Constant rate infusions (CRI) of analgesic drugs are an excellent way to manage pain in both dogs and cats. A CRI of analgesic agents has several advantages over multiple repeated injections for pain relief, including:

1. A more stable plane of analgesia with less incidence of break-through pain (which can be difficult to treat);
2. A lower drug dosage delivered at any given time, resulting in a lower incidence of dose-related side effects;
3. Greater control over drug administration (easy to change the dose);
4. Decreased need for stimulation of resting patients to administer drugs; and
5. Decreased cost (when compared to technician time, needles, and syringes required for repeat injections).

Drugs that are useful for CRIs include fentanyl, hydromorphone, morphine, butorphanol, ketamine, lidocaine, and a myriad of combinations of these drugs. Dosages available are shown in Tables 1 and 2.

**Opioids**

The opioid class of drugs includes some of the most potent analgesic drugs available, and opioids should be considered for any patient experiencing moderate to severe pain. Although opioids are generally sedating in dogs, they can cause excitement in cats. Fortunately, the low dose of opioids delivered in a CRI rarely results in sedation or excitement. However, if excitement does occur, a light dose of a sedative (e.g., acepromazine or dexmedetomidine) can be administered to the cat and the CRI rate be maintained (if excitement is mild) or reduced (if excitement is moderate). If sedation occurs, the dose of the CRI can be decreased. Fentanyl, hydromorphone, and morphine are potent full agonist opioids that provide profound dose-related analgesia. These full agonists are the most commonly used opioids, but butorphanol, an agonist-antagonist, has an advantage in that this drug is more likely to provide sedation than excitement in cats. However, butorphanol provides only moderate analgesia and has a ceiling effect for pain relief (i.e., a point is reached where higher dosages result in more sedation but not more analgesia). Thus, butorphanol is only appropriate for short-term, mild to moderate pain and should be used as part of a multimodal protocol rather than as a sole agent.

**N-methyl-D-aspartate (NMDA) Receptor Antagonists**

Painful impulses cause N-methyl-D-aspartate (NMDA) receptors (among others) in the dorsal horn of the spinal cord to depolarize, and prolonged depolarization of these receptors can lead to an amplification of the pain stimulus, resulting in what we commonly refer to as “wind-up” or “hypersensitization.” When this occurs, the patient may feel more pain than expected (hyperalgesia) or even feel pain in response to a nonpainful stimulus (allodynia). By administering drugs that antagonize these receptors (like ketamine), we are able to alleviate this exaggerated response and make the pain easier to control. Ketamine is the NMDA-receptor antagonist most commonly used in veterinary medicine, and NMDA receptor antagonist effects are achieved when ketamine is used as a low-dose CRI. A single high-dose bolus of ketamine (e.g., like the anesthetic induction dose) can serve as a loading dose for a CRI but is unlikely to provide analgesia when used alone. Furthermore, the NMDA receptor antagonists strictly mediate hypersensitivity and do not provide true analgesia; thus, these drugs must be administered in conjunction with true analgesic drugs (e.g., opioids or NSAIDs).

**Lidocaine**

Lidocaine can be administered systemically to provide analgesia, but its mechanism of action when used systemically is not entirely clear. Proposed mechanisms include blockade of sodium channels or potassium currents in the dorsal horn of the spinal cord and direct inhibition of abnormal electrical charges from injured or inflamed peripheral nerves. Lidocaine CRIs are extremely useful in dogs but are somewhat controversial in cats because 1) cats appear to be more sensitive to the lidocaine-induced side effects than other species are, and 2) there is evidence that lidocaine may cause excessive cardiovascular depression in cats. Point 1 is potentially (although not unequivocally) true, and a lower dosage of lidocaine is recommended for cats than is recommended for dogs. Point 2 is most commonly reported in anesthetized cats, and the cardiovascular depression could result from a physiologic interaction between lidocaine and anesthetic agents. Also, some argue that lidocaine CRI has been used successfully for anti-arrhythmic therapy in cats without undue cardiovascular depression and should be appropriate for analgesia, especially since the dose for analgesic therapy is actually on the low end of the dose used for anti-arrhythmic
therapy. Because of the uncertainty of lidocaine effects in cats, some veterinarians feel that lidocaine CRI is not warranted in the cat at all, while others feel that it is an appropriate means to treat pain, especially in patients where other options may be limited. If lidocaine CRI is chosen, using low dosages in conscious cats (i.e., not under anesthesia) is recommended. Lidocaine CRIs are commonly used in dogs, especially in dogs with gastro-intestinal pain (e.g., pain from exploratory laparotomy, gastric dilatation-volvulus [GDV], pancreatitis, parvovirus, etc . . . ).

**Combinations of Opioids, Ketamine, and (Possibly) Lidocaine**

CRIs that include multiple drugs are often more effective than CRIs of single drugs because the effects of analgesic agents from different drug classes are generally additive or synergistic. Combinations include opioids + ketamine or opioids + ketamine + lidocaine.

**Calculations of CRI Dosages**

Generally, dosing tables or individualized spreadsheets (e.g., there are very useful spreadsheets available at multiple websites, including vasp.org) should be used for constant rate infusions. These sheets greatly improve the speed at which CRIs can be initiated and greatly decrease the chance of mathematical errors. However, CRI dosages can also be easily calculated using this formula:

\[
\text{ml of drug to add to diluent} = \frac{A \times B \times C \times D}{E \times F \times 1000}
\]

**Summary**

Constant rate infusions are extremely easy to use and extremely beneficial to the patient. A variety of drugs can be used in the CRI, and drug choice should be based not only on what is best for the patient (e.g., analgesic potency and safety) but also on what is best for the hospital (e.g., comfort level with and availability of drugs). Because calculating CRI dosages can be cumbersome, math is often the only limitation to using these valuable tools. Thus, rather than calculating drug dosages for each CRI, a “cheat sheet” or computer program is recommended.

**Table 1. Dosages for constant rate infusions (CRIs) used in cats**

<table>
<thead>
<tr>
<th>Drug</th>
<th>Loading Dose</th>
<th>CRI Dose</th>
<th>Quick Calculation</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morphine*</td>
<td>0.10 mg/kg IM</td>
<td>0.03 mg/kg/hr (0.5 mic/kg/min)</td>
<td>Add 15 mg to 500 ml LRS &amp; run at 1 ml/kg/hr</td>
<td>Cat may need light sedation; can be combined with ketamine &amp;/or lidocaine.</td>
</tr>
<tr>
<td>Hydromorphone</td>
<td>0.05 mg/kg IV</td>
<td>0.012 mg/kg/hr</td>
<td>Add 6 mg to 500 ml LRS &amp; run at 1 ml/kg/hr</td>
<td>May cause hyperthermia; can be combined with ketamine &amp;/or lidocaine.</td>
</tr>
<tr>
<td>Fentanyl</td>
<td>0.001–0.003 mg/kg IM or IV (1–3 mic/kg IV)</td>
<td>0.0012 mg/kg/hr (0.02 mic/kg/min) (1–2 mic/kg/hr)</td>
<td>Add 0.6 mg to 500 ml LRS &amp; run at 1 ml/kg/hr 0.6 mg = 12 ml fentanyl, remove 12 ml LRS before adding fentanyl; can be combined with ketamine &amp;/or lidocaine.</td>
<td></td>
</tr>
<tr>
<td>Butorphanol</td>
<td>0.1 mg/kg IV</td>
<td>0.1–0.2 mg/kg/hr</td>
<td>Add 50 mg to 500 ml LRS &amp; run at 1 ml/kg/hr for 0.1 mg/kg/hr</td>
<td>Only moderately potent &amp; has ceiling effect; use as part of multimodal protocol.</td>
</tr>
<tr>
<td>Ketamine*</td>
<td>0.25 mg/kg IV</td>
<td>0.12 mg/kg/hr (2 mic/kg/min)</td>
<td>Add 60 mg to 500 ml LRS &amp; run at 1 ml/kg/hr</td>
<td>Generally combined with opioids; may cause dysphoria.</td>
</tr>
</tbody>
</table>
Lidocaine

0.25 mg/kg IV

1.5 mg/kg/hr (25 mic/kg/min)

Some sources recommend no more than 10 mic/kg/min in cats

Add 750 mg to 500 ml LRS & run at 1 ml/kg/hr

10 mic/kg/min would be 300 mg lidocaine in 500 ml LRS with a rate of 1 ml/kg/hr

750 mg = 37.5 ml, remove 37.5 ml LRS before adding lidocaine; can be combined with opioid &/or ketamine.

Lidocaine MAY be contraindicated in the cat due to cardiovascular effects.

Morphine*/Ketamine*

M: 0.10 mg/kg IM
K: 0.25 mg/kg IV

0.03 mg/kg/hr M & 0.12 mg/kg/hr K

Add 15 mg M & 60 mg K to 500 ml LRS & run at 1 ml/kg/hr

Can be administered up to 3 ml/kg/hr but dysphoria MAY occur. Can substitute hydromorphone or fentanyl for morphine.

Morphine/Ketamine/Lidocaine (MLK)

M: 0.10 mg/kg IM
K: 0.25 mg/kg IV
L: 0.25 mg/kg IV

0.03 mg/kg/hr M, 0.12 mg/kg/hr K; 1.5 mg/kg/hr L

Add 15 mg of M, 60 mg K and 750 mg (or 300 mg) L to 500 mls & run at 1 ml/kg/hr

Can substitute hydromorphone or fentanyl for morphine.

* For morphine, ketamine, and morphine/ketamine infusions, 7.5 mg of morphine and 30 mg of ketamine can be used and the CRI administered at 2+ ml/kg/hr if more fluids are needed.

Table 2. Dosages for constant rate infusions (CRIs) used in dogs

<table>
<thead>
<tr>
<th>Drug</th>
<th>Loading Dose</th>
<th>CRI Dose</th>
<th>Quick Calculation</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morphine*</td>
<td>0.5 mg/kg IM (or 0.25 mg/kg SLOWLY IV)</td>
<td>0.12 mg/kg/hr (2.0 mic/kg/min)</td>
<td>Add 60 mg to 500 ml LRS &amp; run at 1 ml/kg/hr</td>
<td>MAY cause sedation; can be combined with ketamine &amp;/or lidocaine.</td>
</tr>
<tr>
<td>Hydromorphone</td>
<td>0.1 mg/kg IV</td>
<td>0.05 mg/kg/hr</td>
<td>Add 24 mg to 500 ml LRS &amp; run at 1 ml/kg/hr</td>
<td>MAY cause sedation; can be combined with ketamine &amp;/or lidocaine.</td>
</tr>
<tr>
<td>Fentanyl</td>
<td>0.001–0.003 mg/kg IM or IV (1–3 mic/kg IV)</td>
<td>0.0012 -0.005 mg/kg/hr (0.02-0.08 mic/kg/min) (1–5 mic/kg/hr)</td>
<td>Add 0.6 to 2 mg to 500 ml LRS &amp; run at 1 ml/kg/hr</td>
<td>0.6 mg = 12 ml fentanyl, remove 12 ml LRS before adding fentanyl; can be combined with ketamine &amp;/or lidocaine; post-op dose may be higher.</td>
</tr>
<tr>
<td>Butorphanol</td>
<td>0.1 mg/kg IV</td>
<td>0.1-0.2 mg/kg/hr</td>
<td>Add 50 mg to 500 ml LRS &amp; run at 1 ml/kg/hr for 0.1 mg/kg/hr</td>
<td>Only moderately potent &amp; has ceiling effect - use as part of multimodal protocol.</td>
</tr>
<tr>
<td>Ketamine*</td>
<td>0.25 mg/kg IV</td>
<td>0.12 mg/kg/hr (2 mic/kg/min)</td>
<td>Add 60 mg to 500 ml LRS &amp; run at 1 ml/kg/hr</td>
<td>Generally combined with opioids; may cause dysphoria; post-op dose may be higher.</td>
</tr>
<tr>
<td></td>
<td>Dosage</td>
<td>IV Rate (25–50 mc/kg/min)</td>
<td>Add 750 mg to 500 ml LRS &amp; run at 1 ml/kg/hr for 25 mic/kg/min</td>
<td>750 mg = 37.5 ml, remove 37.5 ml LRS before adding lidocaine; can be combined with opioid &amp;/or ketamine.</td>
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</tr>
<tr>
<td><strong>Lidocaine</strong></td>
<td>0.5–1.0 mg/kg IV</td>
<td>1.5–3.0 mg/kg/hr</td>
<td>Add 750 mg to 500 ml LRS &amp; run at 1 ml/kg/hr for 25 mic/kg/min</td>
<td>750 mg = 37.5 ml, remove 37.5 ml LRS before adding lidocaine; can be combined with opioid &amp;/or ketamine.</td>
</tr>
<tr>
<td><em><em>Morphine</em>/Ketamine</em>*</td>
<td>M: 0.5 mg/kg IM, K: 0.25 mg/kg IV</td>
<td>0.12 mg/kg/hr M &amp; 0.12 mg/kg/hr K</td>
<td>Add 60 mg M &amp; 60 mg K to 500 ml LRS &amp; run at 1 ml/kg/hr</td>
<td>Can be administered up to 3 ml/kg/hr but sedation or dysphoria MAY occur. Can substitute hydromorphone or fentanyl for morphine.</td>
</tr>
<tr>
<td><strong>Morphine/Ketamine/Lidocaine (MLK)</strong></td>
<td>M: 0.5 mg/kg IM, K: 0.25 mg/kg IV, L: 0.5 mg/kg IV</td>
<td>0.12 mg/kg/hr M, 0.12 mg/kg/hr K, 1.5 mg/kg/hr L</td>
<td>Add 60 mg of M, 60 mg K and 750 mg L to 500 mls &amp; run at 1 ml/kg/hr</td>
<td>Can substitute hydromorphone or fentanyl for morphine.</td>
</tr>
</tbody>
</table>

* For morphine, ketamine, and morphine/ketamine infusions, 30 mg of morphine and 30 mg of ketamine can be used and the CRI administered at 2+ ml/kg/hr if more fluids are needed.