Module 4

Constant Rate Infusions (CRI)

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Welcome to this course on constant rate infusions (CRI). In this course, we are going to discuss the physiology of pain and pain management and the drugs commonly delivered by CRI. You will also have the chance to create a pain management plan and practice calculating drug doses. Admittedly, some calculations can be difficult, especially for very tiny patients like small mammals. But we have designed this course so that you will not be intimidated by the mathematical calculations necessary for using CRIs. By the conclusion of this course, I hope that you will feel confident enough to talk about using CRIs in your practice or workplace.

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Pain involves an incredibly complicated myriad of physiochemical responses leading to the perception of an unpleasant sensation arising from actual or potential tissue damage. While the full complexities of the pain process are beyond the scope of this discussion, an understanding of the terminology and basic neurophysiology involved is helpful in preventing and treating discomfort in our patients.

TYPES OF PAIN

Acute: Pain that arises from a sudden stimulus, such as surgery or trauma. Occurs with injury, surgery, inflammation, and infection.
Acute pain limits mobility and is temporary.

Chronic: Pain that persists beyond the time normally associated with tissue healing. Occurs with age-related disorders.
Chronic pain is slow to develop and the animal may learn to cope.

PAIN CLASSIFICAIONS

Physiologic /adaptive: Physiologic pain refers to the body's protective mechanism to avoid tissue injury. It protects the body from further injury and inflammation. An example is the pain produced from an incision or a fracture.

Pathologic/maladaptive: Pathologic pain arises from tissue injury and inflammation, or from damage to a portion of the nervous system.
This pain persists after the stimulus has been removed and can occur due to in appropriately managed adaptive pain.

PATHOLOGIC PAIN DEFINITIONS

Nociceptive: occurs in peripheral tissue injury

Neuropathic: damage to peripheral nerves or spinal cord

Visceral: stimulation of pain receptors in the thoracic or abdominal viscera

Somatic: injury to tissues other than viscera, such as bones, joints, muscles, and skin

FACTORS AFFECTING PAIN

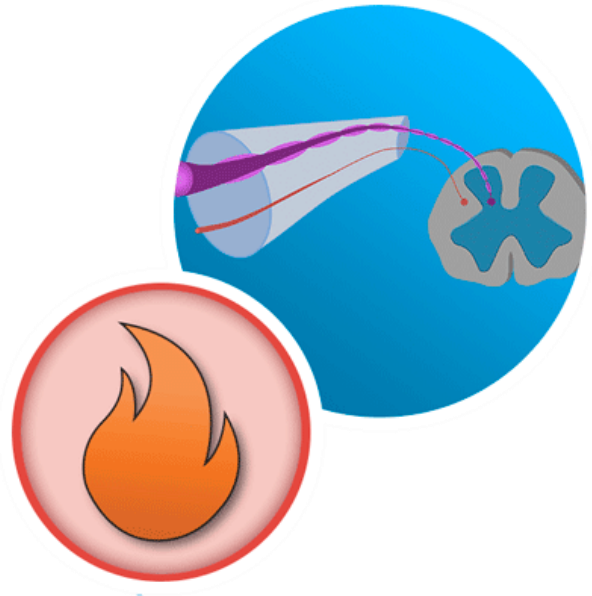
Stress can exacerbate pain through modification of the nervous system in response to tension. Stress can be a result of pain from surgery or trauma, it can be due to external stressors like severe weather, a trip to the veterinarian, or the owner leaving on vacation, or stress can be caused by the physiologic changes that result from a disease process, such as diabetes or cancer.

Anxiety can lead to distress, which is an aversive state in which an animal is unable to adapt completely to stressors. Their resulting stress shows maladaptive behaviors, such as inappropriate urination or destructive, self-mutilating behaviors.

Wind-up is the perceived in crease in pain intensity over time when a given stimulus is delivered repeatedly above a critical rate. Examples include the dachshund with disk disease that cries out in pain when any part of its body is touched, the cocker spaniel with a chronic ear infection that can no longer tolerate normal petting, or the cat with continual degenerative joint disease pain that can no longer tolerate being brushed.

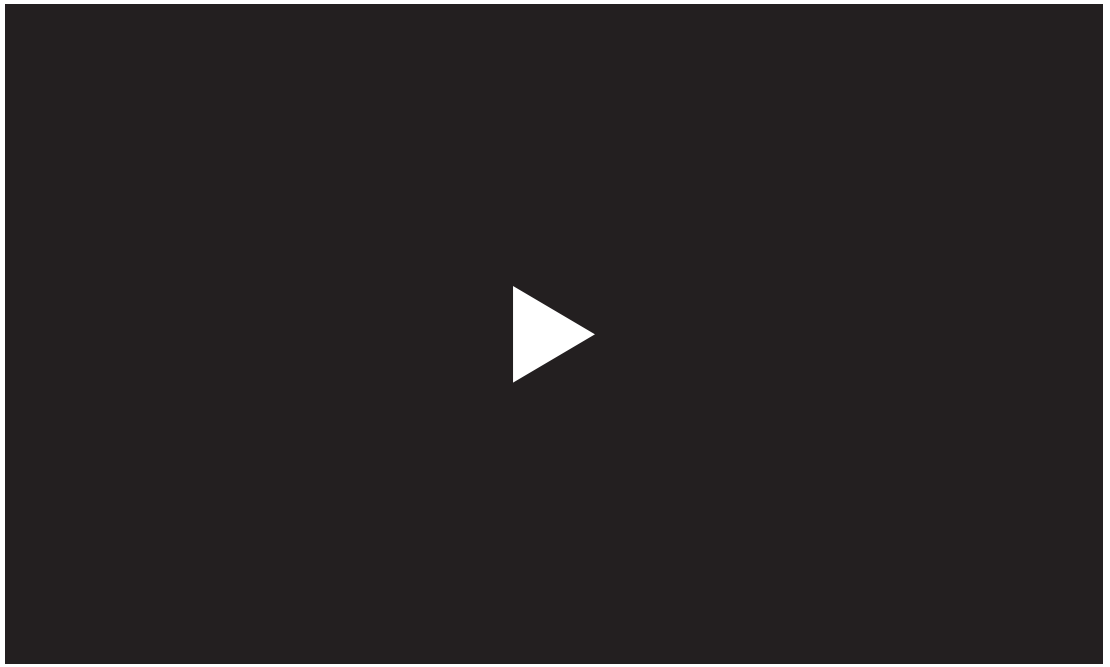
Central sensitization refers to an increase in the excitability of spinal neurons, mediated in part by the activation of N-methyl-D-aspartate (NMDA) receptors in dorsal horn neurons. The net effect is expanded receptor fields, which causes pain in neighboring areas not subjected to injury (secondary hyperalgesia) and painful responses to normally innocuous stimuli (allodynia).

To help define pain, you need to understand the language. The activity in the nervous system produced by a painful situation is called nociception. Nociception is essentially the pathway that pain takes on its way to the brain. It is composed of four elements: transduction, transmission, modulation, and perception. Knowledge of this pathway is important because it can help us determine the best treatment options for a patient.



Module 4-1

Pain Pathway



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Preemptive analgesia is pain medication given in anticipation of pain (before the painful stimulus occurs), which can decrease the intensity and duration of post-operative pain and minimize the likelihood of a chronic pain state. By administering analgesics prior to insult, the spinal cord is not bombarded by impulses that induce changes that can lead to central sensitization.

Multimodal (or balanced) analgesia is the strategy of combining two or more analgesic drugs to achieve an additive or synergistic effect, which reduces the individual drug doses (lowering the risk of side effects). This works best when each drug has a different mechanism of action (blocks a different portion of the pain pathway).

A combination of preemptive and multimodal analgesia has distinct advantages. It offers more complete analgesia, suppresses the stress response, decreases formation of a chronic pain state, and shortens recovery time. It also requires lower doses of drugs, which decreases unwanted side effects. Ultimately, this results in healthier patients, as well as happier staff and owners.

The best way to control pain is to treat it along multiple points of the pain pathway.

Transduction

NSAIDs - carprofen, meloxicam, robenacoxib, etc.
Opioids – morphine, hydromorphine, etc.
Local anesthetic – lidocaine, bupivacaine
Corticosteroids – dexamethasone, depo-Medrol, prednisone, etc.

Transmission

Local anesthetic - lidocaine, bupivacaine
Alpha-2 agonists - dexmedetomidine, xylazine

Modulation

Local anesthetic - lidocaine, bupivacaine
NSAIDs - carprofen, meloxicam, robenacoxib, etc.
Opioids - morphine, hydromorphine, etc.
Alpha-2 agonists - dexmedetomidine, xylazine
NMDA antagonists - ketamine, amantadine
Tricyclic antidepressants - amitriptyline
Anticonvulsants – gabapentin

Perception

Opioids - morphine, hydromorphine, etc
Alpha-2 agonists - dexmedetomidine, xylazine
General anesthetics - isoflurane, sevoflurane
Benzodiazepines - diazepam, midazolam
Phenothiazines - acepromazine

Based only on their effect on the pain pathway, which of the following drug combinations would be best for modulating pain?

- ○ Carprofen and dexamethasone
- ○ Morphine and fentanyl
- ○ Carprofen and dexamedetomidine
- ○ Acepromazine and gabapentin

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- ○ Acepromazine and gabapentin

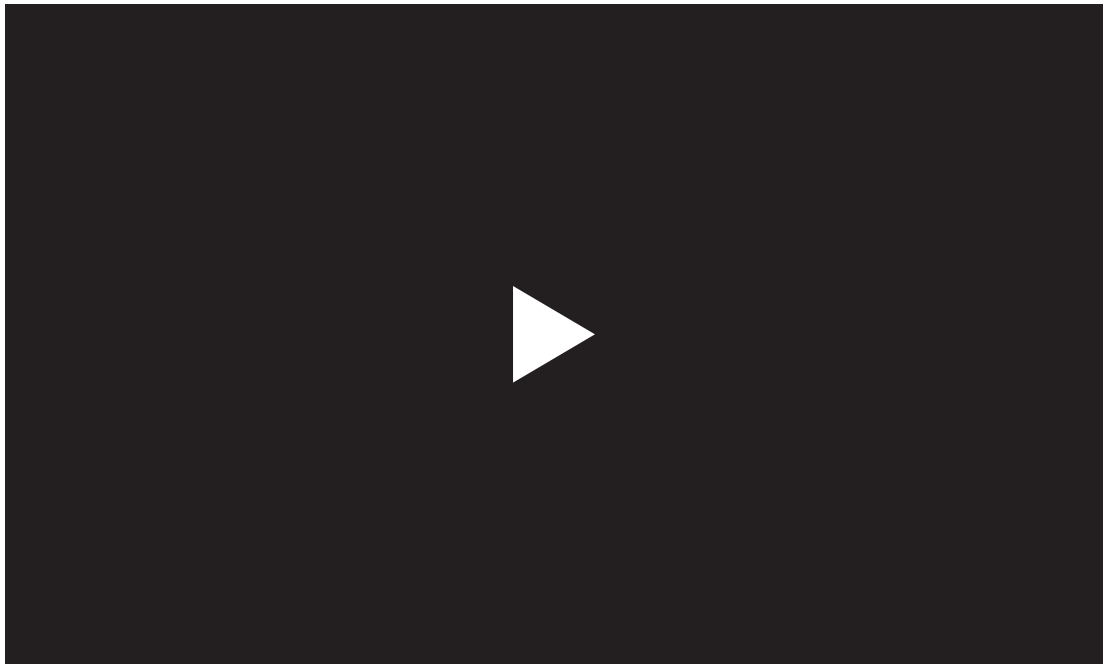
A simple CRI can be created just by adding analgesic drugs to a bag of intravenous (IV) fluids. CRIs can be used for pre-, intra-, and postoperative pain, as well as medical pain. Many drug options are available, so doctors can choose their favorites. They are cost effective and can be utilized in any practice.

For maximum patient comfort and pain control, it is important to administer drugs before, during, and after a painful stimulus. Decreasing pain and stress can have a profound effect on patients' physiologic and psychologic outcomes. *To learn more about the advantages of CRIs, click/tap the first video.*

While CRI management requires 24-hour monitoring and specialized knowledge by the veterinary staff, the ability to maintain medications at therapeutic levels at all times make CRIs worth the time and knowledge.

Module 4-2

Nursing Concerns



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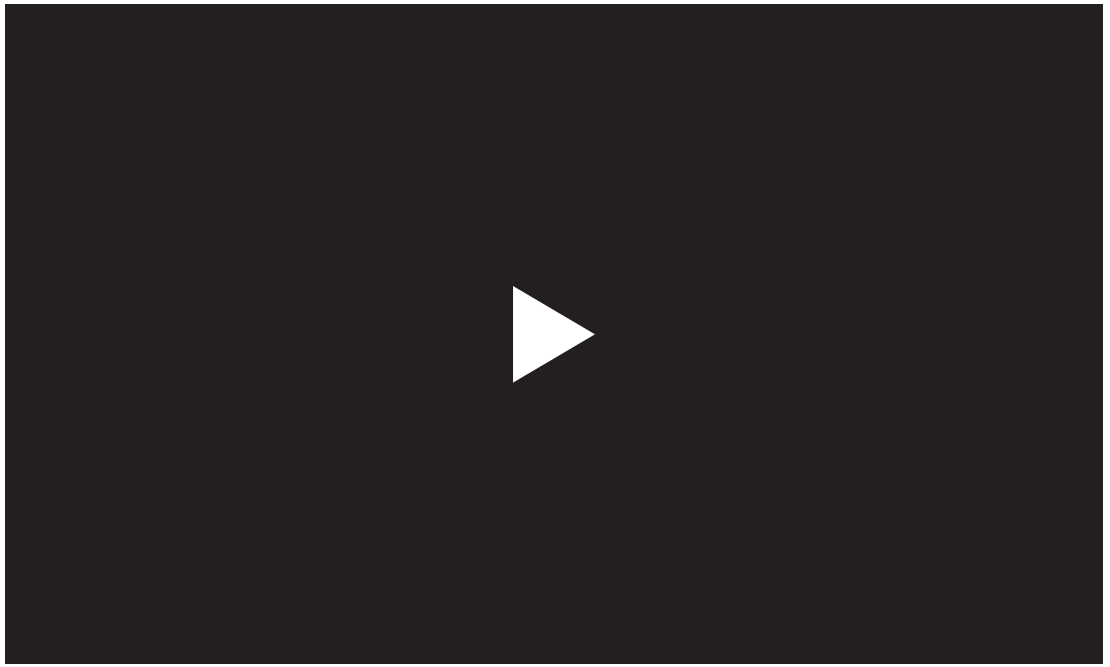
Module 4-3

CRI Advantages



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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 and ketamine or opioids, ketamine, and lidocaine.

Opioids

Morphine

- Commonly used alone or in combination with ketamine ± lidocaine.
- Caution with use in cats. Morphine CRIs are not commonly administered alone to cats when awake due to the likelihood of causing dysphoria and excitation.
- Morphine is sensitive to light. The syringe or fluid bag should be covered when using a morphine CRI long term.
- Dilution: add 15 mg (1 mL) to 9 mL NaCl → 5 mg/mL or add 30 mg (2 mL) to 8 mL NaCl → 3 mg/mL.
- Loading dosage: 0.1–0.2 mg/kg IV (very slowly) given prior to start of CRI if no other μ-agonist opioid has been administered.
- CRI rate: 2-6 μg/kg/min (0.1–0.3 mg/kg/h).

Hydromorphone

- Can be used alone or in combination with ketamine ± lidocaine.
- Does not cause histamine release.
- Dilution: add 2 mg (1 mL) to 9 mL NaCl → 0.2 mg/mL.
- Loading dosage: 0.03–0.05 mg/kg given prior to starting the CRI if no other μ-agonist opioid has been administered.
- CRI rate: 0.1–0.8 μg/kg/min.

Fentanyl

- Commonly used in a CRI as the sole agent or can be combined with ketamine ± lidocaine.
- A single IV bolus will only last approximately 20–30 minutes.
- Fentanyl has a context sensitive half-life. When used as a CRI for greater than 2 hours, the drug will start to accumulate in the tissues. Once accumulation has occurred, the plasma concentration does not decrease rapidly once the CRI is discontinued. To prevent a prolonged recovery, it may be beneficial to decrease the fentanyl CRI and/or make adjustments to the vaporizer about 30–40 minutes prior to the end of surgery. The effects tend to last much longer in cats compared to dogs.
- Extremely high dosages may depress ventilation and cause bradycardia.
- No dilution of drug necessary if using a syringe pump.
- Loading dosage: 1–5 μg/kg IV given prior to the start of the CRI if no other μ-agonist opioid has been administered.
- CRI rate: 0.1–0.7 μg/kg/min (6-42 μg/kg/h). Recommended to start with 0.1 μg/kg/min and adjust the dosage up depending on patient response to surgical stimulus.
- CRI rate (post-op): 0.03–0.05 μg/kg/min (2–3 μg/kg/h).

Remifentanil

- Commonly used alone in a CRI or can be combined with ketamine ± lidocaine.
- Metabolized by nonspecific plasm esterases to inactive metabolites. This makes remifentanil superior to fentanyl for patients with renal or hepatic dysfunction.
- Rapid onset of action and short duration of action.
- Non-cumulative effects within the body, so recovery is rapid after CRI is discontinued.
- Extremely high dosages may cause profound sedation, respiratory depression, and bradycardia.
- Supplied as 1 mg of powder that must be reconstituted with sterile saline prior to use. Commonly reconstituted to 50 µg/mL or 100 µg/mL.
- Loading dosage: 1–5 µg/kg IV given prior to starting the CRI if no other µ-agonist opioid has been administered.
- CRI rate: 0.1–0.7 µg/kg/min.

Methadone (10 mg/mL)

- Can be used alone or in combination with ketamine ± lidocaine.
- Also acts as an NMDA receptor antagonist to help treat and prevent central sensitization.
- Dilution: add 10 mg (1 mL) to 9mL NaCl → 1 mg/mL.
- Loading dosage: 0.1–0.5 mg/kg IV given prior to starting the CRI if no other µ-agonist opioid has been administered.
- CRI rate: 0.05-2

Lidocaine

- Minimum Alveolar Concentration (MAC) sparing effect on inhalants and analgesic effects when administered as a CRI intra-op.
- Classified as a sodium channel blocker and a class IB antiarrhythmic.
- Displays free radial scavenging effects, which may be helpful at preventing reperfusion injury.
- Acts as an inflammatory modulator by decreasing neutrophil chemotaxis and platelet aggregation.
- Prokinetic that enhances gut motility and helps prevent ileus.
- NOT recommended for use in cats due to its potential for toxicity. If used, do not exceed a dosage of 10 µg/kg/min and monitor closely for seizure activity and bradycardia.
- Commonly used as a first-line treatment for ventricular premature complexes (VPCs) or ventricular tachycardia.
- Some brands of lidocaine are sensitive to light. If lidocaine comes in a brown bottle, the syringe or fluid bag containing the lidocaine should be covered when used as a CRI long term.
- Loading dosage: 1–2 mg/kg should be given prior to starting CRI.
- CRI rate: 25–75 µg/kg/min.

Ketamine

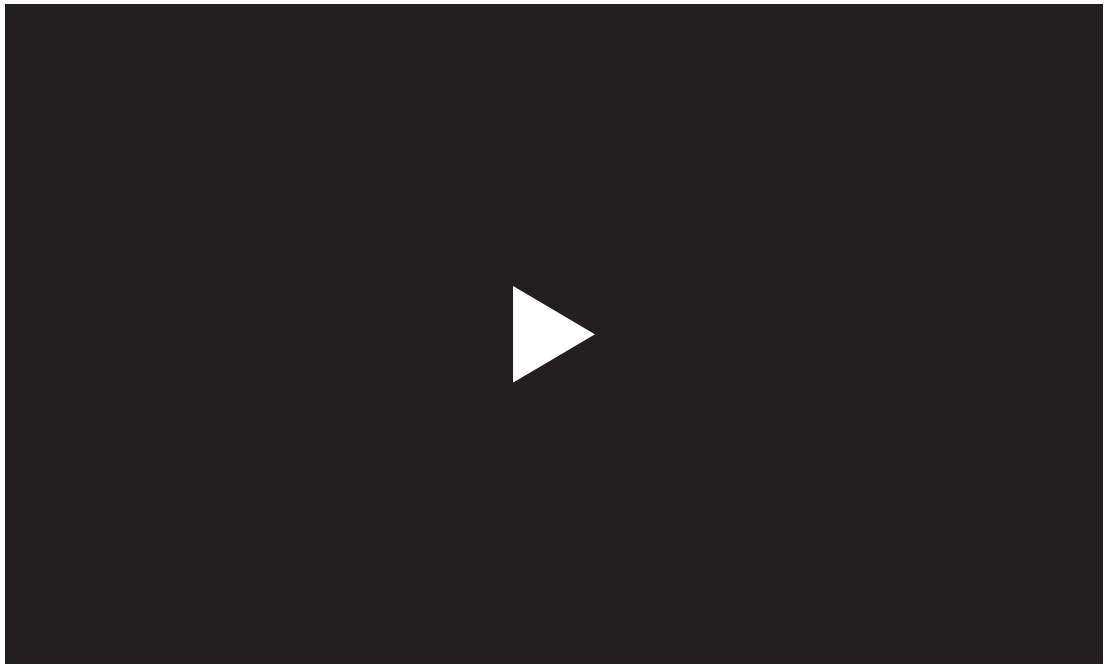
- Classified as an NMDA receptor antagonist that effectively blocks central sensitization from occurring in the dorsal horn of the spinal cord and helps prevent hyperalgesia and allodynia.
- Does not have any direct analgesic effects but is used as an adjunct to other analgesic drugs, such as opioids. It may help improve opioid receptor sensitivity. DO NOT use ketamine as the sole analgesic agent.
- Dosages for the CRI are given at sub-anesthetic levels so no dissociative effects are seen during CRI administration.
- Starting a ketamine CRI prior to a painful stimulus will provide best means of preventing CNS sensitization, but it is still effective in patients that present with established pain.
- Loading dosage: 0.5 mg/kg IV should be given prior to starting CRI in order to achieve initial therapeutic blood levels. Induction with ketamine/diazepam or Telazol will provide an effective loading dose.
- CRI rate (intra-op): 10-20 µg/kg/min.
- CRI rate (post-op): 2-10 µg/kg/min for at least 24 hours.

Before beginning a CRI, loading doses of the drugs to be used should be given intravenously or intramuscularly to get serum concentrations to a therapeutic level so that the CRI has immediate benefit. The loading doses can be given as part of the patient's premedication (e.g., an opioid) or as an induction agent (e.g., ketamine). A drug in the same class as the agent to be used in the CRI may be substituted for the loading dose. For example, morphine and fentanyl are both μ-opioids. If fentanyl is to be incorporated in the CRI, morphine can be given as a premedication.

There are two main methods of administering the infusions: (1) use of syringe pump and (2) the "bag" technique, which involves adding the drug(s) to the bag of crystalloid and administering it as maintenance fluid, in most cases.

Module 4-4

Starting a Constant Rate Infusion



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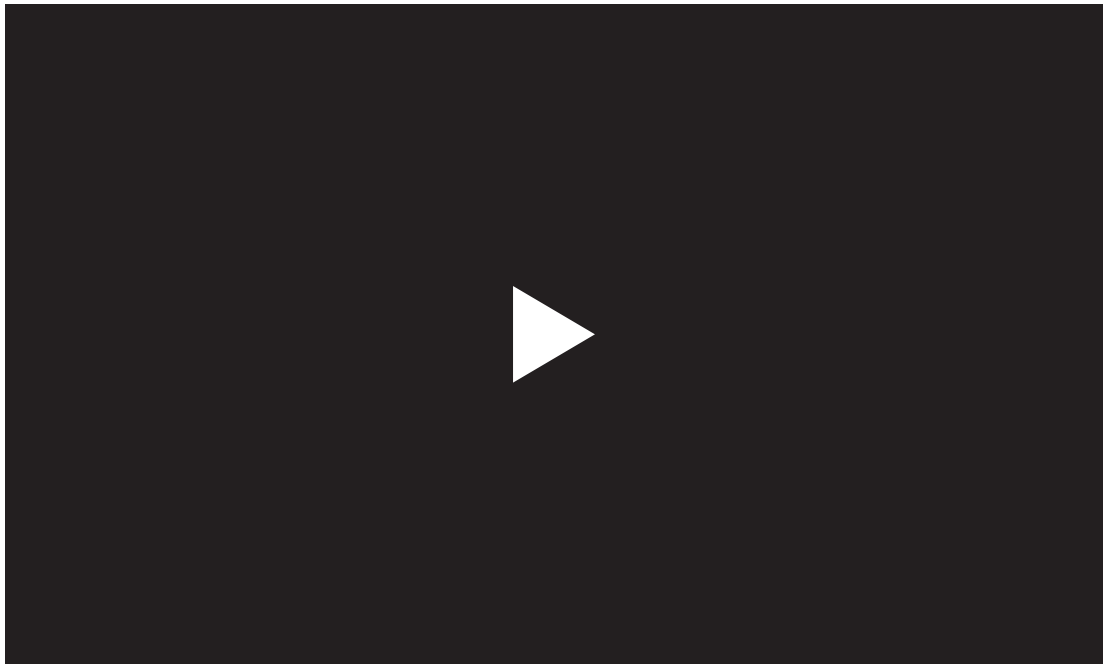
Generally, dosing tables or individualized spread sheets should be used for constant rate infusions. These sheets greatly improve the speed at which CRIs can be initiated and greatly decrease the chance of mathematical errors. The Veterinary Anesthesia & Analgesia Support Group (www.vasg.org), for example, has a number of spreadsheets available.

Module 4-5

Calculations for Doses



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CRI doses can be calculated using the formula:

$$\frac{A \times B \times C \times D}{E \times F \times G} = \text{mL of drug to add to fluid volume}$$

A: desired dosage rate
(e.g. µg/kg/min, µg/kg/h, mg/kg/h)

B: dosage units adjustment
if the dosage is mg/kg/h, enter 1
if µg/kg/min, enter 0.06
if µg/kg/h, enter 0.001

C: body weight (kg)

D: desired total CRI volume (mL)

E: rate of infusion (mL/h)

F: concentration of drug (mg/mL or µg/mL)

G: concentration units adjustment
if the concentration is mg/mL, enter 1
if µg/mL, enter 0.001

Calculate how many mL of morphine are needed to add to a 500-mL bag of LRS at a dose rate of 0.18 mg/kg/h for a 30-kg dog at a fluid rate of 10 mL/h (morphine concentration, 15 mg/mL).

- ○ Morphine 0.018 mL
- ○ Morphine 8.2 mL
- ○ Morphine 18 mL
- ○ Morphine 36 mL

Calculate how many mL of morphine are needed to add to a 500-mL bag of LRS at a dose rate of 0.18 mg/kg/h for a 30-kg dog at a fluid rate of 10 mL/h (morphine concentration, 15 mg/mL).

- ○ Morphine 0.018 mL
- ○ Morphine 8.2 mL
- ○ Morphine 18 mL
- ○ Morphine 36 mL

Calculate how many mL of hydromorphone are needed to add to a burette (150 mL) at a dosage of 0.3 μg/kg/min for a 7-kg cat at a fluid rate of 15 mL/h (hydromorphone concentration, 2.0 mg/mL).

- ○ Morphine 0.63 mL
- ○ Morphine 1.39 mL
- ○ Morphine 10.5 mL
- ○ Morphine 175 mL

Calculate how many mL of hydromorphone are needed to add to a burette (150 mL) at a dosage of 0.3 μg/kg/min for a 7-kg cat at a fluid rate of 15 mL/h (hydromorphone concentration, 2.0 mg/mL).

- ○ Morphine 0.63 mL
- ○ Morphine 1.39 mL
- ○ Morphine 10.5 mL
- ○ Morphine 175 mL

Calculate how much lidocaine is needed to add to a 250-mL bag of LRS at a dosage of 25 μg/kg/min for a 77-pound dog at a fluid rate of 15 mL/h (lidocaine concentration, 20 mg/mL).

- ○ Lidocaine 3.3 mL
- ○ Lidocaine 4.4 mL
- ○ Lidocaine 33.1 mL
- ○ Lidocaine 43.75 mL

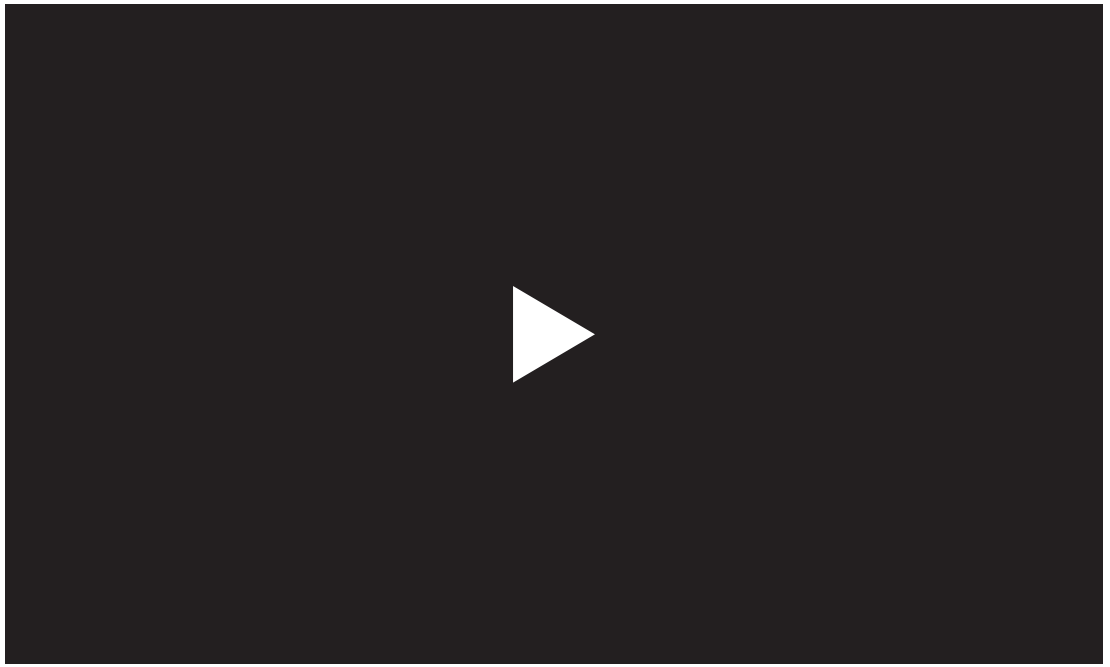
Calculate how much lidocaine is needed to add to a 250-mL bag of LRS at a dosage of 25 μg/kg/min for a 77-pound dog at a fluid rate of 15 mL/h (lidocaine concentration, 20 mg/mL).

- ○ Lidocaine 3.3 mL
- ○ Lidocaine 4.4 mL
- ○ Lidocaine 33.1 mL
- ○ Lidocaine 43.75 mL

If you are not the person who performed the initial calculations to figure out how much drug to add to a fluid bag, the label might only provide the fluid rate (mL/h). In this case, you will want to determine drug dosage (μg/kg/h, μg/kg/min, mg/kg/h) was used to make up the CRI.

Module 4-6

Calculations for CRI Dosages



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CRI dosages can be calculated using the formula:

$$\frac{E \times F \times G \times H}{B \times C \times D} = \text{drug dosage}$$

B: desired drug dosage units
- if the desired dosage units are mg/kg/h, enter 1
- if µg/kg/min, enter 0.06
- if µg/kg/h, enter 0.001

C: body weight (kg)

D: desired total CRI volume (mL)

E: rate of infusion (mL/h)

F: concentration of drug (mg/mL or µg/mL)

G: concentration units adjustment
- if the concentration is mg/mL, enter 1
- if µg/mL, enter 0.001

H: mL of drug added to fluid volume

Calculate the dosage (in mg/kg/h) of morphine administered in a 500-mL bag of LRS for a 30-kg dog at a fluid rate of 10 mL/h, if 18 mL was added to the bag (morphine concentration, 15 mg/mL).

- ○ Morphine 0.18 mg/kg/h
- ○ Morphine 0.36 mg/kg/h
- ○ Morphine 1.8 mg/kg/h
- ○ Morphine 3.6 mg/kg/h

Calculate the dosage (in mg/kg/h) of morphine administered in a 500-mL bag of LRS for a 30-kg dog at a fluid rate of 10 mL/h, if 18 mL was added to the bag (morphine concentration, 15 mg/mL).

- ○ Morphine 0.18 mg/kg/h
- ○ Morphine 0.36 mg/kg/h
- ○ Morphine 1.8 mg/kg/h
- ○ Morphine 3.6 mg/kg/h

Calculate the dosage (in μg/kg/min) of hydromorphone administered in a burette (150 mL) for a 10-kg cat at a fluid rate of 18 mL/h, if 0.8 mL was added to the bag (hydromorphone concentration, 2.0 mg/mL).

- ○ Hydromorphone 0.3 μg/kg/h
- ○ Hydromorphone 0.6 μg/kg/h
- ○ Hydromorphone 0.9 μg/kg/h
- ○ Hydromorphone 1.2 μg/kg/h

Calculate the dosage (in µg/kg/min) of hydromorphone administered in a burette (150 mL) for a 10-kg cat at a fluid rate of 18 mL/h, if 0.8 mL was added to the bag (hydromorphone concentration, 2.0 mg/mL).

- ○ Hydromorphone 0.3 µg/kg/h
- ○ Hydromorphone 0.6 µg/kg/h
- ○ Hydromorphone 0.9 µg/kg/h
- ○ Hydromorphone 1.2 µg/kg/h

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 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.

ANALGESIA DROP BY DROP: CONSTANT RATE INFUSIONS MADE EASY ANESTHESIA

Tamara Grubb, DVM, MS, DACVA

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 5 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 vasg.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:

CRI formula

A = desired dose µg/kg/min
B = body weight (kg)
C = drip set (drops/ml)
D = desired diluent volume (ml)
E = desired drops/min
F = concentration of drug (mg/ml)

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

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

Drug	Loading Dose	CRI Dose	Quick Calculation	Comment
Morphine*	0.10 mg/kg IM	0.03 mg/kg/hr (0.5 mic/kg/min)	Add 15 mg to 500 ml LRS & run at 1 ml/kg/hr	Cat may need light sedation; can be combined with ketamine &/or lidocaine.
Hydromorphone	0.05 mg/kg IV	0.012 mg/kg/hr	Add 6 mg to 500 ml LRS & run at 1 ml/kg/hr	May cause hyperthermia; can be combined with ketamine &/or lidocaine.
Fentanyl	0.001–0.003 mg/kg IM or IV (1–3 mic/kg IV)	0.0012 mg/kg/hr (0.02 mic/kg/min) (1–2 mic/kg/hr)	Add 0.6 mg to 500 ml LRS & run at 1 ml/kg/hr	0.6 mg = 12 ml fentanyl, remove 12 ml LRS before adding fentanyl; can be combined with ketamine &/or lidocaine.
Butorphanol	0.1 mg/kg IV	0.1–0.2 mg/kg/hr	Add 50 mg to 500 ml LRS & run at 1 ml/kg/hr for 0.1 mg/kg/hr	Only moderately potent & has ceiling effect; use as part of multimodal protocol.
Ketamine*	0.25 mg/kg IV	0.12 mg/kg/hr (2 mic/kg/min)	Add 60 mg to 500 ml LRS & run at 1 ml/kg/hr	Generally combined with opioids; may cause dysphoria.
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 a t 1ml/kg/hr 10 mic/kg/min would be 300 mg lidocai-ne in 500 ml LR S with a rate of 1 mlkg/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 & 60mg 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

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

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Question 1

Which of the following terms is correctly described by the following: “Exaggerated response to a painful stimulus”

- ○ Hyperesthesia
- ○ Hyperalgesia
- ○ Central sensitization
- ○ Wind-up

Question 2

Place the four steps of the pain pathway in the proper order:

- ○ Transduction, Transmission, Modulation, Perception
- ○ Transmission, Transduction, Perception, Modulation
- ○ Perception, Transduction, Transmission, Modulation
- ○ Modulation, Perception, Transmission, Transduction

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Question 3

Multimodal analgesia is most effective when each drug used affects a different part of the pain pathway.

○ True

○ False

Question 4

Which of the following is TRUE?

○ Drugs that are incompatible cannot be placed into the same IV bag, but can be combined in the same syringe for CRIs.

○ Administering multiple injections for pain relief at regular intervals eliminates the “peak and valley” of analgesia.

○ To increase the dosage of a drug with a syringe pump, you must also increase the fluid rate.

○ CRI use can lower gas anesthetic needs by providing continuous analgesia.

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Question 5

When adding a drug to a fluid bag, you should add the drug first and then remove the same volume of fluid from the bag.

○ True

○ False

Question 6

Calculate how many mL of morphine are needed to add to a 250-mL bag of LRS at a dose rate of 0.2 mg/kg/h for a 10-kg dog at a fluid rate of 10 mL/h (morphine concentration, 15 mg/mL).

○ 0.3 mL morphine

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