MODULE 5

DILUTION OF DRY POWDERS AND SOLUTIONS

Dilution of Powders and Solutions Module

OBJECTIVES:

1. Given a dose of a drug that is to be administered to a patient and a specific amount of drug placed in a stated volume of solution or the concentration of the prepared drug solution, calculate the volume of drug solution required to administer the specified dose.

2. Given a dose of a drug that is to be administered to a patient and the directions for the dilution of a dry powdered drug, calculate the volume of drug solution required to administer the specified dose.

3. Given the concentration of a more concentrated stock solution and the volume and concentration of a less concentrated solution that is to be prepared, calculate the volume of the more concentrated stock solution and the volume of a diluent (like 0.9% Sodium Chloride Injection) required to prepare the less concentrated solution.

The skills required to perform these calculations are not unlike the skills you have been using in the previous modules. You will probably recognize many drugs that you have administered or have seen administered to patients in the past.

Many drug powders that were once reconstituted by personnel in the operating room are now prepared by the Pharmacy Service. You may still be required to perform some dosage calculations with these prepared solutions. If--and when--you are in a field situation, you may be required to prepare the solutions on your own. In any event, it is imperative that you demonstrate the ability to perform these calculations.

In some cases, the Pharmacy Service will reconstitute the powdered drugs like thiopental sodium for you. In these instances, you must be able to use the expressed concentration of the solution to calculate a dose of the drug.

Suppose the Pharmacy Service prepared the following standard item.

THIOPENTAL ANESTHESIA KIT:

The kit consists of one 5-gram bottle of thiopental sodium for injection and one 250-milliliter bottle of sodium chloride injection. Therefore, once reconstituted, the 250 milliliters of solution contains 5 grams of thiopental sodium.

PROBLEM:

You wish to administer 250 milligrams of thiopental sodium to a patient. Calculate the volume of the solution that would be used to administer the thiopental to the patient.

STEP 1: Express the strength of the drug solution as your "IF" ratio statement:

$$\text{IF} \quad \frac{\text{5 grams of thiopental}}{\text{250 milliliters of solution}}$$

STEP 2: Express the unknown quantity as your "THEN" ratio statement:

$$\text{THEN} \quad \frac{\text{0.250 gram of thiopental}}{\text{X milliliters of solution}}$$

(NOTE: Remember that the amounts must be expressed in the same units.)

STEP 3: Combine the "IF" and the "THEN" statements to make a ratio and proportion statement and solve for X.

$$\text{IF} \quad \frac{\text{5 grams thiopental}}{\text{250 milliliters soln}} \quad \text{THEN} \quad \frac{\text{0.25 gram thiopental}}{\text{X milliliter soln}}$$

$$(5)(X) = (0.25)(250)$$

$$X = 62.5$$

(Divide each side of the equation by 5)

$$X = 12.5 \text{ milliliters}$$

Perform the calculations as indicated:

The Pharmacy Service has prepared a 2.5% solution of thiopental sodium. You wish to administer a dose of 300 milligrams of thiopental to a patient. Calculate the volume of the 2.5% thiopental solution required to supply the 300 mg of the drug.

STEP 1: Express the strength of the drug solution as your "IF" statement:

2.5% = IF _____ grams of thioipental
_____ milliliters of solution

STEP 2: Express the unknown quantity as your "THEN" ratio statement:

THEN _____ gram of thiopental
_____ milliliters of solution

STEP 3: Combine the "IF" and the "THEN" statements to make a ratio and proportion statement and solve for X.

IF _____ = THEN _____

ANSWER: 2.5% = 2.5 grams of thiopental / 100 milliliters of solution

IF 2.5 grams of thiopental / 100 milliliters of solution = THEN 0.3 gram of thiopental / "X" milliliters of solution

(2.5)(X) = (100)(0.3)

2.5 X = 30

(Divide each side of the equation by 2.5)

X = 12 milliliters of thiopental

QUESTION:

You are supplied with a Thiopental Anesthesia Kit which contains the following: one 5-gram bottle of thiopental sodium for injection and one 250-milliliter bottle of sodium chloride injection. You wish to administer a dose of 275 milligrams of thiopental to a particular patient. Calculate the volume of the prepared solution you must administer to the patient in order to supply the 275 milligrams of drug.

STEP 1: Express the strength of the prepared drug solution as your "IF" ratio statement:

IF

STEP 2: Express the unknown quantity as your "THEN" ratio statement:

THEN

STEP 3: Combine the "IF" and the "THEN" statements to make a ratio and proportion statement and solve for X.

ANSWER: IF $\frac{\text{5 grams thiopental}}{\text{250 milliliters solution}}$ = THEN $\frac{\text{0.275 gram thiopental}}{\text{X milliliters solution}}$

(5)(X) = (0.275)(250)

5 X = 68.75

(Divide each side of the equation by 5)

X = 13.75 rounded to 13.8 milliliters

QUESTION:

You are supplied with a 0.5% solution of Lidocaine HCL for a IV regional block. Calculate the volume of this solution required to supply a dose of 250 milligrams of lidocaine for the block.

SOLUTION: STEP 1: IF 0.5% = $\frac{\text{0.5 grams of lidocaine}}{\text{100 milliliters of soln}}$

STEP 2: THEN: $\frac{\text{0.250 gram of lidocaine}}{\text{X milliliters of soln}}$

STEP 3: IF $\frac{\text{0.5g lidocaine}}{\text{100 ml solution}}$ = THEN $\frac{\text{0.25g lidocaine}}{\text{X ml solution}}$

(0.5) (X) = (0.25) (100)

(Divide each side of the equation by 0.5)

X = 50 milliliters

In some instances, you may wish to dilute a concentrated solution (like 2% lidocaine HCl) in order to prepare a dilute solution (like 0.5% lidocaine). You must realize that in order to prepare a weaker solution from a concentrated solution you must be provided with the following information:

(a) The concentration of the concentrated solution you have on hand.

(b) The concentration of the weaker solution you are to prepare.

(c) The volume of the weaker solution that you are to prepare.

Thus, the dilution of a concentrated solution is not difficult if you follow the steps listed below:

STEP 1: Calculate the amount of the drug/chemical that must be present in the prepared weaker solution.

STEP 2: Calculate the volume of the concentrated solution that required to supply the amount of drug/chemical that you calculated in STEP 1.

STEP 3: Determine the volume of diluent that must be used to prepare the weaker solution.

The following is an example problem that is solved using this STEP-BY-STEP procedure. After the problem is solved, a diagram will be provided which illustrates the steps of the problem solving technique.

PROBLEM: You wish to prepare 50 milliliters of 0.5% lidocaine hydrochloride solution. In supply you have 2.0% lidocaine

hydrochloride solution in a multiple-dose vial and a bottle of 0.9% Sodium Chloride Injection. Calculate the volume of 2% lidocaine solution and the volume of 0.9% Sodium Chloride Injection required to prepare the 0.5% solution.

STEP 1: Calculate the amount of lidocaine that must be present in 50 milliliters of 0.5% lidocaine solution.

$$0.5\% = \frac{0.5 \text{ gram of lidocaine}}{100 \text{ milliliters of solution}}$$

Thus, if you were preparing 100 milliliters of 0.5% lidocaine solution, you would need 0.5 gram of lidocaine. HOWEVER, you are only going to prepare 50 milliliters of the 0.5% solution.

$$\text{IF } \frac{0.5 \text{ g lidocaine}}{100 \text{ ml solution}} = \text{THEN } \frac{X \text{ g lidocaine}}{50 \text{ ml solution}}$$

$$(100)(X) = (0.5)(50)$$

$$100X = 25$$

(Divide each side of the equation by 100)

$$X = 0.25 \text{ grams (or 250 milligrams)}$$

Thus, 0.25 gram (or 250 milligrams) of lidocaine must be present in 50 milliliters of 0.5% lidocaine solution.

STEP 2: Calculate the volume of the 2% lidocaine solution that is required to supply the amount of drug calculated in STEP I (0.25 grams).

$$\text{2\% lidocaine solution} = \frac{2 \text{ grams of lidocaine}}{100 \text{ milliliters of solution}}$$

$$\text{IF } \frac{2 \text{ g lidocaine}}{100 \text{ ml solution}} = \text{THEN } \frac{0.25 \text{ g lidocaine}}{X \text{ ml solution}}$$

$$(2)(X) = (0.25)(100)$$

$$2X = 25$$

(Divide each side of the equation by 2)

$$X = 12.5 \text{ milliliters of } 2\% \text{ lidocaine soln}$$

Therefore, 12.5 milliliters of 2% solution will supply 0.250 g of lidocaine.

STEP 3: Determine the volume of diluent that must be used to prepare the weaker solution.

Remember, you wanted to prepare 50 milliliters of 0.5% lidocaine solution.

From STEP 2, you calculated that 12.5 milliliters of 2% solution was required to prepare the final solution.

Final volume of 0.5% lidocaine soln you are to prepare	=	50 ml
subtract the volume of 2% lidocaine solution used to prepare 0.5% soln	= -	12.5 ml
Volume of 0.9% NaCl Inj. required to prepare 0.5% soln		37.5ml

In order to prepare 50 milliliters of 0.5% lidocaine solution, one must combine 12.5 milliliters of 2% lidocaine solution and 37.5 milliliters 0.9% NaCl.

STEP 1: 50 milliliters of 0.5% lidocaine must contain 0.25 gram of lidocaine.

STEP 2: 12.5 milliliters of 2% solution would supply 0.25 gram of lidocaine.

STEP 3: 37.5 milliliters of 0.9% Sodium Chloride Injection added to the 12.5 milliliters of 2% solution would provide 50 milliliters of 0.5% lidocaine solution.

Solve the parts as indicated:

You wish to prepare 20 milliliters of 1% lidocaine solution. In supply you have a multiple-dose vial of 2% lidocaine solution and a bottle of 0.9% Sodium Chloride Injection. Calculate the volume of the 2% lidocaine solution and the volume of the 0.9% Sodium Chloride Injection required to prepare the 1% solution.

STEP 1: Calculate the amount of lidocaine that must be present in 20 milliliters of 1% lidocaine solution:

STEP 2: Calculate the volume of the 2% lidocaine solution that is required to supply the amount of lidocaine that was calculated in STEP 1.

STEP 3: Determine the volume of diluent that must be used to prepare the weaker solution:

SOLUTION: STEP 1 $1\% = \frac{1 \text{ gram lidocaine}}{100 \text{ milliliters solution}}$

IF $\frac{1 \text{g lidocaine}}{100 \text{ ml solution}} = \text{THEN} \quad \frac{X \text{ g lidocaine}}{20 \text{ ml solution}}$

$(100)(X) = (1)(20)$

$100X = 20$

(Divide each side of the equation by 100)

$X = 0.2$ gram of lidocaine

Thus, 20 milliliters of 1% lidocaine solution must contain 0.2 gram of lidocaine.

STEP 2 $2\% = \frac{2 \text{ grams of lidocaine}}{100 \text{ milliliters solution}}$

IF $\frac{2 \text{ g lidocaine}}{100 \text{ ml solution}} = \frac{0.2 \text{ g lidocaine}}{X \text{ ml solution}}$ THEN

$(2)(X) = (0.2)(100)$

$2X = 20$

(Divide each side of the equation by 2)

$X =$ 10 milliliters of the 2% solution

STEP 3

Volume of 1% solution that is to be prepared	=	20 ml
Minus the volume of 2% solution to be used to prepare 1% soln	=	- 10 ml
Volume of 0.9% NaCl Inj.. to be used as diluent	=	10 ml

Thus, 10 milliliters of 2% lidocaine solution added to 10 milliliters of 0.9% Sodium Chloride Injection will provide 20 milliliters of 1% lidocaine solution.

You wish to prepare 30 milliliters of 0.5% lidocaine solution. In supply, you have a multiple-dose vial of 1 1/2% lidocaine solution and a bottle of 0.9% Sodium Chloride Injection. Calculate the volume of 1 1/2% lidocaine solution and the volume of 0.9% NaCl Injection required to prepare the 30 milliliters of 0.5% lidocaine solution.

STEP 1: Calculate the amount of lidocaine that must be present in 30 milliliters of 0.5% lidocaine solution.

STEP 2: Calculate the volume of the 1 1/2% lidocaine solution that is required to supply the amount of lidocaine that was calculated in STEP 1:

STEP 3: Determine the volume of diluent that must be used to prepare the weaker solution:

SOLUTION:

STEP 1 IF $\frac{0.5\text{ g lidocaine}}{100\text{ ml solution}}$ = THEN $\frac{X\text{ g lidocaine}}{30\text{ ml solution}}$

$(100)(X) = (0.5)(30)$

$100X = 15$

(Divide each side of the equation by 100)

$X = 0.15$ gram of lidocaine

STEP 2 IF $\frac{1.5\text{ g lidocaine}}{100\text{ ml solution}}$ = THEN $\frac{.0.15\text{ g lidocaine}}{X\text{ ml solution}}$

$(1.5)(X) = (0.15)(100)$

$1.5X = 15$

(Divide each side of the equation by 1.5)

$X =$ 10 milliliters of 1 ½ % solution

STEP 3:

Volume of 0.5% solution that is to be prepared	=	30 ml
Menus the volume of 1 1/2% solution that is to be used to prepare 0.5% soln =		- 10 ml
Volume of 0.9% NaCl Inj..' to be used as diluent	=	20 ml

Thus, in order to prepare 30 milliliters of 0.5% lidocaine solution,
10 milliliters of 1 ½ % lidocaine solution would be combined with
20 milliliters of 0.9% Sodium Chloride Injection.

Here is another dilution problem that you may encounter during your practice:

You are supplied with fentanyl labeled 50 mcg/ml in a 5 ml vials and a bottle of 0.9% Sodium Chloride Injection. You wish to prepare 100 milliliters of fentanyl solution in a concentration of 5 mcg/ml. Calculate the volume of the concentrated fentanyl solution and the volume of the 0.9% NaCl Inj. required to prepare the weaker solution.

STEP 1: Calculate the amount of fentanyl (in micrograms) that must be present in 100 milliliters of fentanyl solution labeled 5 mcg/ml.

STEP 2: Calculate the volume of the 50 mcg/ml fentanyl solution that is required to supply the amount of fentanyl you calculated in STEP 1.

STEP 3: Determine the volume of 0.9% NaCl Injection required to prepare the product.

SOLUTION: We want to calculate the amount of fentanyl contained in 100 milliliters of solution labeled 5 mcg/ml.

STEP 1

IF $\frac{\text{5 mcg fentanyl}}{\text{1 ml solution}}$ = THEN $\frac{\text{X mcg fentanyl}}{\text{100 ml solution}}$

(1) (X) = (5) (100)

(X) = 500 mcg in 100 cc solution

STEP 2

IF $\frac{\text{50 mcg fentanyl}}{\text{1ml fentanyl}}$ = THEN $\frac{\text{500 mcg fentanyl}}{\text{X ml fentanyl}}$

(5)(X) = (1)(500)

5 X = 500

(Divide each side of the equation by 50)

X = 10 milliliters of the 50 mcg/ml soln

STEP 3:

Volume of 5 mcg/ml fentanyl solution to be prepared	=	100 ml
Menus volume of 50 mcg/ml fentanyl soln. used to prepare weaker soln	=	- 10 ml
Volume of 0.9% NaCl Inj. needed to prepare weaker solution	=	90 ml

Therefore, in order to prepare 100 milliliters of 5 mcg/ml fentanyl solution, 10 milliliters of 50 mcg/ml (2 vials) fentanyl solution and 90 milliliters of 0.9% NaCl Injection must be combined.

Solve the following problem:

You wish to prepare 50 milliliters of sufentanil solution in a concentration of 2 micrograms per milliliter. In supply, you have sufentanil in a concentration of 50 mcg/ml (2 ml vials) and a bottle of 0.9% NaCl Injection. Calculate the volume of the 50 mcg/ml sufentanil solution and the volume of the 0.9% NaCl Injection required to prepare the 2 mcg/ml solution.

SOLUTION:

STEP 1: Calculate the amount of sufentanil (in micrograms) that must be present in 50 milliliters of sufentanil solution labeled 2 mcg/ml.

$$\text{IF } \frac{\text{2 mcg sufentanil}}{\text{1 ml solution}} = \text{THEN } \frac{\text{X mcg sufentanil}}{\text{50 ml solution}}$$

(1) (X) = (2) (50)

X = 100 mcg of sufentanil

STEP 2: Calculate the volume of the 50 mcg/ml sufentanil solution that is required to supply the 100 mcg of sufentanil you calculated in STEP 1:

$$\text{IF } \frac{50 \text{ mcg sufentanil}}{1 \text{ ml solution}} = \text{THEN } \frac{100 \text{ mcg sufentanil}}{X \text{ ml solution}}$$

$$(50)(X) = (1)(100)$$

$$50X = 100$$

(Divide each side of the equation by 50)

$$X = 2 \text{ ml of the 50 mcg/ml sufentanil solution}$$

STEP 3: Determine the volume of 0.9% NaCl Injection required to prepare the product:

Volume of 2 mcg/ml sufentanil solution to be prepared	=	50 ml
Menus the volume of 50 mcg/ml sufentanil soln used to prepare weaker soln	=	- 2 ml
Volume of 0.9% NaCl Injection needed to prepare weaker soln	=	48 ml

The 2 milliliters of 50 mcg/ml sufentanil solution and 48 milliliters of 0.9% NaCl Injection combined will provide 50 milliliters of 2 mcg/ml sufentanil solution.

When you use these agents in your practice, you must certainly read and understand the strength of the medication provided. One of the agents you might encounter is sodium nitroprusside (Nipride), a potent vasodilator used as an antihypertensive. In order to prepare this agent, 50 milligrams of sodium nitroprusside (which is supplied in a vial) is diluted and added to 500 milliliters or 1,000 milliliters of 5% Dextrose Injection. The drug is infused at a rate of 0.25 to 10 micrograms/kilogram/minute.

PROBLEM: You wish to administer sodium nitroprusside at a dose of 0.5 mcg (microgram)/kg/minute to a patient who weighs 176 pounds. You prepared the medication by adding 50 mg of the drug to a 500 ml bottle of 5% Dextrose Injection. Calculate the volume of the drug solution that should be administered to the patient during a 1-minute period of time.

(NOTE: 1 milligram = 1,000 micrograms [mcg])

STEP 1: Calculate the amount of sodium nitroprusside (in micrograms) the patient is to receive during a 1-minute time period.

STEP 2: Calculate the volume of the prepared solution that must be administered to the patient in order to deliver the amount of nitroprusside figured in step 1.

SOLUTION:

(a)Convert the patient's weight into kilograms:

$$\text{IF } \frac{2.2 \text{ lb}}{1 \text{ kg}} = \text{THEN } \frac{176 \text{ lb}}{X \text{ kg}}$$

$$(2.2)(X) = (1)(176)$$

$$X = 80 \text{ kilograms}$$

(b) Calculate the amount of the drug the patient is to receive:

Dose: 0.5 microgram (mcg) per kilogram of body weight per minute.

Patient's Body Weight: 80 kilograms
Thus, the dose per one minute is:

$$\text{IF } \frac{0.5 \text{ mcg}}{1 \text{ kg}} = \text{THEN } \frac{X}{80 \text{ kg}}$$

$$(1)(X) = (0.5)(80)$$

$$X = 40 \text{ micrograms of drug per minute}$$

The drug solution was prepared by adding 50 milligrams of nitroprusside to a 500 milliliter bottle of 5% Dextrose Injection.

(a)Express the concentration of the drug solution:

$$\frac{50 \text{ milligrams of nitroprusside}}{500 \text{ milliliters of solution}}$$

By observation, the solution can be further simplified as follows:

NOTE: Divide the numerator and denominator by 50

$$\frac{1 \text{ milligram of nitroprusside}}{10 \text{ milliliter of solution}}$$

(b) Express the concentration of the drug in terms of micrograms per 10 milliliters of solution: (1000mcg = 1 mg)

$$\frac{\text{1000 micrograms of nitroprusside}}{\text{10 milliliters of solution}}$$

or $\frac{\text{100 micrograms of nitroprusside}}{\text{1 milliliter of solution}}$

(c) Calculate the volume of drug solution required to supply 40 micrograms of nitroprusside.

$$\text{IF } \frac{\text{100 mcg drug}}{\text{1 ml soln}} = \text{THEN } \frac{\text{40 mcg drug}}{\text{X ml soln}}$$

$$(100)(X) = (1)(40)$$

$$100X = 40$$

$$X = 0.4 \text{ milliliters of the prepared solution}$$

Therefore, a dose of 0.4 milliliters of the prepared nitroprusside solution would be administered to the patient during a 1-minute period of time in order to provide the 40 micrograms of drug.

Solve the following problem:

You wish to administer Sodium Nitroprusside at a dose of 0.8 mcg/kg/minute to a patient who weighs 154 pounds. You prepared the solution by adding 50 milligrams of nitroprusside to a 500 ml bottle of 5% Dextrose Injection. Calculate the volume of the prepared drug solution that should be administered to the patient during a 1-minute period of time.

SOLUTION:

STEP 1: Calculate the amount of sodium nitroprusside (in micrograms) the patient is to receive during 1 minut

(a) Convert the patient's weight from pounds to kilograms:

$$\text{IF } \frac{2.2 \text{ lb}}{1 \text{ kg}} = \text{THEN } \frac{154 \text{ lb}}{X \text{ kg}}$$

$$(2.2)(X) = (1)(154)$$

$$2.2X = 154$$

$$X = 70 \text{ kilograms}$$

(b) Calculate the dose of the drug in micrograms:

$$\text{IF } \frac{0.8 \text{ mcg}}{1 \text{ kg}} = \text{THEN } \frac{X \text{ mcg}}{70 \text{ kg}}$$

$$(1)(X) = (0.8)(70)$$

$$X = 56 \text{ micrograms of nitroprusside}$$

STEP 2: Calculate the volume of the prepared solution that must be administered to the patient in order to deliver the 56 micrograms of nitroprusside.

(Remember 1 mg = 1,000 mcg.)

$$\frac{50 \text{ mg drug}}{500 \text{ ml soln}} = \frac{50{,}000 \text{ mcg drug}}{500 \text{ ml soln}} = \frac{100 \text{ mcg drug}}{1 \text{ ml soln}}$$

Thus, the concentration of the drug is 100 micrograms per 1 ml of soln.

IF $\frac{\text{100 mcg nitroprusside}}{\text{1 ml solution}} = \text{THEN} \quad \frac{\text{56 mcg nitroprusside}}{\text{X ml solution}}$

$(100)(X) = (1)(56)$

$100X = 56$

(Divide each side of the equation by 10

$X = 0.56$ milliliters of the prepared nitroprusside soln

Therefore, the patient would be administered 0.56 milliliters of the prepared nitroprusside solution during a 1-minute period of time.

Solve the Following:

1. You wish to administer Esmolol Injection at a dose of 100 mcg/kg/minute for 5 minutes, to a patient who is hypertensive and tachycardiac. The patient weighs 176 pounds.

Calculate the number of milligrams (mg) the patient would receive in a 5-minute period.

2. You wish to administer Vecuronium Bromide (Norcuron) Injection at a rate of 0.8 mg/kg/minute, to a patient who weighs 110 pounds. Vecuronium 10 milligrams is supplied to you in 100 ml of 5%.dextrose. Calculate the volume (milliliters) of the prepared Norcuron solution that must beadministered to the patient in order to deliver 0.8 mcg/kg/minute.

3. You wish to administer Propofol (Diprivan) Injection at a dose of 0.2 mg/kg/minute, to a patient who weighs 132 pounds. Diprivan 500 mg/ 50 ml bottle is supplied to you. Calculate the volume in milliliters of the Diprivan solution that must be administered to the patient in order to deliver 0.2 mg/kg/minute.

4. You wish to administer Atracurium Besylate (Tracrium) Injection to a acute renal failure patient who weighs 154 pounds. Patient is to receive 0.3mg/kg of the drug. Tracrium is supplied in a 5-ml vial labeled 10 mg/ml. Calculate the volume (milliliters) of the Tracrium Injection that must be administered to the patient in order to deliver 0.3 mg/kg.

ANSWERS:

1. The patient would receive 40 milligrams of Esmolol in a 5-minute period.

2. The patient would receive 0.4 milliliters of Vecuronium Bromide solution per minute.

3. The patient would receive 1.2 milliliters of Diprivan per minute.

4. The patient would receive 2.1 milliliters of Atracurium.