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Constant-Rate Infusions:
Practical Use

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Overview

In recent years, delivery of drugs with CRI has become fairly routine in critical care referral practices and in veterinary teaching hospitals. Despite advances in technology allowing for more accurate administration of fluids through intravenous fluid pumps, many veterinarians continue to avoid use of CRI.

Several cardiac and vasoactive drugs have potent hemodynamic effects that can markedly affect the outcome of critically ill veterinary patients. Drugs that have a rapid onset of action and a short half-life are ideal for CRI delivery because the veterinarian can provide a continuous, steady-state concentration of the drug and titrate it to the desired effect. The CRI method is also an excellent way to deliver analgesic agents because it eliminates the peak and trough effects that occur with intermittent dosing.

Why It's Avoided

There seem to be three reasons why many veterinarians avoid CRI. First, the mathematics used to calculate dosages can be intimidating, especially when miscalculations can be fatal. Second, because many of the drugs administered via CRI are relatively new, veterinarians may have little experience in their use. Finally, proper administration of CRI drugs ideally involves the use of specialized equipment, such as infusion pumps and blood pressure monitors. Although lacking in many practices, these items are readily available and have become more affordable for the average veterinarian.

The purpose of this article is to provide some user-friendly formulas and to simplify the calculations needed to administer drugs via CRI. (Numbers in answers are rounded as appropriate.) While it should provide the groundwork needed to start administering drugs with CRI, acquiring the necessary equipment and gaining the confidence and experience needed to use these drugs is the responsibility of the veterinarian.

CRI=constant-rate infusion

How to Calculate Dosages*

Formula 1

By convention, the dosage for many CRI drugs is given as **μg/kg/min**. The calculations can be confusing since most drugs are available in concentrations of **mg/ml** and are delivered at a fluid rate of **ml/hr**. The following formula allows the clinician to "plug in" the numbers and solve for the number of milligrams of drug to add to the base solution.

$$M = \frac{(D)\,(W)\,(V)}{(R)\,(16.67)} \qquad OR \qquad R = \frac{(D)\,(W)\,(V)}{(M)\,(16.67)}$$

M = number of mg of drug to add to base solution
D = dosage of drug in μg/kg/min
W = body weight in kg
V = volume in ml of base solution
R = rate of delivery in ml/hr
16.67 = conversion factor

Case Example 1: *A 6-year-old, 28-kg, male Doberman pinscher presents with severe, left-sided heart failure and pulmonary edema due to dilated cardiomyopathy. After treatment with furosemide (2 mg/kg IV) and oxygen, the pulse remains weak and perfusion is poor. Dobutamine, at a dosage of 15 μg/kg/min, is chosen to provide immediate positive inotropic effects. Because the dog has pulmonary edema, a low fluid rate of 10 ml/hr is chosen to administer the drug. The drug was to be added to 100 ml of 5% dextrose solution, because high-sodium fluids should be avoided in patients with congestive heart failure.*

* Answers have been rounded as appropriate.

Drugs Commonly Administered by CRI

Drug	Actions/Indication	Dosage
Atracurium besylate 10 mg/ml	Paralytic agent used for mechanical ventilation	0.3–0.5 mg/kg IV loading dose, then 4–9 μg/kg/min
Butorphanol 10 mg/ml	Analgesic for mild to moderate pain	Loading dose 0.2–0.4 mg/kg IV, then 0.1–0.2 mg/kg/hr
Diazepam 5 mg/ml	Seizure control	4–16 μg/kg/min (0.2 mg/kg/hr)
Diltiazem 5 mg/ml	Calcium-channel blocker for supraventricular tachyarrhythmias	0.15–0.25 mg/kg IV over 2 min, then 1–8 μg/kg/min
Dobutamine 12.5 mg/ml	Positive inotrope for cardiogenic or septic shock	5–20 μg/kg/min Cats: 2–5 μg/kg/min
Dopamine (low-dose) 40, 80, or 160 mg/ml	Dilates renal arteries, increases renal blood flow	1–3 μg/kg/min
Dopamine (middle dose) 40, 80, or 160 mg/ml	Positive inotrope for cardiogenic or septic shock	4–6 μg/kg/min
Dopamine (high dose) 40, 80, or 160 mg/ml	Pressor agent, promotes peripheral vasoconstriction, increases blood pressure	7–20 μg/kg/min
Epinephrine 1 mg/ml or 0.1 mg/ml	Anaphylaxis, cardiac and blood pressure support	0.025–0.3 μg/kg/min
Esmolol 10 mg/ml	Short-acting β-blocker to slow heart rate and decrease blood pressure (supraventricular tachycardia)	0.05–0.1 mg/kg IV, then 50–200 μg/kg/min
Fentanyl 0.05 mg/ml	Analgesic for moderate to severe pain	Loading dose of 0.003 mg/kg IV, then Dogs: 0.002–0.005 mg/kg/hr Cats: 0.001–0.0025 mg/kg/hr
Furosemide 10 mg/ml	Diuretic, promotes diuresis in acute oliguric renal failure	3–8 μg/kg/min
Heparin 1000 U/ml	Prevention of thrombosis, disseminated intravascular coagulopathy	80 IU/kg IV bolus, then 18 IU/kg/hr; check partial thromboplastin time Q 6 H and adjust to 1.5–2.0 × baseline partial thromboplastin time
Insulin (regular) 100 U/ml	Ketoacidotic diabetes	0.1 U/kg/hr
Isoproterenol 0.2 mg/ml	Vasodilator, positive inotrope, bronchodilator	0.01–0.1 μg/kg/min.

$$M = \frac{(15 \ \mu g) \ (28 \ kg) \ (100 \ ml)}{(10) \ (16.67)} = 250 \ mg$$

Dobutamine is available as a concentration of 12.5 mg/ml (**see Table**).

$$250 \ mg \div 12.5 \ mg/ml = 20 \ ml$$

Twenty ml of dobutamine are added to 80 ml 5% dextrose solution to make a total volume of 100 ml administered at 10 ml/hr.

To illustrate how Formula 1 can be used to adjust the dosage based on clinical signs, consider the following problem:
The dog develops tachycardia when dobutamine is administered at a dosage of 15 μg/kg/min. The dosage can be decreased to 10 mg/kg/min, and we can solve for R to determine the rate adjustment necessary to deliver the drug at the reduced dosage.

$$R = \frac{(D) \ (W) \ (V)}{(M) \ (16.67)} = \frac{(10) \ (28) \ (100)}{(250) \ (16.67)} = 7$$

The fluid rate is decreased to 7 ml/hr.

Formula 2

A quick-and-easy formula that allows the clinician to convert directly from the drug dosage in μg/kg/min to mg requires that a standard volume of 250 ml be administered at a standard rate of 15 ml/hr.

Drug dosage (μg/kg/min) × BW (kg) = no. mg to add to 250 ml base solution at a rate of 15ml/hr

Ketamine 100 mg/ml	Adjunctive agent to add to opioids to increase analgesia	Loading dose 0.3–0.5 mg/kg IV, then 0.3 mg/kg/hr (up to 1.2 mg/kg/hr if needed)
Lidocaine 20 mg/ml	Ventricular antiarrhythmic, adjunctive agent to add to opioids for multimodal analgesia	Dogs: 2–4 mg/kg IV bolus, then 25–80 μg/kg/min Cats: 0.25–0.75 mg/kg slow IV, then 10–40 μg/kg/min
Magnesium sulfate, 12.5% mEq/ml	Refractory ventricular arrhythmias in critically ill patients	0.15 to 0.3 mEq/kg over 5–15 min, then 0.75–1 mEq/kg/day
Medetomidine 1.0 mg/ml	Adjunctive agent to add to opioids to increase analgesia and sedation	Loading dose 1 μg/kg IV (if immediate calming required), then 0.0015 mg/kg/hr
Metoclopramide 5 mg/ml	Antiemetic	1–2 mg/kg/day (0.16–1.3 μg/kg/min)
Morphine sulfate 15 mg/ml	Analgesic for moderate to severe pain	Loading dose 0.2 mg/kg IM, then Dogs: 0.1–0.5 mg/kg/hr Cats: 0.05–0.1 mg/kg/hr
Nitroprusside 10 or 25 mg/ml	Vasodilator, acute congestive heart failure	1–10 μg/kg/min (start at 2 μg/kg/min and raise Q 20 min by 1 μg/kg/min to desired effect)
Norepinephrine 1 mg/ml	Pressor agent, short-term blood pressure support	0.5–2 μg/kg/min
Pancuronium 1 or 2 mg/m	Paralytic agent used for mechanical ventilation	0.06–0.15 mg/kg IV, then 0.2–2.5 μg/kg/min
Pentobarbital 50 mg/ml	To induce coma for uncontrollable seizures, mechanical ventilation	2–15 mg/kg IV to effect, then 0.2–1.0 mg/kg/hr
Phenylephrine 10 mg/ml	Vasopressor agent for refractory hypotension	5–20 μg/kg IV Q 10–15 min PRN, then 0.1–0.5 μg/kg/min
Procainamide 100 mg/ml	Ventricular antiarrhythmic	6–8 mg/kg IV over 5 min, then 10–40 μg/kg/min
Propofol 10 mg/ml	Short-acting barbiturate anesthetic agent; CRI used for mechanical ventilation or seizure control	4–6 mg/kg slow IV, then 100–400 μg/kg/min
Vasopressin 20 U/ml	Refractory hypotension	0.001–0.004 U/kg/min
Verapamil 2.5 mg/ml	Supraventricular arrhythmias, tachycardias	0.05–0.15 mg/kg IV, then 2–10 μg/kg/min

Case Example 2: *A 30-kg dog in septic shock has a blood pressure of 60/40 mm Hg that has not improved with fluid resuscitation. You decide to try to increase the pressure with a pressor dose of dopamine at 10 µg/kg/min.*

$$(10 \text{ µg}) (30 \text{ kg}) = 300 \text{ mg dopamine}$$
added to 250 ml at 15 ml/hr

Dopamine is available as a 40 mg/ml solution, so 7.5 ml (300/40) is added to 250 ml base solution. This formula could be manipulated further by multiplying by 2 to determine how many mg to add to 500 ml or by 0.4 to determine how much to add to 100 ml.

Formula 3

Some drugs, including many analgesic agents, are given in a dosage of mg/kg/hr. For these drugs, the easiest way to calculate the daily dose is to administer in a 250-ml fluid bag at 10 ml/hr. At this rate, the CRI will last for 25 hours. Note that most analgesic agents require a loading dose before CRI is begun.

$$\frac{\text{Dose (mg/kg/hr)} \times \text{BW(kg)} \times 25 \text{ hr}}{\text{Drug (mg/ml)}} = \text{no. of ml drug to add to 250 ml base at 10 ml/hr}$$

Case Example 3: *A 20-kg dog is placed on a morphine drip for postoperative analgesia. Following a loading dose of 0.2 mg/kg IM, the dog is placed on CRI at a dosage of 0.2 mg/kg/hr.*

$$\frac{(0.2 \text{ mg}) (20 \text{ kg}) (25 \text{ hr})}{15 \text{ mg/ml}} = 6.7 \text{ ml added to 250 ml base at 10 ml/hr (will provide continuous pain control for 25 hours)} \blacksquare$$

The Medfusion 2010 Syringe pump ($2200; Medex, Inc., Carlsbad, CA) can accurately deliver drugs in syringes ranging in size from 3 to 60 ml.

The Abbott Plum XLD IV pump ($2389; Abbott Laboratories, Abbott Park, IL) contains a primary and secondary function so that a secondary infusion can be programmed for administration. This pump cannot deliver both infusions simultaneously.

The Trilogy Multichannel Infusion pump ($4000, Medex, Inc., Carlsbad, CA) can simultaneously deliver three fluid types at three different rates.

A "Y-port" can be used to deliver two separate infusions to the same patient.

Fluid pumps can be stacked to deliver separate infusions at different rates to the same patient.

See Aids & Resources, back page, for references, contacts, and appendices.