Dosage Calculations

KEY TERMS
- body surface area
- conversion
- metric system
- nomogram
- ratio and proportion

LEARNING OBJECTIVES
Upon completion of this chapter, you will be able to:
1. Convert within the measuring system when given drug orders and available forms of the drugs.
2. Calculate the correct dose of a drug when given examples of drug orders and available forms of the drugs ordered.
3. Discuss why children require different dosages of drugs than adults.
4. Explain the calculations used to determine a safe paediatric dose of a drug.
To determine the correct dose of a particular drug for a patient, one should take into consideration the patient’s gender, weight, age and physical condition, as well as other drugs the patient may be taking. Frequently, the dose that is needed for a patient is not the dose that is available, and it is necessary to convert the dosage form available into the prescribed dosage. Doing the necessary mathematical calculations to determine what should be given is the responsibility of the prescriber who orders the drug, the pharmacist who dispenses the drug and the nurse who administers the drug. This helps to provide for a thorough set of checks on the dosage being given before the patient actually receives the drug. All nurses must ensure that they are familiar with each aspect of a drug label (Figure 5.1). In many institutions, drugs arrive at the patient care area in unit-dose form, prepackaged for each individual patient. The nurse who will administer the drug may come to rely on the prepackaged unit-dose that is sent from the pharmacy and may not even recalculate or recheck the dose to match the order that was written. Always ensure that the five ‘rights’ of medication administration (Nursing and Midwifery Council, 2008) are adhered to:

1. Right drug?
2. Right route?
3. Right dose?
4. Right time?
5. Right patient?

But mistakes can still happen, and the nurse, as the person who is administering the drug (and usually the last person to protect the patient from medication errors), is legally and professionally responsible for any error that might occur. It is necessary for practicing nurses to know how to convert drug orders into available forms of a drug to ensure that the right patient is getting the right dose of a drug.

FIGURE 5.1 Reading a drug label (sample drug label courtesy of Sanofi Aventis, Guildford, UK).
lists the standard units of the metric system. It is extremely important to be able to perform conversions within this measuring system, for example from grams into milligrams (mg). Some of the examples below will demonstrate this conversion. Box 5.1 illustrates how these conversions are performed. Where appropriate, always include the zero in front of the decimal point, for example 0.75 mg should not be written down as .75 mg; the zero should always be present. Likewise, 5 mg should not be written down as 5.0 mg. If the decimal point was not noted by the person administering the dose, a patient could receive 10 times too much.

### Other Systems

Some drugs are measured in units other than the metric system. These measures may reflect chemical activity or biological equivalence. One of these measures is the unit. A unit usually reflects the biological activity of the drug in 1 ml of solution. The unit is unique for the drug it measures: a unit of heparin would not be comparable with a unit of insulin.

The concentration, or strength, of some medicines can be expressed using other nomenclature:

- **The number of parts (by weight) of the active ingredient (drug) contained in a given volume (ml).** For example, the subcutaneous administration of 1 in 1000 adrenaline during acute anaphylaxis. This represents 1 g of adrenaline contained in 1000 ml of the injection solution.

- **Expressed as a percentage.** This is most commonly used to represent injections of large volume and for topical drugs. Where this percentage relates to a mixture of two solid drugs, this percentage is referred to as weight/weight (w/w). If the solid drug is dissolved in a liquid, the percentage is referred to as weight/volume (w/v), that is weight in g where the volume is 100 ml. Lastly, if the drug is a liquid dispersed in another liquid, this is known as volume/volume (v/v). For example, an intravenous 0.9% saline solution to replace lost fluids. A value of 0.9% represents 0.9 parts in 100, meaning 0.9 g of sodium chloride in 100 ml of the product.

- **Molarity.** This approach is used on a limited number of occasions, for example potassium chloride (KCl) infusions. To use this approach, students need to know that one ‘mole’ of a drug weighs (in grams) the same as the relative molecular weight of that drug. For example, the molecular weight of KCl is 74.6. Therefore, a one mole solution of KCl infusion contains 74.6 g KCl in 1 l of the solvent.

- In many cases, millimoles (mmol) are used to describe the molarity of a solution, where there are 1000 millimoles in a molar solution. For example, the KCl infusion is available in 20, 27 and 40 mmol/l solutions. Electrolyte values are also given in mmol. To calculate mmol the amount of substance in the blood in mg is divided by

### Measuring Systems

The **metric system** is the system of measure used in drug preparation and delivery. The European Pharmacopoeia established standards requiring that all prescriptions include the metric measure for quantity and strength of drug. The metric system is used worldwide and makes the sharing of knowledge and research information possible. The metric system uses the gram (g) as the basic unit of solid measure and the litre (l) as the basic unit of liquid measure. Table 5.1 lists the standard units of the metric system.

### Table 5.1 Basic Units of Measure in the Metric System

<table>
<thead>
<tr>
<th>Solid Measure</th>
<th>Liquid Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kilogram (kg) = 1000 grams (g)</td>
<td>1 litre (l) = 1000 ml</td>
</tr>
<tr>
<td>1 gram (g) = 1000 milligrams (mg)</td>
<td>1 millilitre (ml) = 1000 microlitres (µl)</td>
</tr>
<tr>
<td>1 milligram (mg) = 1000 micrograms (µg)</td>
<td></td>
</tr>
<tr>
<td>1 microgram (µg) = 1000 nanograms (ng)</td>
<td></td>
</tr>
</tbody>
</table>

**BOX 5.1 CONVERTING BETWEEN DIFFERENT UNITS**

As shown in Table 5.1, there are 1000 micrograms (µg) in every gram and 1000 grams in every kilogram. There are also 1000 ml in every l. Note how the units are in multiples of a thousand. You should be able to confidently convert between the units.

**Example 1:** Convert 650 mg into grams.

Knowing that there are 1000 mg in every 1 g, you should be able to work out that your answer is going to be less than 1 g. In this case, divide 650 mg by 1000 to give you the answer as 0.65 g.

**Example 2:** Convert 2360 g into kg.

Knowing that there are 1000 g in every 1 kg, you should be able to work out that your answer is going to be more than 1 kg. In this case, divide 2360 g by 1000 to give you the answer as 2.36 kg.

In examples 1 and 2, the values were converted from smaller units into larger ones, for example from g into kg; and the decimal point is moved to the left. If the conversion is from a larger to a smaller unit, you need to multiply your answer by 1000 or move your decimal point to the right three places.

**Example 3:** Convert 0.075 g into mg.

Knowing that there are 1000 mg in every 1 g, you should be able to work out that your answer is going to be less than 1 g. In this case, multiply 0.075 g by 1000 to give you the answer as 75 mg.

The same process is applied when converting between the units of volume.

**Example 1:** Convert 250 ml into l.

Knowing that there are 1000 ml in every 1 l, you should be able to work out that your answer is going to be less than 1 l. In this case, divide 250 ml by 1000 to give you the answer as 0.25 l.
the atomic weight, for example the amount of potassium in blood is 100 mg/l and the atomic weight is 40. Therefore 100 divided by 40 = 2.5 mmol/l.

**Calculating Dosage**

As mentioned above, because drugs are made available only in certain forms or dosages, it may be necessary to calculate what the patient should be receiving when interpreting a drug order. Frequently, tablets or capsules for oral administration are not available in the exact dose that has been ordered. In these situations, the nurse who is administering the drug must calculate the number of tablets or capsules that should be given to make up the ordered dose. The easiest way to determine this is to set up a *ratio and proportion* equation between the known values and the unknown values. The known value is the amount of drug available in one tablet or capsule; the unknown is the number of tablets or capsules that are needed for the prescribed dose:

\[
\frac{\text{amount of drug available}}{\text{one tablet or capsule}} = \frac{\text{amount of drug prescribed}}{\text{number of tablets or capsules to give}}
\]

This is more easily explained by working through an example. An order is written for 400 mg of paracetamol. The tablets that are available each contain 200 mg of paracetamol. How many tablets should be given? First, set up the equation given above where \(Y\) is the unknown number of tablets:

\[
\frac{200 \text{ mg}}{1 \text{ tablet}} = \frac{400 \text{ mg}}{Y}
\]

By cross-multiplying the ratio:

\[
200 \text{ mg} \times Y = 400 \text{ mg} \times 1 \text{ (tablet)}
\]

Rearrange and cancel units and numbers:

\[
Y = \frac{400 \text{ mg} \times 1 \text{ tablet}}{200 \text{ mg}}
\]

\(Y = 2\) tablets should be administered orally.

Try another example. An order is written for 0.05 g spironolactone to be given orally. The spironolactone is available in 25 mg tablets. How many tablets would you have to give? First, you will need to convert the grams into milligrams. Remember when converting from a larger unit to a smaller unit, you will need to multiply by 1000 (see Box 5.1).

To convert 0.05 g into mg:

\[
0.05 \times 1000 \text{ mg} = 50 \text{ mg}
\]

Therefore, 50 mg is the same as 0.05 g and the order has now been converted into the same unit as the available tablets. Now solve for the number of tablets that you will need.

\[
\frac{25 \text{ mg}}{1 \text{ tablet}} = \frac{50 \text{ mg}}{Y}
\]

\[
25 \text{ mg} \times Y = 50 \text{ mg} \times 1 \text{ (tablet)}
\]

\[
Y = \frac{50 \text{ mg} \times 1 \text{ tablet}}{25 \text{ mg}}
\]

\(Y = 2\) tablets should be administered orally.

Some tablets come with score markings that allow them to be cut. However, many tablets today come in a matrix system that allows for slow and steady release of the active drug. These drugs cannot be cut, crushed or chewed. Some drugs are enteric-coated to prevent them dissolving in the stomach, for example aspirin. In addition, neither capsules nor tablets that are designated as having delayed or sustained release should be cut. If the only way to deliver the correct dose to a patient is by cutting one of these preparations, consult the pharmacist to see if the drug is available in a smaller strength. Alternatively, a different drug or a different approach to treating the patient should be tried.

Other oral drugs come in liquid preparations. Many of the drugs used in paediatrics and for adults who might have difficulty in swallowing a pill or tablet are prepared in a liquid form. Some drugs that do not come in a standard liquid form can be prepared as a liquid by the pharmacist. If the patient is unable to swallow a tablet or capsule, check for other available forms and consult with the pharmacist about the possibility of preparing the drug in a liquid as a suspension or a solution. The same principle used to determine the number of tablets needed to arrive at a prescribed dose can be used to determine the volume of liquid that will be required to administer the prescribed dose. The ratio on the left of the equation shows the known equivalents, and the ratio on the right side contains the unknown. The phrase ‘amount of drug’ must appear in the numerator (top) of both ratios, and the volume to administer is the unknown (Y).

\[
\frac{\text{amount of drug available}}{\text{volume available}} = \frac{\text{amount of drug prescribed}}{\text{volume to administer}}
\]

Try this example: An order has been written for 200 mg ampicillin. The bottle states that the solution contains 125 mg/5 ml. How much of the liquid should you give?

\[
\frac{125 \text{ mg}}{5 \text{ ml}} = \frac{200 \text{ mg}}{Y}
\]

By cross-multiplying the ratio:

\[
125 \text{ mg} \times Y = 200 \text{ mg} \times 5 \text{ ml}
\]

Rearrange and cancel units and numbers:

\[
Y = \frac{200 \text{ mg} \times 5 \text{ ml}}{125 \text{ mg}}
\]

\(Y = 8\) ml of ampicillin will be administered orally.
Tailoring Drug Doses to Individual Patients

Drug doses can be calculated using the patient’s body weight, for example cytotoxic drugs used in chemotherapy. To calculate a drug dose, multiply the body weight of the patient by the drug dose required per kg body weight. For example, a patient weighing 65 kg requires a dose of 150 μg/kg:

\[
\text{body weight} \times \frac{\text{amount/kg}}{\text{body weight}} = \text{amount administered}
\]

\[65 \text{ kg} \times 150 \mu\text{g} = 9750 \mu\text{g} = 9.75 \text{ mg}
\]

Alternatively, the dose can be calculated from the patient’s body surface area (BSA); a more accurate representation of an individual’s metabolic processes than body weight. The BSA is calculated using a nomogram. A nomogram uses the patient’s body weight and height to calculate the BSA and is especially useful when calculating certain drug doses for paediatric patients (Figure 5.2) and patients receiving particular antineoplastic drugs. Using a ruler, a line is drawn between the patient’s body weight and height – where the line crosses the central scale, this is the patient’s BSA.

Methotrexate is administered orally at a dose of 15 mg/m². If a patient’s BSA is 2.1 m², what dose would you administer?

\[
\text{surface area} \times \frac{\text{amount/m}^2}{\text{surface area}} = \text{amount administered}
\]

\[2.1 \text{ m}^2 \times 15 \text{ mg/m}^2 = 31.5 \text{ mg of methotrexate}
\]

Practice your calculation skills regularly to make sure that you can figure out the dose of a drug to give. Periodically throughout this text you will find a ‘Focus on Calculations’ box to help you refresh your dosage calculation skills as they apply to the drugs being discussed.

Parenteral Drugs

All drugs administered parenterally (i.e. either by intradermal, subcutaneous, intramuscular or intravenous injection) must be administered in liquid form. The person administering the drug needs to calculate the volume of liquid that must be given to administer the prescribed dose. The same formula can be used for this determination that was used for determining the dose of an oral liquid drug:

\[
\frac{\text{amount of drug available}}{\text{volume available}} = \frac{\text{amount of drug prescribed}}{\text{volume of administer}}
\]

Try this example: an order has been written for 75 mg pethidine to be given intramuscularly. The vial states that it contains 1 ml of pethidine at 50 mg/ml. Set up the equation just as before:

\[
\frac{50 \text{ mg}}{1 \text{ ml}} = \frac{75 \text{ mg}}{Y}
\]

\[50 \text{ mg} \times Y = 75 \text{ mg} \times 1 \text{ ml}
\]

\[Y = \frac{75 \text{ mg} \times 1 \text{ ml}}{50 \text{ mg}}
\]

\[Y = 1.5 \text{ ml of pethidine will be delivered by intramuscular injection}\]

Intravenous Solutions

Intravenous (IV) solutions are used to deliver a prescribed amount of fluid, electrolytes, vitamins, nutrients or drugs directly into the bloodstream, either as a single dose or as an infusion. Single doses can be calculated using the equations described above. For infusions, although most hospitals now use electronically monitored delivery systems, it is still important to be able to determine the amount of an IV solution that should be given using standard calculations.

Infusions can be administered under the influence of gravity or using an infusion pump. The rate of flow using
a gravity-fed system will depend upon whether either a drug/clear fluid or blood/blood components are delivered: clear solutions are delivered at 20 drops/ml, blood/blood components at 15 drops/ml and paediatric giving sets (burettes) are delivered at 60 drops/ml. It is important to check these rates against the information provided with each giving set.

Information on the amount of drug to infuse and the length of time the infusion is to take are required when using the gravity-fed system.

The following equation is used to determine how many drops of fluid to deliver per minute:

\[
m\text{ drops/minute} = \frac{m\text{l of solution prescribed per h} \times \text{ drops delivered per ml}}{60 \text{ min/1 h}}
\]

That is, the number of drops per minute, or the rate that you will set by adjusting the valve on the IV tubing, is equal to the amount of solution that has been prescribed per hour times the number of drops delivered per millilitre (ml) divided by 60 minutes in an hour.

Try the following example: an order has been written for a patient to receive 400 ml of 5% (w/v) glucose over a period of 4 hours. Calculate how fast the delivery should be. Note that this is a clear solution and therefore should be delivered at 20 drops/ml.

Using the above equation:

\[
Y = \frac{400\text{ ml/4 h} \times 20\text{ drops/ml}}{60\text{ min/h}}
\]

Simplify:

\[
Y = \frac{100\text{ ml/1 h} \times 20\text{ drops/ml}}{60\text{ min/h}}
\]

\[
Y = \frac{2000\text{ drops/h}}{60\text{ min/h}}
\]

\[
Y = 33.33\text{ rep.}
\]

\[
= 33\text{ drops/min (to the nearest whole number)}
\]

If a patient has an order to be given an IV drug, the same principle can be used to calculate the speed of the delivery. For example, an order is written for a patient to receive 75 ml of an antibacterial over 30 min. The IV set should deliver the drug at 20 drops/ml. Calculate how fast the delivery should be.

\[
Y = \frac{75\text{ ml/0.5 h} \times 20\text{ drops/ml}}{60\text{ min/h}}
\]

\[
Y = \frac{150\text{ ml/1 h} \times 20\text{ drops/ml}}{60\text{ min/h}}
\]

\[
Y = \frac{3000\text{ drops/h}}{60\text{ min/h}}
\]

\[
Y = 50\text{ drops/min}
\]

If using an infusion pump, the flow rate in ml/h must be calculated. To calculate the flow rate, the prescribed volume in ml is divided by the duration of the infusion (in hours).

\[
\text{flow rate} = \frac{\text{total volume (in ml)}}{\text{duration (h)}}
\]

If a volume of 500 ml is to be delivered over 4 hours, calculate the flow rate using the above equation.

\[
\text{flow rate} = \frac{500\text{ ml}}{4\text{ h}}
\]

\[
\text{flow rate} = 125\text{ ml/h}
\]

**Paediatric Considerations**

For most drugs, children require dosages different from those given to adults. The 'standard' drug dosage that is listed on package inserts and in many references refers to the dose that has been found to be most effective in the adult male. A child's body may handle a drug differently in all areas of pharmacokinetics: absorption, distribution, metabolism and excretion. The responses of the child's organs to the effects of the drug may also vary because of the immaturity of the organs. Most of the time a child requires a smaller dose of a drug to achieve the comparable critical concentration. On rare occasions, a child may require a higher dose of a drug.

For ethical reasons, drug research per se is not done on children. Over time, however, enough information can be accumulated from experience with the drug to have a recommended paediatric dosage. The British National Formulary (BNF) used in the clinical setting will have the paediatric dose listed if this information is available. Where the dose for children is not stated, prescribers should consult the BNF for Children. Sometimes there is no recommended dosage but a particular drug is needed for a child. In these situations, the appropriate dose can be determined using either (1) the child's exact body weight (as described above for adults), (2) ideal body weight for age as listed in the BNF, (3) using a nomogram specifically for infants and children (see Figure 5.2) or (4) BSA based on the adult dose. The latter approach is based on knowledge that the average BSA of a 70-kg adult is 1.8 m²:

\[
\text{approximate dose} = \frac{\text{surface area of patient in m}^2}{1.8\text{ m}^2} \times \text{adult dose}
\]

**Points to Remember**

- The metric system is used in drug preparation and delivery.
- The European Pharmacopoeia requires that all prescriptions include the metric measure for quantity and strength of drug. All drugs are dispensed in the metric system.
• It is important to know how to convert dosages within the metric system. The method of ratio and proportion, which uses basic principles of algebra to find an unknown, is the easiest method of converting doses within systems.
• Children require different dosages of most drugs from those of adults because of the way their bodies handle drugs and the way that drugs affect their tissues and organs.
• The dose given to a child should be calculated according to either the recommended dose for their age, their body weight or by using a nomogram to calculate their BSA.

CHECK YOUR UNDERSTANDING

Answers to the questions in this chapter may be found in the answer key in the back of the book.

Multiple Choice
Select the most appropriate response to the following.

1. Digoxin 0.125 mg is ordered for a patient who is having difficulty swallowing. The bottle of digoxin elixir reads 0.05 mg/2 ml. How much would you give?
   a. 5 ml 
   b. 0.5 ml 
   c. 1.5 ml 
   d. 1 ml

2. An order is written for 250 mg ampicillin orally. The drug is supplied in liquid form as 125 mg/5 ml. How much of the liquid should be given?
   a. 12.5 ml 
   b. 10 ml 
   c. 7.5 ml 
   d. 5 ml

3. An order is written for 1000 ml of normal saline to be administered intravenously over 10 hours. What is the IV flow rate?
   a. 50 ml/h at 20 drops/ml 
   b. 50 ml/h at 15 drops/ml 
   c. 100 ml/h at 20 drops/ml 
   d. 100 ml/h at 15 drops/ml

4. Capecitabine is administered orally to adults at a dose of 1.25 mg/m². If a patient has a surface area of 1.84 m², what dose of capecitabine would be needed?
   a. 230 mg 
   b. 23 mg 
   c. 2.3 mg 
   d. 0.23 mg

5. A patient needs to take 0.75 g tetracycline orally. The drug comes in 250 mg tablets. How many tablets should the patient take?
   a. 2 tablets 
   b. 3 tablets 
   c. 4 tablets 
   d. 30 tablets

6. Aminophylline is supplied in a 500 mg/2.5 ml solution. How much would be given if an order were written for 100 mg aminophylline IV?
   a. 5 ml 
   b. 1.5 ml 
   c. 2.5 ml 
   d. 0.5 ml

Complete the Following Problems

1. Change to equivalents within the system:
   a. 100 mg = _____g 
   b. 1500 g = _____kg 
   c. 1l = _____ml 
   d. 500 ml = _____l


3. Ordered: 0.4 mg. Available: 1.2 mg/2 ml. Dose administered: _____ml.


Bibliography and References

British Medical Association and Royal Pharmaceutical Society of Great Britain. (2008). British National Formulary. London: BMJ & RPS Publishing. This publication is updated biannually; it is imperative that the most recent edition is consulted.

British Medical Association and Royal Pharmaceutical Society of Great Britain. (2008). British National Formulary for Children. London: BMJ & RPS Publishing. This publication is updated annually; it is imperative that the most recent edition is consulted.


