Intravenous Therapy: Dose and Flow Rate Calculation – CE

ALERT

Don appropriate personal protective equipment (PPE) based on the patient's signs and symptoms and indications for isolation precautions.

Take steps to eliminate interruptions and distractions during medication preparation.

Remember to route tubes and catheters having different purposes in different, standardized directions (e.g., IV lines routed toward the head; enteric lines toward the feet).[6]

OVERVIEW

Many different types of medications are delivered as continuous IV infusions in acute, ambulatory, long-term, home care, and critical care settings.

Medication error is an important topic to consider for all who administer IV medications. These errors, which may have serious negative consequences, can be eliminated or kept to a minimum by standardizing medication nomenclature, concentration, and dosing and by implementing medication safety factors, such as electronic order entry, bar coding, procedures for distraction-free medication administration, protocols for high-risk IV drugs, and the use of smart technologies.

Smart technologies are electronic devices that perform calculations for doses and flow rates after information is entered and programmed by the user. These devices include computers, bedside monitors, and electronic infusion devices. Smart electronic infusion devices have built-in safeguards that identify and correct programming errors before the error reaches the patient by triggering an alarm when drug parameters are too high or too low. They can also detect flow problems, air bubbles in the tubing, and other safety concerns.

The type of administration system used for a continuous IV medication depends on the age and acuity of the patient, the type of medication ordered, the organization's practice, and the setting. Flow rate devices range from simple mechanical devices using gravity to computerized smart electronic infusion devices. Regardless of the type of administration system used to administer the continuous IV infusion, the goal is controlling the rate of flow. Whether the administration system is simple or complex, it should be viewed as an enhancement to patient care and not a substitution for nursing care.

A continuous IV infusion is an infusion of medication in a solution into the venous system. Continuous IV infusions are often used when the medication needs to be greatly diluted, the drug level in the blood must be tightly controlled, or large volumes of fluids need to be infused.

Drug Calculations Components

The metric system is the universally accepted system of measurement for calculating drug dosages (Box 1). The components of calculating a medication dosage include:[7]

- Amount of drug to be given (G) or desired dose: the amount of medication to be administered over a certain length of time (e.g., lidocaine 2 mg/min)
- Dose ordered (D): the amount of medication prescribed (e.g., 2.5 mg)
- Strength on hand (H): the medication available (e.g., 400 mg)
- Volume on hand (V): the amount of solution available for dilution (e.g., 400 mg/2 ml indicates 400 mg of medication in 2 ml of liquid volume)
- Concentration of a drug (C): the amount of medication diluted in a volume of IV solution (e.g., 400 mg dopamine/250 ml) (Box 2)
- Flow rate: the speed at which the IV fluid infuses expressed as volume over time (e.g., 20 ml/hr)
- Drop factor: the number of drops in the IV drip chamber that is equivalent to 1 ml
- Length of administration (Box 3)
- Conversion factors

All units of measure used in the formula must be the same when calculations are performed. If they are not, the units of measure must be converted (Box 4) (Box 5).

Weight-Based Drug Calculations
Choosing which weight to use can be challenging. Distribution of specific medications across fat and fluid body compartments varies, affecting the therapeutic level. Much disagreement and inconsistency exist in the literature as to which weight to use. Thus, the organization's practice should be followed regarding which of these weights to use: ideal body weight, admitting weight, daily weight, or dry body weight.

Because most drugs are titrated to the patient's response and a desired clinical endpoint, a consistent approach is using the patient's admission weight for initial dose calculations. *Titrating* is adjusting the dose to attain the desired patient response. *Weaning* is gradually decreasing the dose when the medication is being discontinued. The clinical pharmacist should be consulted for patients who are obese and for medications that have potentially dangerous toxicities.

Pounds to Kilograms
Medication dosages based on weight are calculated using kilograms instead of pounds. The universal conversion formula is 1 kg = 2.2 lb.

If the patient expresses concern regarding the accuracy of a medication, the medication should not be given. The concern should be explored, the practitioner notified, and the order verified.

Tubing or catheter should be traced from the patient to the point of origin before connecting or reconnecting any device or infusion.[6] Tubing should be labeled at the connection site closest to the patient and at the connection site closest to the source when there are different access sites or several bags.[6] Labeling reduces the chance of misconnection, especially in circumstances where multiple IV lines or devices are in use. Connections should not be forced, and equipment should

only be used for its intended purpose.[6] Forced connections or workarounds could indicate that the connection should not be made.

EDUCATION

- Provide developmentally and culturally appropriate education based on the desire for knowledge, readiness to learn, and overall neurologic and psychosocial state.
- Provide the patient and family with an explanation of the equipment and the procedure.
- Explain to the patient and family the indications and expected response to the medication.
- Instruct the patient and family regarding the potential side effects and adverse reactions of the medication.
- Instruct the patient and family to report signs and symptoms, including pain, burning, itching, or swelling at the vascular access device (VAD) exit site; dizziness; shortness of breath; palpitations; and chest pain.
- Explain to the patient receiving a vesicant agent to report pain, swelling, or stiffness in the extremity to the nurse immediately.
- Explain to the patient that excessive movement of the IV tubing or manipulation of the catheter can increase the risk of extravasation.
- Instruct the patient to let the nurse know immediately if tubing is accidentally pulled or tugged so the IV catheter can be checked.
- Discuss the progression of symptoms with the patient and family if extravasation occurs.
- Encourage questions and answer them as they arise.

ASSESSMENT AND PREPARATION

Assessment

1. Perform hand hygiene and don PPE as indicated for needed isolation precautions.
2. Introduce yourself to the patient.
3. Verify the correct patient using two identifiers.
4. Assess the patient for medication allergies.
5. Assess the patient for contraindications to receiving the medication and notify the practitioner accordingly.
6. Obtain vital signs, hemodynamic parameters, and laboratory results, if applicable.
7. Obtain other assessment information relevant to the medication, such as a sedation scale score for a sedative or a pain scale score for an analgesic.

Preparation

1. Select the most appropriate IV site to minimize the risk of extravasation and infiltration of the medication.[4]
2. Determine which weight to use if the dosage is weight based.
3. Verify the patient's actual admission weight in kilograms. Reweigh the patient if appropriate.[5] Stated, estimated, or historical weight should not be used.[5]
4. Obtain the medication, check the practitioner's order, verify the expiration date, and inspect the medication for particulates, discoloration, or other loss of integrity.

Intravenous Therapy: Dose and Flow Rate Calculation – CE

Do not use medication that is cloudy or precipitated unless such is indicated by its manufacturer as being safe.

PROCEDURE

1. Perform hand hygiene and don gloves and appropriate PPE based on the patient's signs and symptoms and indications for isolation precautions.
2. Verify the correct patient using two identifiers.
3. Explain the procedure to the patient and ensure that he or she agrees to treatment.
4. Ensure the six rights of medication safety: right medication, right dose, right time, right route, right patient, and right documentation. Use a bar code system or compare the medication administration record (MAR) to the patient's identification band.
5. Establish patency of the VAD before administering the medication.

a. Assess and confirm peripheral VAD patency by aspirating for blood return and flushing the VAD using, at a minimum, a 5-ml syringe filled with preservative-free 0.9% sodium chloride solution.[2]
b. Assess and confirm central VAD patency by aspirating for blood return and flushing the central VAD using, at a minimum, a 10-ml syringe filled with preservative-free 0.9% sodium chloride solution.[2]

6. Remove the protective cap from the medication container.
7. Remove the protective cap from the spike of the IV administration set tubing.
8. Insert the administration set spike into the medication container.
9. Hang the medication container on the IV pole.
10. Label the container with the date and time the container was hung, any additives, and the nurse's initials.
11. Squeeze the drip chamber to fill it approximately one-half full.
12. Attach an inline filter to the end of the administration set per the organization's practice.

    Rationale: Some IV medications (e.g., amiodarone) require an inline particulate-retentive filter for administration.

13. Open the clamp on the IV administration set, allow the tubing to fill slowly, and expel air. If an electronic infusion device is used, purge air from the tubing according to the manufacturer's recommendations.
14. Close the clamp on the IV administration set tubing when air is expelled.
15. Label the tubing with the date in accordance with the organization's practice.

    Rationale: Some organizations label the tubing with the date the tubing was hung, and some organizations label the tubing with the date the tubing needs to be changed.

16. Trace tubing or catheter from the patient to point of origin.[6]

17. Disinfect the needleless connector using vigorous mechanical scrubbing for a minimum of 5 to 60 seconds,[1] according to the organization's practice with an appropriate disinfecting agent (e.g., 70% isopropyl alcohol, an iodophor such as povidone-iodine, or greater than 0.5% chlorhexidine in alcohol solution), and allow the solution to dry.[1]

Specific guidelines directing the appropriate technique, disinfectant, or amount of time required to clean various devices have not been determined.[1]

There is moderate quality evidence to support the recommendation to apply mechanical friction for no less than 5 seconds.[1]

18. Remove the protective cover from the end of the IV administration set tubing and attach the tubing to the VAD via the needleless connector.
19. Determine the correct flow rate using the manual mathematical calculation method, an electronic device, or both methods before opening the clamp on the IV administration tubing or initiating an IV continuous infusion.

a. Manual mathematical calculation method

i. Determine the flow rate: ml/hr ÷ 60 min/hr = ml/min (Box 6).
ii. Determine the number of drops/minute: ml/min × drops/ml = drops/min (Box 6).
iii. Convert to the same units of measure, if applicable.

b. Smart electronic infusion device method

i. Refer to the manufacturer's user guide to program the smart electronic infusion device accurately.

Monitor the infusion for flow rate accuracy.

ii. Enter the necessary information, such as the patient's weight, drug name, concentration of solution, and ordered dose, into the device.

Rationale: Entering the patient's weight, drug name, concentration, and ordered dose ensures the patient's safety and prevents mathematical errors or data entry and programming errors.

Review the organization's practice regarding medications that must be infused using a smart electronic infusion device.

iii. Program the device to calculate the flow rate electronically.

20. For high-alert medications, double-check the flow rate with another qualified person to verify that the order and the set rate of infusion match.
21. Label the tubing at the connection site closest to the patient and the source.[7]

22. Discard supplies, remove PPE, and perform hand hygiene.
23. Document the procedure in the patient's record.

MONITORING AND CARE

1. Evaluate the patient's response by monitoring the indicated parameters for the medication.

   Rationale: Medications administered by continuous infusions often have potent effects and potentially serious adverse effects. Most medications administered by continuous infusions have a quick onset of action. Frequent monitoring is necessary during the initiation of the infusion.

   Reportable conditions: Adverse reactions, hemodynamic instability, cardiac arrhythmias, excessive sedation, respiratory depression, pruritis, urticaria

2. If the patient's response is inadequate, titrate the dosage as ordered until the response is adequate.

   Reportable condition: Desired response not achieved with current dosage range

3. Monitor the patient for adverse and allergic reactions to the medication. Recognize and immediately treat respiratory distress and circulatory collapse, which are signs of a severe anaphylactic reaction. Follow the organization's practice for emergency response.
4. Assess the VAD exit site for signs of phlebitis, infiltration, or extravasation routinely based on type of therapy, the device, and the risk factors.

   Reportable conditions: Extravasation of medication, IV line infiltration, phlebitis

5. Change the administration sets as indicated based on the type of solution administered and the type of infusion (continuous vs. intermittent) and if contamination is suspected.

a. Change primary and secondary continuous administration sets used to deliver fluids other than lipids, blood, or blood products (and any add-on devices that are part of the administration set) no more frequently than every 96 hours.[3]
b. Change detached secondary and primary intermittent administration sets (and any add-on devices that are part of the administration set) 24 hours.[3]

   Rationale: Increased risk of contamination exists with an increased number of disconnections and reconnections.[3]

c. Place a new sterile cap on the end of the administration set after each intermittent use.[3] Do not attach the exposed end of the administration set to a port on the same set.[3]
d. Change administration sets used to administer fat emulsions (and add-on devices that are part of the administration set) every 12 hours and with each new container.[3]

e. Change the administration set used to administer parenteral nutrition (and add-on devices that are part of the administration set) every 24 hours and with each new container.[3]
f. Change dedicated administration sets used to administer propofol (Diprivan®) (and add-on devices that are part of the administration set) every 6 or 12 hours per the manufacturer's instructions and with each new container.[3]

Rationale: Fat emulsions promote bacterial growth and can contribute to infection.

g. Change administration sets used for blood and blood products (and add-on devices that are part of the administration set) every 4 hours.[3]
h. Label the tubing with the date and time of the change per the organization's practice.

EXPECTED OUTCOMES

- Medication is administered per the six rights of medication safety.
- Desired patient response is achieved without adverse effects.
- VAD and exit site remain without complications.
- Dose is titrated to achieve and maintain desired patient response.

UNEXPECTED OUTCOMES

- Medication is not administered per the six rights of medication safety.
- Adverse effects of or reactions to the medication occur.
- Incorrect dose of medication is administered.
- Desired patient response is not achieved and maintained.
- Occlusion of VAD occurs.
- Infiltration or extravasation of medication occurs.

DOCUMENTATION

- Education
- Drug name and concentration
- Infusion start time
- Infusion rate
- Infusion stop time
- VAD exit site assessment
- VAD used
- VAD patency
- Patient's response to the medication, including any adverse reactions
- Unexpected outcomes and related interventions
- Patient's weight in kilograms per the organization's practice

Intravenous Therapy: Dose and Flow Rate Calculation – CE

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*In these skills, a “classic” reference is a widely cited, standard work of established excellence that significantly affects current practice and may also represent the foundational research for practice.

AACN Levels of Evidence

- **Level A** - Meta-analysis of quantitative studies or metasynthesis of qualitative studies with results that consistently support a specific action, intervention, or treatment
- **Level B** - Well-designed, controlled studies, with results that consistently support a specific action, intervention, or treatment
- **Level C** - Qualitative studies, descriptive or correlational studies, integrative reviews, systematic reviews, or randomized controlled trials with inconsistent results
- **Level D** - Peer-reviewed professional organizational standards with clinical studies to support recommendations
- **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

SUPPLIES

- Gloves and PPE, as indicated
- Antiseptic
  - >0.5% chlorhexidine in alcohol solution
  - Povidone-iodine

- 70% isopropyl alcohol
- Calculator
- Smart electronic infusion device
- IV administration set tubing
- Prepared IV solution of medication to administer
- Preservative-free 0.9% sodium chloride prefilled syringe(s)

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Box 1 Basic Drug Calculation Formulas

Drug Dosage Determinations

A. Ratio-Proportion Method **H:V = D:G**

Drug on hand: Volume of the drug on hand = Dose ordered: Amount to give

B. Formula Method

$$\text{Amount to give (G)} = \frac{\text{Dose ordered (D)}}{\text{Strength on Hand (H)}} \times \text{Volume (V)}$$

Several formulas can be used to calculate drug dosages. For each, the following information is required: Amount of drug to be given (G), dose ordered (D), strength on hand (H), and volume on hand (V).

The two methods below can be used to answer this question: If a vial contains clindamycin 600 mg/4 ml and the order is for 300 mg of clindamycin, what volume must be given?

Formula Method

$$G = \frac{D \times V}{H}$$

To answer the question, a nurse would follow these steps:

1. $G = \frac{300 \text{ mg} \times 4 \text{ ml}}{600 \text{ mg}}$
2. $G = \frac{300 \text{ mg} \times 4 \text{ ml}}{600 \text{ mg}}$
3. $G = \frac{1200 \text{ ml}}{600}$
4. G = 2 ml of clindamycin (300 mg/2 ml)

Box 1 continued on next page

Intravenous Therapy: Dose and Flow Rate Calculation – CE

Box 1 Basic Drug Calculation Formulas *(continued on from previous page)*

Ratio-Proportion Method

A ratio compares two related items. Proportion is the equality of two ratios.
H (mg):V (ml) = D (mg):G (ml)

To answer the question, a nurse would use this ratio:
600 mg:4 ml = 300 mg:G

Because the product of the means (4 ml × 300 mg) equals the product of the extremes (600 mg × G), a nurse would follow these steps:
1. Multiply the extremes (600 ~~mg~~ × G)
2. Multiply the means (4 ml × 300 ~~mg~~)
3. 600 G = 1200 ml
4. G = 1200 ÷ 600
5. G = 2 ml clindamycin

Box 2 Concentration of Drug

Total amount of drug (mg) ÷ total volume of solution (ml) = concentration of the solution (mg/ml)

Drug Concentration Determination

Concentration may be expressed as the amount of medication per milliliter of fluid or by a fraction, a percentage of solution, or mass.

Mg/ml

1. Determine the concentration of drug.
Total mg of drug ÷ total volume of solution (ml) = concentration of the solution (mg/ml)
2. Determine the infusion rate.
Desired amount of drug (mg/min) ÷ concentration of solution (mg/ml) = infusion rate (ml/min)
3. Convert to ml/hr:
ml/min × 60 min/hr = ml/hr

Percentage by Mass

A percentage solution is a measure based on parts of 100. The conversion factor is 1% solution = 1 gm of drug in 100 ml of solution.
Mass of medication ÷ the mass of fluid × 100.

To determine the percentage by mass of a 100-gm sodium chloride solution containing 20 gm of medication, the nurse would apply the formula as follows:
1. 20 gm of medication/100 gm of solution × 100
2. 20%

Box 2 continued on next page

Intravenous Therapy: Dose and Flow Rate Calculation – CE

Box 2 Concentration of Drug *(continued on from previous page)*

Percentage by Volume

$$\frac{\text{volume of medication}}{\text{total volume of solution}} \times 100\%$$

A 1000-ml bag of fluid contains 50 ml of medication. To determine the percentage by volume, the nurse would apply the formula as follows:

1. $\frac{50 \text{ ml (volume of medication)}}{1000 \text{ ml (total volume of solution)}} \times 100\%$
2. $(50 \div 1000) \times 100\% = 5\%$

(Data from Turner, M.S., Poole, S.K. (2014). Chapter 3: Pharmacology. In M. Alexander and others (Eds.), *Core curriculum for infusion nursing* (4th ed., pp. 131-162). Infusion Nurses Society. Philadelphia: Wolters Kluwer.)

Box 3 Length of Administration and Flow Rate

Volume to be infused (ml) ÷ milliliters/hour (ml/hr) = number of hours for infusion

Length of Administration

An infusion of D_5W in 0.45% sodium chloride solution has 600 ml remaining in the medication container. The rate of flow is 20 drops/min, and the drop factor is 12 drops/ml. To determine how many hours it will take for the medication to infuse, the nurse follows these steps:

1. Convert 600 ml to hours.

600 ml = x drops = x min = x hours

$$600 \text{ ml} \times \frac{\text{x drops}}{\text{x ml}} \times \frac{\text{x min}}{\text{x drops}} \times \frac{\text{x hr}}{\text{x min}}$$

2. Fill in the known information.

$$600 \cancel{\text{ml}} \times \frac{12 \cancel{\text{drops}}}{1 \cancel{\text{ml}}} \times \frac{1 \cancel{\text{min}}}{20 \cancel{\text{drops}}} \times \frac{1 \text{ hr}}{60 \cancel{\text{min}}} = \frac{7200 \text{ hr}}{1200}$$

3. $\frac{7200 \text{ hr}}{1200} = 6 \text{ hr}$

Flow Rate Conversion Calculations

ml/min to drops/min

A patient is to receive 240 ml of medication over 30 minutes. The drop factor of the IV administration set is 20 drops/ml. The nurse would determine the drops/min as follows:

1. $\frac{240 \cancel{\text{ml}}}{30 \text{ min}} \times \frac{20 \text{ drops}}{1 \cancel{\text{ml}}} = \frac{\text{x drops}}{\text{min}} = \frac{4800 \text{ drops}}{30 \text{ min}}$
2. $\frac{160 \text{ drops}}{\text{min}}$

Box 3 continued on next page

Intravenous Therapy: Dose and Flow Rate Calculation – CE

Box 3 Length of Administration and Flow Rate *(continued on from previous page)*

(mU)/min to microdrops/min

A patient is to receive 1000 ml of D_5W with 10 units of oxytocin at 10 mU/min. The drop factor of the IV administration set tubing is 60 microdrops/ml. The nurse would determine the microdrops/min as follows:

1. Identify the conversion factor: 1000 mU = 1 unit (u)
2. Change the rate of flow from mU/min to microdrops/min:

$$\frac{10\ \text{mU}}{1\ \text{min}} \times \frac{x\ \text{u}}{x\ \text{mU}} \times \frac{x\ \text{ml}}{x\ \text{u}} \times \frac{x\ \text{microdrops}}{x\ \text{ml}} = \frac{\text{microdrops}}{\text{min}}$$

3. Identify known information: 1000 mU = 1 u, 1000 ml = 10 u, and 60 microdrops = 1 ml.
4. Set up the equation with known information:

$$\frac{\cancel{10\ \text{mU}} \times 1\ \cancel{\text{u}}}{1\ \text{min}} \times \frac{\cancel{1000\ \text{ml}} \times 60\ \text{microdrops}}{\cancel{1000\ \text{mU}}\quad \cancel{10\ \text{u}}\quad 1\ \cancel{\text{ml}}}$$

5. $\frac{60\ \text{microdrops}}{\text{min}}$

D_5W, 5% dextrose in water; *mU*, milliunits

Box 4 Metric Conversion Factors

WEIGHT				
1 kilogram	×	1000	=	1000 grams
1 gram	×	1000	=	1000 milligrams
1 milligram	×	1000	=	1000 micrograms
1 microgram	÷	1000	=	0.001 milligram
1 milligram	÷	1000	=	0.001 gram
1 gram	÷	1000	=	0.001 kilogram
VOLUME				
1 liter	×	1000	=	1000 milliliters
1 milliliter	÷	1000	=	0.001 liter

Box 5 Metric System Abbreviations

WEIGHT	VOLUME	LENGTH
Kilogram = kg	Liter = L	Centimeter = cm
Gram = gm	Milliliter = ml	Millimeter = mm
Milligram = mg	Cubic centimeter = cc	
Microgram = mc		

Intravenous Therapy: Dose and Flow Rate Calculation – CE

Box 6 Flow Rate Determination

The units of measure for the flow rate may be ml/hr, ml/min, or drops/min.

A. Flow rate/hour:
Total volume (ml) ÷ administration time (hr) = milliliters/hour (ml/hr)

B. Flow rate/minute:
Milliliters/hour (ml/hr) ÷ minutes/hour (min/hr) (60) = milliliters/minute (ml/min)

C. Drops/minute:
Milliliters/minute (ml/min) × drop factor = drops/minute (drops/min)

The three methods below can be used to answer this question: If the practitioner orders 2000 ml of medication to infuse over 24 hours, what is the flow rate?

Flow Rate Determination

Flow rate/hr

Total volume (ml) ÷ administration time (hr) = ml/hr
1. 2000 ml ÷ 24 hr = 83.3 ml/hr (round to nearest whole number for gravity administration)
2. Flow rate = 83 ml/hr

Flow rate/min

ml/hr ÷ 60 min per hr = ml/min
1. 83 ml ÷ 60 min = 1.38 ml/min (round to nearest whole number for gravity administration)
2. Flow rate/min = 1 ml/min

Drops/min

ml/min × drops/ml = drops/min
If the drop factor is 15 drops/ml:
1. $\frac{1.4\ \cancel{ml} \times 15\ \text{drops}}{\text{min} \qquad \cancel{ml}} = \frac{21\ \text{drops}}{\text{min}}$
2. 21 drops/min

Hourly Rate Determination

$\frac{(\text{Drops/min} \times 60\ \text{min/hr})}{\text{Drop factor}} = \text{ml/hr}$

For an administration set with a drop factor of 15 drops/ml that is infusing a solution at a rate of 25 drops/min:
1. $\frac{(25\ \text{drops/min} \times 60\ \text{min/hr})}{15\ \text{drops/ml}} = \text{ml/hr}$
2. $\frac{1500}{15} = 100\ \text{ml/hr}$