Medication Math

CHAPTER 4

OBJECTIVES

1. Identify the basic units of measure for weight, length, and volume.
2. Accurately convert milliliters to cubic centimeters, kilograms to pounds, and milligrams to grams (and micrograms).
3. Apply the four basic formulas (single dose, infusion of a measured amount of fluid in a set amount of time, drip infusion not based on weight, and drip infusion based on weight) to solve drug problems and determine dosages.

INTRODUCTION

Medication math can be made simple by mastering only a few basic formulas. The purpose of this chapter is to take away the mystery of medication math and replace it with confidence to learn and achieve ease in calculating drug dosages.

Anaphylaxis, as presented in the following case, is a life-threatening condition that is easily treated. However, without a grasp of the concepts of medication math, you cannot properly administer the medication epinephrine. A thorough knowledge of the concepts of pharmacology and dosing of medications is useless without the ability to make conversions of weight and volume and calculate volumes of drug to be administered based on concentration of the drug. As illustrated in the following case, to administer a simple and common medication such as epinephrine, you will need to make several calculations. To do this in a potentially life-threatening emergency requires a complete grasp of medication math principles.

You and your partner are dispatched to a residence on a call for an allergic reaction. You arrive and are directed to the kitchen, where you find a 6-year-old girl who is sitting in a chair in obvious respiratory distress. The child's mother tells you she stepped on a bee while running barefoot in the backyard. The mother states that the child does not have any known allergies, but she has never been stung by a bee before. The child has stridor and a rapid respiratory rate. She is holding and rubbing a markedly swollen left foot and appears quite anxious.

Your assessment of this situation is that the child is having an anaphylactic reaction from a bee sting. You determine that epinephrine should be administered as quickly as possible, and you do not think waiting to get IV access before administering the epinephrine is prudent. You decide that the best course of action is to administer IM epinephrine (1 : 1000). You ask the mother how much the child weighs, and the mother replies 50 pounds. The pediatric dose for IM epinephrine is 0.01 mg/kg (1 : 1000). The concentration of the epinephrine (1 : 1000) is 1 mg/mL. How many milliliters of epinephrine (1 : 1000) must be administered to this child?

Several questions must be answered before determining how many milliliters to administer.

1. What is the weight of the child in kilograms?
   - The child weighs 50 pounds. To convert to kilograms, 1 kg equals 2.2 pounds.
   - $\frac{50\ \text{lb}}{2.2\ \text{kg/lb}} = \frac{50\ \cancel{\text{lb}}}{2.2\ \text{kg}/\cancel{\text{lb}}} = 22.7\ \text{kg}$
   - 22.7 kg

2. What is the weight-based dose of epinephrine (1 : 1000) IM?
   - IM dose of epinephrine (1 : 1000) is 0.01 mg/kg
   - $\text{Dose} = \frac{0.01\,\text{mg}}{\text{kg}} \times \frac{22.7\,\text{kg}}{1} = \frac{0.01\,\text{mg}}{\cancel{\text{kg}}} \times \frac{22.7\,\cancel{\text{kg}}}{1} = 0.01\,\text{mg} \times 22.7 = 0.23\,\text{mg}$
   - Dose = 0.23 mg
3. What is the volume of epinephrine (1 : 1000) that needs to be administered intramuscularly by the syringe?
   - Concentration of epinephrine 1 mg/mL
   - $\text{Milliliters to administer} = \frac{\text{desired dose}}{\text{dose on hand}} \times \frac{\text{volume/quantity}}{1}$
   - $\text{Milliliters to administer} = \frac{0.23\,\text{mg}}{1\,\text{mg}} \times \frac{1\,\text{mL}}{1}$
   - $\text{Milliliters to administer} = \frac{0.23\,\cancel{\text{mg}}}{1\,\cancel{\text{mg}}} \times \frac{1\,\text{mL}}{1}$
   - Milliliters to administer = 0.23 mL

You administer 0.23 mL epinephrine (1 : 1000) intramuscularly. Shortly after administration, the child's breathing becomes less labored and she is less anxious. You start a peripheral IV, repeat your assessment, and prepare for transport. (Drug therapy for anaphylaxis is covered in detail in Chapter 8).

SYSTEMS OF MEASUREMENT

The first system of measurement for drugs was the **apothecary system.** In that system, the weight of drugs was measured in grains. Linear measures included inches, yards, and miles. **Volume** (i.e., the measurement of fluids and liquids) was measured in minims.

The **metric system** currently is the preferred system for drug measurement and calculation. It is logical and well organized, based on a basic unit and its multiples or submultiples of 10. It is similar to the U.S. monetary system: one dollar is the basic unit of measurement, written as $1.00. It can be divided into 10 dimes (written as $0.10), which can be further divided into 10 pennies (written as $0.01). This analogy is helpful when determining drug dosages.

Just as the apothecary system has basic units of measure for weight, length, and volume, so does the metric system, as follows:

- Weight (solids or mass): gram (g)
- Length: meter (m)
- Volume (liquid or fluid): liter (L)

In addition, several prefixes are commonly used in medicine to distinguish multiples or smaller parts of these units. The four commonly used in drug calculation are **kilo, centi, milli,** and **micro.** They are defined in Table 4-1 along with calculations and examples of equivalents.

Most drugs administered in the field are measured in the following units: **gram (g), milligram (mg),** and **microgram (mcg).** Drugs present in solutions can be measured in

TABLE 4-1

Common Prefixes Used in Medication Calculation

Prefix	Calculation	Examples of Equivalents	Reverse (Also True)	Multiple or Part of a Basic Unit
kilo	1000 × basic unit	1 kg = 1000 g	1000 g = 1 kg	Multiple
centi	1/100 of a basic unit	1 cm = 1/100 m	1/100 m = 1 cm	Part
milli	1/1000 of a basic unit	1 mg = 1/1000 g	1/1000 g = 1 mg	Part
micro	1/1,000,000 of a basic unit	1 mcg = 1/1,000,000 g	1/1,000,000 g = 1 mcg	Part

milliliters (mL). At times, volumes of solutions are also reported in cubic centimeters (cc). Milliliters and cubic centimeters refer to the same volume.

CONVERSIONS

The ability to convert one unit of measure to another is vital to ensure that the intended dose of medication is administered to the patient. Failure to understand and use unit conversions may lead to overdosing the patient inadvertently or providing the patient with a less than optimal dose. Most IV medications are supplied as solutions expressed as a concentrations (e.g., milligrams per milliliter [mg/mL]). Medications are dosed as a mass (e.g., milligrams), and drug doses are often determined based on a patient's weight (e.g., pounds or kilograms) or body surface area (square meters). As mentioned in Chapter 2, lack of experience in the performance of drug calculations and conversions is a common cause of medical error, patient injury, and legal action against the prehospital professional.

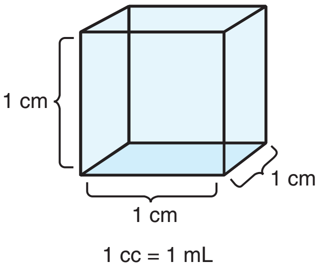
MILLILITERS AND CUBIC CENTIMETERS

The milliliter is a measurement of volume (liquids or fluids in this case) and is equal to 1/1000 of a liter. The cubic centimeter is also a measurement of volume, but it is based on the centimeter, which is equal to 1/100 of a meter. Because 1 cc equals 1 mL, the terms are often used interchangeably.

For example, you may receive an order to administer 2 mL of morphine sulfate. The same order may be given as 2 cc of morphine sulfate. These two doses are considered equivalent. If a box measured 1 cm × 1 cm × 1 cm in dimension, the volume of the box would be a cubic centimeter. If the box were filled with 1 mL of water at a temperature of 4° C, the water would exactly fill the box. Therefore the *volume* is equal to the *space* that was created (Fig. 4-1).

> Remember: 1 cc = 1 mL, but 1 mL does *not* equal 1 mg. *Gram* refers to the weight of a powdered drug, not its volume or the space that it occupies.

Never take medication orders in dosages of volume. For example, you are transporting a 43-year-old man with a severe open femur fracture incurred after he fell off a roof. You call medical direction for an order for morphine, and medical direction gives the order for 3 mL (or 3 cc) of morphine sulfate. Many drugs, morphine included, come in several different concentrations. Injectable morphine comes in concentrations of 2 mg/mL, 4 mg/mL, 5 mg/mL, 8 mg/mL, and 10 mg/mL. For instance, if medical direction thought that the advanced life support (ALS) drug box was stocked with morphine sulfate with a concentration of 2 mg/mL, the intended order to give 2 mL would have resulted in 4 mg being administered. If the drug box was supplied with 4 mg/mL, the order of 2 mL would have



▼ **Fig. 4-1** Volume is equal to the space created. The term *cc* represents cubic centimeter. A cubic centimeter is 1 cm wide, 1 cm long, and 1 cm high. One milliliter (mL) is the equivalent volume of a cubic centimeter. To avoid confusion, the term *milliliter* is preferred over cc, or cubic centimeter.

resulted in the patient getting 8 mg of morphine, or twice the intended dose. Although most drug boxes are supplied with standardized concentrations of medications, administering medications on the basis of volume alone (not concentration) is poor practice and not safe.

KILOGRAMS AND POUNDS

The next conversion commonly used to calculate drug dosages is kilograms (kg) to pounds (lb). Note that these units refer to the *patient's* weight, not the weight of the drug. Many drug dosages, particularly those administered to pediatric patients, are based on the patient's weight in kilograms to ensure safety from overdose.

The equivalent to remember is 1 kg = 2.2 lb. Therefore, to convert weight in pounds to weight in kilograms, divide the number of pounds by 2.2.

Example: If a patient weighs 154 lb, divide 154 lb by 2.2 lb/kg to determine the weight in kilograms.

$$\frac{154\,\text{lb}}{2.2\,\text{lb/kg}} = \text{weight in kilograms}$$

First, cross out "like terms" in the problem; in this case, *lb.*

$$\frac{154\,\cancel{\text{lb}}}{2.2\,\cancel{\text{lb}}\text{/kg}} = \text{weight in kilograms}$$

Now work the problem:

$$\frac{154}{2.2\text{ kg}} = 70\text{ kg}$$

MILLIGRAMS, MICROGRAMS, AND GRAMS

The next conversion is from milligrams to grams and, in reverse, from grams to milligrams. This process also includes converting milligrams to micrograms (mcg) and micrograms to milligrams.

> Remember: *milli* means 1/1000 of a basic unit; in this case, grams. The equivalent is 1000 mg = 1 g.

To use an everyday example, when changing a dollar into coins (e.g., dimes or pennies), the *larger unit* (dollar) is changed into an equivalent sum in *smaller units* (dimes or pennies). Therefore, to get the total number of the smaller unit, multiply the number of dollars (e.g., 5 dollars) by the number of dimes or pennies *per dollar.*

Example 1:

$$\frac{5\text{ dollars} \times 10\text{ dimes}}{\text{dollar}} = \text{number of dimes}$$

Cross out like terms; in this case, *dollar.*

$$\frac{5\,\cancel{\text{dollars}} \times 10\text{ dimes}}{\cancel{\text{dollar}}} = \text{number of dimes}$$

Now work the problem:

$$5 \times 10\text{ dimes} = 50\text{ dimes}$$

Example 2:

$$\frac{5\text{ dollars} \times 100\text{ pennies}}{\text{dollar}} = \text{number of pennies}$$

Cross out like terms; in this case, *dollars*.

$$\frac{5\ \cancel{\text{dollars}} \times 100 \text{ pennies}}{\cancel{\text{dollar}}} = \text{number of pennies}$$

Now work the problem:

$$5 \times 100 \text{ pennies} = 500 \text{ pennies}$$

Note that, when converting a pocket full of change into dollar bills, *smaller units* (coins) are being changed into *larger units* (dollars). The result will be *fewer* larger units (dollars) than smaller units (coins). So, when converting between units, ask yourself, "Am I changing small units for larger units, or large units for smaller units?" This question also applies in practice; you should have an initial sense of whether the numbers and units should be increasing or decreasing in magnitude.

To convert grams to milligrams, multiply grams by 1000. Remember that every 1 g contains 1000 mg; this can be written as 1000 mg/g.

Example:

$$\frac{5 \text{ g} \times 1000 \text{ mg}}{\text{g}} = \text{number of milligrams}$$

Cross out like terms; in this case, *g*.

$$\frac{5\ \cancel{\text{g}} \times 1000 \text{ mg}}{\cancel{\text{g}}} = \text{number of milligrams}$$

Now work the problem:

$$5 \times 1000 \text{ mg} = 5000 \text{ milligrams}$$

This can be quickly accomplished by moving the decimal point to the right the same number of spaces as there are zeros in the number. For example, because 1000 mg has 3 zeros, move the decimal point three decimal places to the right.

$$5 \text{ g} = 5\underline{000} \text{ mg}$$

The same process can be used to convert milligrams (mg) to micrograms (mcg).

milli means × 1000, or add 3 zeros
micro means × 1,000,000, or add 6 zeros

To convert milligrams (3 zeros) to micrograms (6 zeros), simply move the decimal point three more places to the right, for a total of 6 zeros.

$$5000 \text{ mg} = 5{,}000{,}\underline{000} \text{ mcg}$$

To convert milligrams to grams (smaller to larger), divide the number of grams by 1000, or simply move the decimal point three places to the *left*. This is the same as changing 100 pennies back to dollars. The 100 actually means 100 cents. Therefore move the decimal point to the left the same number of places as there are zeros in the equivalent of $1.00 (100 pennies; therefore 2 zeroes, 2 spaces):

100 pennies (cents) = 1.00 dollar

Following are some practice problems. Be sure to master the art of conversion before moving on so that you will understand the rest of the chapter.

Practice Problems

Convert grams to milligrams and milligrams to grams:

1. 1 g = ___________ mg
2. 1000 mg = __________ g
3. 250 mg = ___________ g
4. 400 mg = ___________ g

5. 500 mg = __________ g
6. 0.75 g = __________ mg
7. 1.25 g = __________ mg
8. 10 g = __________ mg
9. 2 g = __________ mg
10. 2500 mg = __________ g

Convert milligrams to micrograms and micrograms to milligrams:

1. 1 mg = __________ mcg
2. 500 mcg = __________ mg
3. 250 mcg = __________ mg
4. 400 mg = __________ mcg
5. 0.2 mg = __________ mcg
6. 800,000 mcg = __________ mg
7. 800 mg = __________ mcg
8. 200 mg = __________ mcg
9. 1000 mcg = __________ mg
10. 200,000 mcg = __________ mg

Answers

Convert grams to milligrams and milligrams to grams:

1. 1 g = 1000 mg
2. 1000 mg = 1 g
3. 250 mg = 0.25 g
4. 400 mg = 0.4 g
5. 500 mg = 0.5 g
6. 0.75 g = 750 mg
7. 1.25 g = 1250 mg
8. 10 g = 10,000 mg
9. 2 g = 2000 mg
10. 2500 mg = 2.5 g

Convert milligrams to micrograms and micrograms to milligrams:

1. 1 mg = 1000 mcg
2. 500 mcg = 0.5 mg
3. 250 mcg = 0.25 mg
4. 400 mg = 400,000 mcg
5. 0.2 mg = 200 mcg
6. 800,000 mcg = 800 mg
7. 800 mg = 800,000 mcg
8. 200 mg = 200,000 mcg
9. 1000 mcg = 1 mg
10. 200,000 mcg = 200 mg

Box 4-1 summarizes basic conversions that are useful in drug calculations.

BOX 4-1

BASIC CONVERSIONS

1 g = 1000 mg
1 mg = 1000 mcg
1 L = 1000 mL or 1000 cc
1 kg = 2.2 lb
2.5 cm = 1 in
Remember: 1 mg does not equal 1 mL or 1 cc.

DRUG PREPARATIONS AND CONCENTRATIONS

Regarding drug dosage calculations, understanding that drugs are supplied in various concentrations with differing preparations is important. The same drug can come in various concentrations, and dosages must be calculated according to the particular preparation. For example, atropine sulfate, a medication commonly used to increase a slow heart rate, comes packaged in two ways in prefilled syringes: 0.5 mg/10 mL and 1 mg/10 mL. The second preparation is twice as concentrated as the first and therefore requires a dose of only half the amount. Another drug, dopamine, which is used by prehospital professionals in certain situations in the field to raise blood pressure, comes in three different concentrations: 0.8 mg/mL, 1.6 mg/mL, and 3.2 mg/mL.

FORMULAS

Formulas are used to solve drug problems or determine dosages for patients. They should be used in conjunction with the basic conversions explained previously. Four basic formulas can be used to solve all prehospital pharmacology math problems:

Formula 1

Single dose (e.g., bolus of lidocaine or IM injection of Benadryl):

$$\frac{\text{desired dose}}{\text{dose on hand}} \times \frac{\text{volume/quantity}}{1} = X$$

Formula 2

To infuse a measured amount of fluid in a set amount of time (e.g., fluid challenge):

$$\frac{\text{total volume} \times \text{drops/mL of IV set}}{\text{time in minutes}} = \text{drops/min}$$

Formula 3

Drip (infusion) not based on weight (e.g., lidocaine drip):

$$\frac{\text{dose desired}}{\text{dose on hand}} \times \frac{\text{drops/mL of IV set}}{1} = \text{drops/min}$$

Formula 4

Drip (infusion) based on weight (e.g., dopamine drip):

$$\frac{\text{dose desired}}{\text{kg}} \times \frac{\text{wt (lb)}}{2.2\ \text{lb/kg}} = \text{dose desired}$$

$$\frac{\text{dose desired}}{\cancel{\text{kg}}} \times \frac{\text{wt}\ \cancel{\text{(lb)}}}{2.2\ \cancel{\text{lb/kg}}}$$

$$\frac{\text{dose desired}}{\text{dose on hand}} \times \frac{\text{drops/mL of IV set}}{1} = \text{drops/min}$$

APPLICATION OF FORMULA 1

The first of the four formulas listed in the previous section is used to calculate the amount of a drug to give a patient in a single dose on the basis of the desired dose (DD), or the amount ordered by medical direction; the dose on hand (DH) or the amount of the weight of the drug (grams, milligrams, micrograms); and the volume (V) or quantity (Q), or the amount of solution in which the drug is dissolved.

A 64-year-old woman is enjoying a round of golf when she suddenly steps in a hornets' nest and is stung multiple times. Because she is allergic to bee stings, she quickly heads back to the clubhouse and asks for help. A paramedic unit is dispatched. On arrival, the patient is in mild distress, with large hives appearing on her face and neck. Because of her age and the relatively mild signs and symptoms at this point, the paramedics avoid epinephrine and choose to administer diphenhydramine (Benadryl) 25 mg IM. Their prefilled syringe reads 50 mg/mL. How many milliliters should they administer?

Step 1: Choose the proper formula.

$$\frac{\text{desired dose}}{\text{dose on hand}} \times \frac{\text{volume (quantity)}}{1} =$$

Step 2: Fill in known values.

$$\frac{25\ \text{mg} \times 1\ \text{mL}}{50\ \text{mg}} =$$

Step 3: Cross out like terms; in this case, milligrams.

$$\frac{25\ \cancel{mg} \times 1\ mL}{50\ \cancel{mg}} = \frac{25 \times 1\ mL}{50} = \frac{25}{50}\ mL = 0.5\ mL$$

Step 4: Administer 0.5 mL of Benadryl IM to the patient.

Remember: whenever the dosage is less than 1, always place a zero before the decimal point.

Formula 1 Practice Problems

Remember the steps: cross out like terms and multiply across.

1. Administer epinephrine (Adrenalin) 1:1000 0.3 mg Sub-Q. The prefilled syringe reads 1 mg/mL. How many milliliters should you administer?
2. Administer furosemide (Lasix) 20 mg IV. Furosemide is supplied in a concentration of 40 mg/5 mL. How many milliliters should you administer?
3. Administer atropine sulfate 0.5 mg rapid IV push. The prefilled syringe reads 1 mg/10 mL. How many milliliters should you administer?
4. Administer verapamil (Isoptin) 5 mg slow IV push. The prefilled syringe reads 5 mg/2 mL (2.5 mg/mL). How many milliliters should you administer?
5. Administer adenosine 12 mg rapid IV push. The prefilled syringe reads 6 mg/2 mL. How many milliliters should you administer?

Formula 1 Answers

1. $$\frac{\text{DD: } 0.3\ \cancel{mg} \times \text{V(Q): } 1\ mL}{\text{DH: } 1\ \cancel{mg}} = 0.3 \times 1\ mL = \frac{0.3 \times \cancel{1}\ mL}{\cancel{1}} = \mathbf{0.3\ mL}$$

2. $$\frac{\text{DD: } 20\ \cancel{mg} \times \text{V(Q): } 5\ mL}{\text{DH: } 40\ \cancel{mg}} = \frac{20 \times 5\ mL}{40} = \frac{100}{40}\ mL = \mathbf{2.5\ mL}$$

3. $$\frac{\text{DD: } 0.5\ \cancel{mg} \times \text{V(Q): } 10\ mL}{\text{DH: } 1\ \cancel{mg}} = \frac{0.5 \times 10\ mL}{1} = \frac{5\ mL}{1} = \mathbf{5\ mL}$$

4. $$\frac{\text{DD: } 5\ \cancel{mg} \times \text{V(Q): } 2\ mL}{\text{DH: } 5\ \cancel{mg}} = \frac{5 \times 2\ mL}{5} = \frac{10}{5}\ mL = \mathbf{2\ mL}$$

5. $$\frac{\text{DD: } 12\ \cancel{mg} \times \text{V(Q): } 2\ mL}{\text{DH: } 6\ \cancel{mg}} = \frac{12 \times 2\ mL}{6} = \frac{24}{6}\ mL = \mathbf{4\ mL}$$

APPLICATION OF FORMULA 2

Formula 2 is used to calculate the amount of a drug to give a patient when infusing a measured amount of fluid in a set amount of time, such as in fluid challenges.

Your ALS unit is called out during a snowstorm to attend to an elderly man who has had the flu since yesterday. His daughter tells you that he has been vomiting, has had diarrhea for more than 24 hours, and has not been able to keep any fluids down. Your patient is weak and warm to the touch. He has elevated respiratory and pulse rates but a blood pressure of 88/60 mm Hg. His lung sounds are present bilaterally and clear. Medical direction tells you to administer a fluid bolus of 200 mL normal saline over a 20-minute period and then reevaluate the patient and call back. You decide to use a macrodrip infusion set that delivers 10 gtt (drops)/mL.

Step 1: Choose the proper formula.

$$\frac{\text{total volume} \times \text{gtt/mL of IV set}}{\text{time (in minutes)}} = \text{gtt/min}$$

Step 2: Fill in known values.

$$\frac{200\text{ mL} \times 10\text{ gtt/mL}}{20\text{ min}} = \text{gtt/min}$$

Step 3: Cross out like terms.

$$\frac{200\ \cancel{\text{mL}} \times 10\text{ gtt/}\cancel{\text{mL}}}{20\text{ min}} = \text{gtt/min}$$

Step 4: Multiply across.

$$\frac{200 \times 10\text{ gtt}}{20\text{ min}} = \frac{2000\text{ gtt}}{20\text{ min}} = \frac{100\text{ gtt}}{\text{min}}$$

Sometimes a measured amount of fluid is ordered to be given over a period of hours. To make this conversion, change hours to minutes by multiplying by 60 (for example, 5 ~~hr~~ × 60 min/~~hr~~ = 300 min) and continue as before.

You reassess the patient during and after the fluid challenge. His lungs remain clear, his pulse begins to drop to a normal range, his respirations are less frequent, and his blood pressure rises to 96/70 mm Hg. Medical direction tells you to continue the IV at a keep-open rate and transport the patient to the hospital.

Formula 2 Practice Problems

Remember the steps: cross out like terms and multiply across.

1. Administer 60 mL of fluid containing a medication over a 10-minute period. Use a microdrip IV infusion set that delivers 60 gtt/mL. How many drops per minute should be administered?
2. Administer 120 mL of Ringer's lactate as a fluid challenge over a 20-minute period with an IV infusion set that delivers 20 gtt/mL. How many drops per minute should be administered?
3. Administer 150 mL of normal saline over a 30-minute period with an IV infusion set that delivers 10 gtt/mL. How many drops per minute should be administered?
4. Administer 300 mL of Ringer's lactate over a 30-minute period with an IV infusion set that delivers 10 gtt/mL. How many drops per minute should be administered?
5. Administer 1000 mL of normal saline over a 5-hour period with a macrodrip IV infusion set that delivers 15 gtt/mL. How many drops per minute should be administered?

Formula 2 Answers

1. $$\frac{60\ \cancel{\text{mL}} \times 60\text{ gtt/}\cancel{\text{mL}}}{10\text{ min}} = \frac{60 \times 60\text{ gtt}}{10\text{ min}} = \frac{3600\text{ gtt}}{10\text{ min}} = 360\text{ gtt/min}$$

2. $$\frac{120\ \cancel{\text{mL}} \times 20\text{ gtt/}\cancel{\text{mL}}}{20\text{ min}} = \frac{120 \times 20\text{ gtt}}{20\text{ min}} = \frac{2400\text{ gtt}}{20\text{ min}} = 120\text{ gtt/min}$$

3. $$\frac{150\ \cancel{\text{mL}} \times 10\text{ gtt/}\cancel{\text{mL}}}{30\text{ min}} = \frac{150 \times 10\text{ gtt}}{30\text{ min}} = \frac{1500\text{ gtt}}{30\text{ min}} = 50\text{ gtt/min}$$

4. $$\frac{300\ \cancel{\text{mL}} \times 10\,\text{gtt}/\cancel{\text{mL}}}{30\ \text{min}} = \frac{3000\ \text{gtt}}{30\ \text{min}} = 100\,\text{gtt/min}$$

5. $$\frac{1000\,\cancel{\text{mL}} \times 15\,\text{gtt}/\cancel{\text{mL}}}{300\ \text{min}} = \frac{15000\ \text{gtt}}{300\ \text{min}} = 50\,\text{gtt/min}$$

APPLICATION OF FORMULA 3

Formula 3 is used to calculate the amount of a drug to give a patient by drip (infusion) when the dosage is based not on weight but on dose of medication per minute.

You are called to respond to the home of the base commander. On arrival, you find a 62-year-old male complaining of heart palpitations. You connect the cardiac monitor to find the patient with a narrow-complex supraventricular tachycardia at a rate of 178 beats/min. You have attempted to correct the arrhythmia with vagal maneuvers and adenosine to no avail. Medical direction orders you to administer an infusion of procainamide at 20 mg/min.

You have a peripheral IV in place capable of delivering 60 gtt/mL. Your secondary premixed bag of procainamide reads 100 mg/mL. At how many drops per minute should you run the procainamide to administer the proper dose?

Step 1: Choose the proper formula.

$$\frac{\text{DD (in minutes)} \times \text{gtt/mL of IV set}}{\text{DH}} = \text{gtt/min}$$

Step 2: Fill in known values.

$$\frac{20\ \text{mg/min} \times 60\ \text{gtt/mL}}{100\ \text{mg/mL}} = \text{gtt/min}$$

Step 3: Cross out like terms. In this case, both mg and mL can be crossed out.

$$\frac{20\ \cancel{\text{mg}}/\text{min} \times 60\,\text{gtt}/\cancel{\text{mL}}}{100\ \cancel{\text{mg}}/\cancel{\text{mL}}} = \text{gtt/min}$$

Step 4: Multiply across for drops per minute.

$$\frac{20/\text{min} \times 60\ \text{gtt}}{100} = \frac{20/\text{min} \times 60\ \text{gtt}}{100} = \frac{1200}{100}\ \text{gtt/min} = 12\ \text{gtt/min}$$

Formula 3 Practice Problems

Remember the steps: Cross out like terms and multiply across.

1. Administer an epinephrine infusion at 4 mcg/min. Add 1 mg epinephrine to a bag of 250 mL normal saline. Use a microdrip infusion set that delivers 60 gtt/mL. What is the drip rate in drops per minute?
2. Administer a procainamide infusion at 3 mg/min. Prepare the infusion by adding 1 g procainamide to a bag of 250 mL normal saline. Use a microdrip infusion set that delivers 60 gtt/mL. What is the drip rate in drops per minute?
3. Administer an epinephrine infusion at 2 mcg/min. Prepare the infusion by adding 1 mg epinephrine to a bag of 500 mL normal saline. What is the drug concentration (DH)? What is the drip rate if a microdrip infusion set that delivers 60 gtt/mL is used?

Formula 3 Answers

1. 1 mg = 1000 mcg, so the DH (drug concentration) is 1000 mcg/250 mL = 4 mcg/mL.

$$\frac{\text{DD: } 4\ \text{mcg/min} \times 60\ \text{gtt/mL}}{\text{DH: } 4\ \text{mcg/mL}} = \frac{4\ \cancel{\text{mcg}}/\text{min} \times 60\ \text{gtt}/\cancel{\text{mL}}}{4\ \cancel{\text{mcg}}/\cancel{\text{mL}}} = \frac{4/\text{min} \times 60\ \text{gtt}}{4}$$
$$= \frac{240}{4}\ \text{gtt/min} = 60\ \text{gtt/min}$$

2. 1 g = 1000 mg, so the DH is 1000 mg/250 mL = 4 mg/mL.

$$\frac{\text{DD: } 3\ \text{mg/min} \times 60\ \text{gtt/mL}}{\text{DH: } 4\ \text{mg/mL}} = \frac{3\ \cancel{\text{mg}}/\text{min} \times 60\ \text{gtt}/\cancel{\text{mL}}}{4\ \cancel{\text{mg}}/\cancel{\text{mL}}} = \frac{3/\text{min} \times 60\ \text{gtt}}{4}$$
$$= \frac{180}{4}\ \text{gtt/min} = 45\ \text{gtt/min}$$

3. 1 mg = 1000 mcg, so the DH is 1000 mcg/500 mL = 2 mcg/mL.

$$\frac{\text{DD: } 2\ \text{mcg/min} \times 60\ \text{gtt/mL}}{\text{DH: } 2\ \text{mcg/mL}} = \frac{2\ \cancel{\text{mcg}}/\text{min} \times 60\ \text{gtt}/\cancel{\text{mL}}}{2\ \cancel{\text{mcg}}/\cancel{\text{mL}}} = \frac{2/\text{min} \times 60\ \text{gtt}}{2}$$
$$= \frac{120}{2}\ \text{gtt/min} = 60\ \text{gtt/min}$$

APPLICATION OF FORMULA 4

Formula 4 is used to calculate the amount of a drug to give a patient by drip (infusion) when the dosage is based on weight.

... You are transporting an elderly woman with a history of multiple cardiac events to the hospital. En route, her blood pressure begins to drop even though her cardiac rhythm shows only sinus tachycardia at a rate of 120 beats/min. You contact medical direction and are told to begin a dopamine infusion at 2 mcg/kg/min and to titrate it until her blood pressure is approximately 90 mm Hg systolic. Prepare the infusion by adding 800 mg of dopamine to a 500-mL bag of normal saline. The patient weighs 110 pounds.

In this last formula, one more step in the process must be calculated to determine what the desired dose is on the basis of the patient's weight in kilograms. Remember that 1 kg = 2.2 pounds.

Step 1: Choose the proper formula.

$$\frac{\text{DD}}{\text{kg}} \times \frac{\text{lb}}{2.2\ \text{lb/kg}} = \frac{\text{DD}}{\cancel{\text{kg}}} \times \frac{\cancel{\text{lb}}}{2.2\ \cancel{\text{lb}}/\cancel{\text{kg}}} = \text{DD}$$

$$\frac{\text{DD}}{\text{DH}} \times \frac{\text{drops/mL of IV set}}{1} = \text{drops per minute}$$

Step 2: Determine the patient's weight in kilograms by dividing the weight in pounds by 2.2.

$$\frac{110\ \text{lb}}{2.2\ \text{lb/kg}} = \frac{110\ \cancel{\text{lb}}}{2.2\ \cancel{\text{lb}}/\text{kg}} = 50\ \text{kg}$$

Step 3: Multiply the weight in kilograms by DD/kilograms and cross out like terms to determine the DD, *with weight adjustment.* If this patient weighs 50 kg, and the DD is 2 mcg/kg per minute:

$$\frac{50\ \text{kg} \times 2\ \text{mcg}}{\text{kg/min}} = \frac{50\ \cancel{\text{kg}} \times 2\ \text{mcg}}{\cancel{\text{kg}}/\text{min}} = \frac{50 \times 2\ \text{mcg}}{\text{min}} = 100\ \text{mcg/min}$$

Step 4: Prepare the infusion and calculate the DH (drug concentration).

800 mg = 800,000 mcg to be added to 500 mL normal saline

$$\frac{800{,}000\ \text{mcg}}{500\ \text{mL}} = 1600\ \text{mcg/mL}$$

Step 5: Determine the drip rate with a microdrip IV infusion set that delivers 60 gtt/mL.

$$\frac{100\ \text{mcg/min} \times 60\ \text{gtt/mL}}{1600\ \text{mcg/mL}} = \text{gtt/min}$$

Step 6: Cross out like terms and multiply across.

$$\frac{100\ \cancel{\text{mcg}}/\text{min} \times 60\ \text{gtt}/\cancel{\text{mL}}}{1600\ \cancel{\text{mcg}}/\cancel{\text{mL}}} = \text{gtt/min}$$

Note: The zeros can be crossed out if only one above and one below the line are crossed out at a time, as in this example:

$$\frac{10\cancel{0}\ \cancel{\text{mcg}}/\text{min} \times 6\cancel{0}\ \text{gtt}/\cancel{\text{mL}}}{16\cancel{00}\ \cancel{\text{mcg}}/\cancel{\text{mL}}} = \text{gtt/min}$$

If the problem is rewritten by leaving out everything that has been crossed out, it becomes much simpler:

$$\frac{10/\text{min} \times 6\ \text{gtt}}{16} = 3.75\ \text{gtt/min}\quad (\text{round off to } 4\ \text{gtt/min})$$

PRACTICAL APPLICATION PROBLEMS

Answers to the problems in this section are found in Appendix E.

Ventricular Fibrillation

You are assisting in the resuscitation of a 49-year-old man who is unresponsive and apneic. The cardiac monitor shows ventricular fibrillation, and the paramedic in charge has directed you to prepare and give the medications. Cardiopulmonary resuscitation (CPR) is being performed, defibrillation has been appropriately accomplished, the patient has been successfully intubated and is being bagged with 100% oxygen, and an IV has been established. ...

1. The first medication to administer is epinephrine 1:10,000 1 mg IV push. Your prefilled syringe reads epinephrine 1:10,000 1 mg/10 mL. How many milliliters should you administer?

... Five minutes later you are asked to repeat the above dose of epinephrine, but you discover that your IV has infiltrated. The paramedic directs you to administer twice the dose through the endotracheal tube. The patient has good lung sounds bilaterally with bagging. ...

2. You begin to prepare 2 mg of epinephrine 1 : 1000. With prefilled syringes containing 1 mg/mL each, how many milliliters of the epinephrine will you administer?

... After additional ventilating and CPR, the ventricular fibrillation continues. Another IV has been established and is patent. You are now ordered to administer amiodarone 300 mg IV. ...

3. Your prefilled syringe reads amiodarone 50 mg/mL. How many milliliters should you administer?

... CPR, artificial ventilation, and defibrillation continue, and the epinephrine has been appropriately repeated. You are now ordered to administer 150 mg of amiodarone IV. ...

4. With another prefilled syringe that reads amiodarone 50 mg/mL, how many milliliters should you administer this time?

... Attempts to resuscitate have resulted in the patient establishing a rhythm and pulse.

Pulseless Electrical Activity

You have responded to a call for help from the daughter of an 81-year-old man who has fallen. As you pull in the driveway, the dispatcher reports that the daughter called again to say that her father is now unresponsive. On arrival you assess the patient and find that he is apneic and pulseless. You begin CPR, ventilating with 100% oxygen, and apply the quick-look paddles only to see a sinus tachycardia on the monitor at 120 beats/min. You once again check for a pulse but do not find one.

Your partners continue CPR, intubate the patient, and start an IV line. You administer a dose of epinephrine and question his daughter regarding his medical history. You learn that he is a heavy drinker and was vomiting blood earlier today but refused to go to the hospital. Medical direction tells you to evaluate for hypovolemia by administering a bolus of 500 mL normal saline over the next 20 minutes. You set up your IV with a macrodrip IV infusion set that delivers 10 gtt/mL. ...

5. What is your drip rate per minute?

6. What is your drip rate per second?

... You notice that the patient's heart rate has dropped to 50 beats/min on the monitor. Medical direction now tells you to also administer a bolus of atropine 0.5 mg rapid IV push. Your prefilled syringe reads 1 mg/10 mL.

7. How many milliliters will you administer? (Show how your work fits into formula 1.)

Acute Coronary Syndromes

You are caring for a patient who reports chest pain that suggests cardiac origin. You and your partner have begun supportive care, including oxygen at 100%, vital signs, IV of normal saline to keep open, and positioning for comfort. Your protocol says to administer aspirin 320 mg. The bottle of aspirin in your drug box is labeled 160 mg/tablet.

8. How many tablets will you administer? (Hint: Use formula 1.)

Symptomatic Bradycardia

You respond to a law firm office for a 55-year-old woman with mild chest pain, dizziness, and shortness of breath that began when she returned from lunch. She is pale, cool, and moist to the touch but is oriented to person, place, time, and event. After beginning your supportive care, you find that the cardiac monitor shows a sinus bradycardia and her vital signs are as follows: blood pressure, 84/50 mm Hg; pulse, 50 beats/min; respirations, 20 breaths/min; lung sounds are clear.

You consider immediate transport, but the building's electric power is out because of a snowstorm and the elevators are not functioning. You decide to attempt to stabilize on scene.

After administering the maximum dosage of atropine without change and without response to the transcutaneous pacemaker (TCP) that you applied when the patient's heart rate did not improve with the atropine, you are advised by medical direction to initiate a dopamine infusion at 4 mcg/kg per minute. The patient weighs 110 pounds.

Your drug box contains dopamine in a prefilled syringe that reads dopamine 800 mg and bags of 500 mL normal saline. You also choose a microdrip infusion set that delivers 60 gtt/mL. ...

9. Calculate the DD by changing pounds to kilograms and then multiplying kilograms by the desired dose of 4 mcg/kg per minute.

10. Calculate the DH when you add 800 mg (800,000 mcg) to 500 mL.

11. What will the drip rate be per minute?

12. What will the drip rate be per second?

... The dopamine infusion is ineffective, your patient is feeling worse, and the snowstorm is getting worse. Medical direction is depending on you to "bring the emergency department to the patient." They direct you to now try administering an epinephrine infusion by adding epinephrine 1 mg to a bag of 250 mL normal saline and starting the drip at 2 mcg/min. (Hint: You can either add epinephrine 1 : 1000 or epinephrine 1 : 10,000 to the bag; both equal 1 mg, or 1000 mcg.) ...

13. What will the DH be?

14. What will the drip rate be in drops per minute?

15. What will the drip rate be in drops per second?

... Finally the epinephrine infusion works.

Neurologic and Endocrine Emergencies

Your patient is a severe diabetic who takes insulin on a daily basis. However, because of financial constraints, he did not take his insulin yesterday or today. He is confused and disoriented. Because you are not sure whether this is hyperglycemia or hypoglycemia and you do not have access to a glucometer, you choose to start an IV in a large vein and administer dextrose 50% 25 g (50 mL) IV push. The patient has no response, and you begin to suspect a possible drug overdose. Your next choice is naloxone (Narcan).

Your prefilled syringe contains 0.4 mg naloxone in 2 mL normal saline. The order is for 0.4 mg naloxone. You know that if he shows no response you may need to administer as much as 10 mg naloxone depending on what drug was used. You receive an order to give 0.8 mg of naloxone.

16. How much naloxone should you administer if medical direction orders 0.8 mg?

You have now responded to an 11-year-old girl with grand mal seizures. She weighs approximately 88 pounds and has a history of seizures caused by an injury as an infant. Her mother tells you that she had to stop giving her the usual medications because of financial constraints. Medical direction tells you to administer diazepam 5 mg slow IV push or until the seizures stop. Your pre-filled syringe contains 10 mg/mL.

17. How many milliliters will you administer IV push?

Your patient is a 51-year-old man newly diagnosed with diabetes. He is exhibiting signs and symptoms of an acute diabetic emergency, and medical direction advises the administration of 50% dextrose (0.5 g dextrose/mL) IV push. Your partner has established an IV in a large vein, and you estimate his weight to be approximately 165 pounds.

18. If medical direction wants you to give 25 g of 50% dextrose IV push to this patient, how many milliliters will you give?

You have been called by the local police unit to care for a prisoner who is exhibiting signs and symptoms of drug withdrawal while at the local jail. When you discover pinpoint pupils, hypotension, respiratory depression, and nausea, you realize that you are dealing with a patient who has overdosed on a drug. You call medical direction, and they direct you to administer 2 mg of naloxone. Your vial reads 0.4 mg/mL.

19. How many mL will you administer?

On a cold winter night your unit is called to care for and transport a homeless person found in a stairwell covered only with old newspapers. He appears to be hypothermic, and an empty bottle of an alcoholic beverage is found tucked under his body. He is breathing, has a pulse, and has a readable blood pressure. However, even with your examination, he is unresponsive. His pupils are slow to respond but eventually do constrict in response to light. He appears to be malnourished for his height. No identification or other information is available to you.

You bring him immediately into your warmed ambulance and decide to give him 50% dextrose and thiamine because you suspect that he is an undernourished alcoholic. The thiamine in the drug box is packaged as 100 mg/mL.

Once you have moved him to the ambulance, you have fortunately been able to initiate an IV of normal saline to keep open. Medical direction directs you to administer 200 mg of thiamine and transport as soon as possible.

20. How many milliliters will you administer?