PROCEDURE

# 141 Calculating Doses, Flow Rates, and Administration of Continuous Intravenous Infusions

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**PURPOSE:** Calculation of doses and flow rates and administration of continuous intravenous (IV) infusions are performed to ensure accurate delivery of medications administered via the IV route. Many of the medications delivered via continuous IV infusion have potent effects and narrow margins of safety; therefore accuracy in calculation and administration of these agents is imperative.

## PREREQUISITE NURSING KNOWLEDGE

- Knowledge of aseptic technique is necessary.
- Nurses must be aware of the indications, actions, side effects, dosages, administration/storage, assessment, and evaluation for medications administered.
- Many different types of medications are delivered as continuous IV infusions in acute and critical care settings. These medications include, but are not limited to, vasoactive, inotropic, antidysrhythmic, sedative, and analgesic agents.
- Hemodynamic assessment and electrocardiographic (ECG) monitoring are frequently necessary to evaluate the patient's response to medication infusions. The nurse must be familiar with monitoring equipment such as cardiac monitors, arterial catheters, pulmonary artery catheters, and noninvasive blood pressure cuffs.
- Titration refers to the adjustment of the dose of a medication, either increasing or decreasing, to attain the desired patient response.
- Alterations or interruptions of the flow rate can significantly affect the dose of medication being delivered and adversely affect the patient. For accurate delivery of IV medications, volume-controlled infusion devices are required.
- "Smart technologies" are electronic devices, such as computers, bedside monitors, and infusion pumps, that perform calculations of doses and flow rates after information is entered and programmed by the user. Although these devices are not universally available, their use may reduce medication errors.[4]
- Smart pumps are infusion pumps with comprehensive libraries of medications and dose calculation software that can perform a "test of reasonableness" to check that programming is within preestablished institutional limits before the infusion can begin, which can reduce medication errors, improve workflow, and provide a source of data for continuous quality improvement.[10]
- Use of smart infusion pumps with activated dosage error reduction software alerts the nurse when safe doses and infusion rates have been exceeded.[7] The nurse must use the technology consistently to avoid serious medication infusion errors.[6]
- Be aware that double key bounce and double keying errors may occur when pressing a number key once on an infusion pump, resulting in the unintended consequence of a repeat of that same number. This can result in infusing medications at a higher rate than expected.[5]
- Three factors are involved in the calculations for continuous IV infusions:
  - The concentration is the amount of medication diluted in a given volume of IV solution (e.g., 400 mg dopamine diluted in 250 mL normal saline [NS] solution, resulting in a concentration of 1.6 mg/mL, or 2 g lidocaine diluted in 500 mL 5% dextrose in water [$D_5W$], yielding a concentration of 4 mg/mL). The concentration is also expressed as amount of medication per milliliter of fluid.
  - The dose of the medication is the amount of medication to be administered over a certain length of time (e.g., dopamine 5 mcg/kg/min, lidocaine 2 mg/min, or diltiazem 5 mg/hr). The units of measure for the dose differ for various medications. The length of time is 1 minute

or 1 hour. If the medication is weight based, the dose of the medication is per kilogram of patient weight.
- The flow rate is the rate of delivery of the IV fluid solution expressed as volume of IV fluid delivered per unit of time (e.g., 20 mL/hr). The unit of measure of the flow rate is milliliter per hour.

- All units of measure in the formula must be the same. It frequently is necessary to perform some conversions on the concentration before entering it into the formula. The units of measure of the concentration must be converted to the same units of measure of the dose (e.g., the concentration of dopamine is measured in milligrams, but the dose of dopamine is measured in micrograms).
- The mathematical formula for continuous IV infusions uses three factors (Box 141-1). When two factors are known, the third can be calculated with the basic formula. Therefore when the concentration of the solution and the prescribed dose are known, the flow rate can be determined. When the concentration of the solution and the flow rate are known, the dose can be determined. Variations on the basic formula are used to allow for medications delivered per hour or per minute and for medications that are weight based (Boxes 141-2 and 141-3).
- Calculations for weight-based medications include the patient's weight in the formula. The choice of which weight to use can be challenging. Much disagreement and inconsistency are found in the literature as to which weight to use, ideal body weight, actual body weight, or dry body weight.[2,7] Distribution of specific medications across fat and fluid body compartments varies, thus affecting the therapeutic level. Because most medications are titrated to patient response and a desired clinical endpoint, a consistent approach is to use the patient's admission weight for initial dose calculations. The clinical pharmacist then should be consulted for obese patients and for medications that have potentially dangerous toxicities.
- Central IV access should be used for vasoconstrictive medications and medications that can cause tissue damage when extravasated.[3] Mechanisms and agents that may cause tissue damage include osmotic damage from hyperosmolar solutions, ischemic necrosis caused by vasoconstrictors and certain cation solutions, direct cellular toxicity caused by antineoplastic agents, direct tissue damage from pH strong acids and bases, and direct irritation.[9]
- The Joint Commission goal for medication safety includes standardization and limiting the number of drug concentrations available in organizations.[11] Standardized dosing methods for the same medications reduce IV infusion errors.[7]
- The Institute of Healthcare Improvement (IHI) recommendations for IV medication safety include conducting independent double checks, dose calculation aids on IV solution bag labels, use of IV smart infusion pumps with safety features, and use of premade dose and flow-rate charts.[1]
- A review found there is insufficient evidence to suggest that medication errors are caused by nurses' poor calculation skills. More research and direct observational studies are required to examine calculation errors in practice.[8]

**BOX 141-1 Basic Formula***

1. To determine an unknown flow rate:

$$\frac{\text{Dose (mg/hr or mcg/hr)}}{\text{Concentration (mg/mL or mcg/mL)}} = \text{Flow rate (mL/hr)}$$

2. To determine an unknown dose:

$$\text{Flow rate (mL/hr)} \times \text{Concentration (mg/mL or mcg/mL)} = \text{Dose (mg/hr or mcg/hr)}$$

3. To determine the concentration of drug in 1 mL of fluid:

$$\frac{\text{Total amount of drug (mg or mcg)}}{\text{Total volume of fluid (mL)}} = \text{Concentration} \frac{\text{(mg or mcg)}}{\text{(mL)}}$$

*Example:* When flow rate is unknown, diltiazem 125 mg/125 mL $D_5W$ to be administered at 10 mg/hr.

A. Calculate concentration of drug in 1 mL of fluid:

$$\frac{125\text{ mg}}{125\text{ mL}} = \frac{1\text{ mg}}{\text{mL}}$$

B. Enter known factors into the formula and solve:

$$\text{Flow rate (mL/hr)} \times \text{Concentration (mg or mcg/mL)} = \text{Dose (mg or mcg/mL)}$$

$$\frac{10\text{ mL/hr}}{1\text{ mg/mL}} = 10\text{ mL/hr}$$

*Example:* When dose is unknown, diltiazem 125 mg/125 mL $D_5W$ is infusing at 15 mL/hr.

A. Calculate concentration of drug in 1 mL of fluid:

$$\frac{125\text{ mg}}{125\text{ mL}} = \frac{1\text{ mg}}{\text{mL}}$$

B. Enter known factors into the formula and solve:

$$15\text{ mL/hr} \times 1\text{ mg/mL} = 15\text{ mg/hr}$$

*Because there are units on the top of the equation and units on the bottom of the equation, to ensure that the final units are correct, the units on the bottom of the equation must be inverted and multiplied by the units of the top of the equation.

Example: $$\frac{1800\text{ mcg/hr}}{200\text{ mcg/mL}} = \frac{9 \times \text{mL}}{\text{hr}} = 9\text{ mL/hr}$$

# EQUIPMENT

- Prepared IV solution with medication to be administered
- IV tubing
- IV infusion device
- Nonsterile gloves
- Alcohol pads

Additional equipment, to have available as needed, includes the following:

- Calculator
- Medication compatibility table

# PATIENT AND FAMILY EDUCATION

- Explain the indications and expected response to the pharmacological therapy. ***Rationale:*** Patients and families need explanations of the plan of care and interventions.
- Instruct the patient to report adverse symptoms, as indicated. Reportable symptoms include, but are not limited to, pain, burning, itching, or swelling at the IV site; dizziness; shortness of breath; palpitations; and chest pain.

**BOX 141-2 Variation for Medication Doses Measured Per Minute (mg/min or mcg/min)***

1. To determine unknown flow rate:
$$\frac{\text{Dose (mg/min or mcg/min)} \times 60\ \text{min/hr}}{\text{Concentration (mg/mL or mcg/mL)}} = \text{Flow rate (mL/hr)}$$
2. To determine unknown dose:
$$\frac{\text{Flow rate (mL/hr)} \times \text{Concentration (mg/mL or mcg/mL)}}{60\ \text{min/hr}}$$
$$= \text{Dose (mg/min or mcg/min)}$$

*Example:* When flow rate is unknown, nitroglycerin 50 mg/250 mL $D_5W$ to be administered at 30 mcg/min.

A. Convert the concentration to like units of measure:
$$\frac{50\ \text{mg}}{250\ \text{mL}} \times \frac{1000\ \text{mcg}}{1\ \text{mg}} = \frac{50{,}000\ \text{mcg}}{250\ \text{mL}}$$
B. Calculate the concentration of medication in 1 mL of fluid:
$$\frac{50{,}000\ \text{mcg}}{250\ \text{mL}} = \frac{200\ \text{mcg}}{1\ \text{mL}}$$
C. Enter known factors into the formula and solve:
$$\frac{30\ \text{mcg/min} \times 60\ \text{min/hr}}{200\ \text{mcg/mL}} = 9\ \text{mL/hr}$$

*Example:* When the dose is unknown, lidocaine 2 g/500 mL $D_5W$ is infusing at 30 mL/h.

A. Convert the concentration to like units of measure:
$$\frac{2\ \text{g}}{500\ \text{mL}} \times \frac{1000\ \text{mg}}{1\ \text{g}} = \frac{2000\ \text{mg}}{500\ \text{mL}}$$
B. Calculate the concentration of drug in 1 mL of fluid:
$$\frac{2000\ \text{mg}}{500\ \text{mL}} = \frac{4\ \text{mg}}{\text{mL}}$$
C. Enter known factors into the formula and solve:
$$\frac{30\ \text{mL/hr} \times 4\ \text{mg/mL}}{60\ \text{min/hr}} = 2\ \text{mg/min}$$

*The time factor of 60 min/hr must be added to the basic formula.

**BOX 141-3 Variation for Weight-Based Medication Doses Measured Per Minute (mcg/kg/min)***

1. To determine unknown flow rate:
$$\frac{\text{Dose (mcg/kg/min)} \times 60\ \text{min/hr} \times \text{Patient weight (kg)}}{\text{Concentration (mcg/mL)}} = \text{Flow rate (mL/hr)}$$
2. To determine unknown dose:
$$\frac{\text{Flow rate (mL/hr)} \times \text{Concentration (mcg/mL)}}{60\ \text{min/hr} \times \text{Patient weight (kg)}} = \text{Dose (mcg/kg/min)}$$

*Example:* When flow rate is unknown, dopamine 400 mg/250 mL $D_5W$ to infuse at 5 mcg/kg/min. Patient weighs 100 kg.

A. Convert the concentration to like units of measure:
$$\frac{400\ \text{mg}}{250\ \text{mL}} \times \frac{1000\ \text{mcg}}{1\ \text{mg}} = \frac{400{,}000\ \text{mcg}}{250\ \text{mL}}$$
B. Calculate concentration of drug in 1 mL of fluid:
$$\frac{400{,}000\ \text{mcg}}{250\ \text{mL}} = \frac{1600\ \text{mcg}}{1\ \text{mL}}$$
C. Enter known factors into the formula and solve:
$$\frac{5\ \text{mcg/kg/min} \times 60\ \text{min/hr} \times 100\ \text{kg}}{1600\ \text{mcg/mL}} = 18.75\ \text{mL/hr}$$

*Example:* When dose is unknown, dobutamine 500 mg/250 mL $D_5W$ is infusing at 15 mL/hr. Patient weighs 70 kg.

A. Convert the concentration to like units of measure:
$$\frac{500\ \text{mg}}{250\ \text{mL}} \times \frac{1000\ \text{mcg}}{\text{mg}} = \frac{50{,}000\ \text{mcg}}{250\ \text{mL}}$$
B. Calculate concentration of drug in 1 mL of fluid:
$$\frac{50{,}000\ \text{mcg}}{250\ \text{mL}} = \frac{2000\ \text{mcg}}{\text{mL}}$$
C. Enter known factors into the formula and solve:
$$\frac{15\ \text{mL/hr} \times 2000\ \text{mcg/mL}}{60\ \text{min/hr} \times 70\ \text{kg}} = 7.14\ \text{mcg/kg/min}$$

*The patient's weight in kilograms and the time factor of 60 min/hr must be added to the basic formula.

***Rationale:*** Reporting assists the nurse to evaluate the response to the pharmacological therapy and to identify adverse reactions.

# PATIENT ASSESSMENT AND PREPARATION

## Patient Assessment

- Assess medication allergies. ***Rationale:*** Assessment provides identification and prevention of allergic reactions.
- Obtain vital signs and hemodynamic parameters. ***Rationale:*** The need for vasoactive agents is established, and baseline data are provided to evaluate the response to therapy.
- Assess the patient's cardiac rate and rhythm. ***Rationale:*** Assessment establishes the need for antidysrhythmic therapy and provides baseline data.
- Obtain other assessments relevant to the medication being administered (e.g., sedation scale for continuous IV sedatives). ***Rationale:*** Patients are assessed for specific parameters that are affected by various medications in order to note the efficacy of the medications and to ensure their safe delivery.[2]

## Patient Preparation

- Ensure that the patient and family understand information. Answer questions as they arise, and reinforce information as needed. ***Rationale:*** Understanding of previously taught information is evaluated and reinforced.
- Weigh the patient, if the medication is weight based. ***Rationale:*** Calculation of the correct dose based on patient weight is permitted. If the patient's weight has changed during hospitalization because of edema or other causes, use of the baseline admission weight is preferable.[12–14]
- Verify patency or obtain patent, appropriate IV access. ***Rationale:*** Delivery of the medication into the IV space is ensured. Some continuous infusion medications require central line access to prevent irritation or damage to smaller peripheral veins and to reduce the risk for extravasation.

## Procedure for Calculating Doses and Flow Rates and Administering Continuous Intravenous Infusions

| Steps | Rationale | Special Considerations |
|---|---|---|
| 1. Verify the prescribed medication order. | Ensures accuracy of medication administration. | A medication order should include the medication, route, dose, and parameters for titration of the medication.<br>The concentration of the solution and the diluent should be indicated in the order or determined by institutional standards. |
| 2. **HH** | | |
| 3. **PE** | | |
| 4. Verify the five rights of medication administration: right patient, right drug, right dose, right time, and right route. Verify the correct patient with two identifiers.[1–3,11] **(Level E*)** | Reduces the potential for medication administration error. | |
| 5. Connect and flush the IV solution (with prescribed medication) through the tubing system. | Prepares the IV system. | |
| 6. Place the IV infusion in the infusion device. There are two methods to perform the next step; **choose either Step 7 or Step 8 or both** as a double-check. **(Level M*)** | Prepares the infusion system. | Refer to the infusion device user's manual for specific instructions on the use of specific devices. |
| 7. Determine the correct flow rate with manual mathematic calculation method. | Ensures the prescribed dose is administered | Make sure the accurate rate based on the prescribed dose is entered into the infusion pump. |
| A. Convert the concentration of the solution to the same units of measure as the dose. | All units of measure must be the same to perform the mathematic functions. | |
| B. Calculate the concentration of the medication per milliliter of fluid. | Necessary for the medication calculation. | |
| C. Enter the concentration and the dose into the formula and solve for the flow rate. | Necessary for the medication calculation.<br>Entering information into the device is required for the device to infuse at the prescribed rate. | Use alternate formulas if medication dose is a per-minute or weight-based dose (see Boxes 141-1, 141-2, and 141-3). |
| 8. Determine the correct flow rate with electronic devices. **(Level M*)** | Prevents errors in medication administration. | Refer to the manufacturer's user guide for accurate programming of smart pump calculations.<br>Refer to the institutional policy regarding what medications should be infused with smart device capabilities (i.e., Guardrails, Alaris Medical Systems, San Diego, CA). |

*Level E: Multiple case reports, theory-based evidence from expert opinions, or peer-reviewed professional organizational standards without clinical studies to support recommendations.
*Level M: Manufacturer's recommendations only.

*Procedure continues on following page*

## Procedure for Calculating Doses and Flow Rates and Administering Continuous Intravenous Infusions—*Continued*

| Steps | Rationale | Special Considerations |
|---|---|---|
| A. Enter the necessary information into the device, including, but not limited to, patient weight, medication name, concentration of solution, and dose prescribed. | Ensures patient safety. Prevents mathematic errors or data entry and programming errors. | |
| B. Program the device to electronically calculate the flow rate. | | |
| 9. Double-check the flow rate calculations or programming with another qualified individual. | Independent double-checks may reduce errors made when calculating dosages or programming pumps. | |
| 10. Set the flow rate on the infusion pump. | Prepares for medication administration. | |
| 11. Connect the infusion system to the intended IV line or catheter and initiate the infusion. | Initiates the therapy. | Alcohol should always be used to cleanse the IV port (hub) before the infusion is connected. |
| 12. Remove PE and discard used supplies. | | |
| 13. HH | | |

## Expected Outcomes

- The desired patient response is achieved
- The correct dose of medication is administered
- The dose is titrated to achieve/maintain the desired patient response

## Unexpected Outcomes

- Adverse reactions to the medication occur
- The incorrect dose of medication is administered
- The desired patient response is not achieved or maintained
- Infiltration or extravasation of medication occurs

## Patient Monitoring and Care

| Steps | Rationale | Reportable Conditions |
|---|---|---|
| | | *These conditions should be reported if they persist despite nursing interventions.* |
| 1. Evaluate the patient response by monitoring the indicated parameters for the medication being infused. | Medications given as continuous infusions often have potent effects and potentially serious adverse effects. Most medications given as continuous infusions have a quick onset of action. Frequent monitoring of parameters is necessary during initiation of the infusion. | • Adverse reactions<br>• Hemodynamic instability<br>• Cardiac dysrhythmias<br>• Excessive sedation<br>• Respiratory depression |

## Patient Monitoring and Care—*Continued*

| Steps | Rationale | Reportable Conditions |
|---|---|---|
| 2. If the patient response is inadequate, titrate the infusion as prescribed following the prescribed parameters. | The patient's response to many continuous infusions is dose-dependent. To achieve the desired response, titration of the dose is necessary. | • Desired response not achieved within an acceptable dosage range |
| 3. Assess the IV access for catheter placement, catheter patency, and signs of infiltration or extravasation every 1–4 hours and as needed. | Ensures delivery of the medication into the venous system. Prevents interruptions in delivery of the medication. Provides early recognition of complications. | • Extravasation of any medication<br>• Intravenous line infiltration |

## Documentation

*Documentation should include the following:*

- Name of the medication and the type of solution in which the medication is diluted; concentration of the solution; dose; flow rate; and administration times
- Patient and family education
- Assessment of the IV access and site
- Parameters monitored and patient response
- Adverse reactions and interventions to treat the reaction
- Titration

### References and Additional Readings

For a complete list of references and additional readings for this procedure, scan this QR code with any freely available smartphone code reader app, or visit http://booksite.elsevier.com/9780323376624.

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## Additional Readings


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