
  - Rapid uptake and recovery
REFERENCES


