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In this article...
- Reasons why drug calculation errors occur
- How to calculate drug doses and infusion rates

How to calculate drug doses and infusion rates accurately

Key points

Many medication errors are due to health professionals not understanding the units of measurement or making mistakes in their calculations

A number of medication errors are caused by failure to convert between different units of measurement correctly

The main weight measurements nurses must be familiar with, and confident converting between, are grams, milligrams, micrograms and nanograms

It is important to be able to explain calculation methods and how you arrived at an answer

Double-checking is recommended for all complex calculations, with each nurse doing the calculation independently, then checking the answer together

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Abstract Nurses need to be confident in calculating drug doses to safety administer medicines to patients as prescribed. This article provides essential information on how to calculate drug doses and infusion rates. It is an extract from the Nursing Times Learning unit Drug Calculations in Practice, which includes clinical scenarios to test your calculations.

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Many drugs in healthcare are given in error, and miscalculation is one of the factors contributing to these errors (National Patient Safety Agency, 2009a; Department of Health, 2004). The administration of medicines is a fundamental nursing skill, and requires complex knowledge and skills to undertake safely (Nursing and Midwifery Council, 2010). One of the skills required is the ability to calculate drug doses and rates of drug administration to administer them to the patient as prescribed.

Medication errors

In a review of medication error incidents reported to the National Reporting and Learning System over six years between 2005 and 2010, 525,186 incidents were reported. Of these, 86,821 (16%) of incidents reported actual patient harm; 822 (0.9%) resulted in death or severe harm (Cousins et al, 2012). This highlights the importance of ascertaining the factors behind medication errors, and potential solutions to these errors.

Medication errors are most frequently due to the wrong dose, omitted or delayed medication or the wrong medication being administered (NPSA, 2009a).

Calculation errors

The most frequently cited error resulting in the wrong dose being administered stems from calculation errors. However, these can have different contributing factors. Evidence suggests that most medication errors are caused by health professionals:

- Not understanding the units of measurement for medication, for example 'nanograms' and 'micrograms';
- Using the wrong equipment, for example the wrong size needle for injection;
- Making mistakes in their calculations that result in the wrong dose or rate of medicine being administered (NPSA, 2009a; 2009b).

These errors can be the result of health professionals not having the right knowledge or skills, or a result of other factors, such as distractions or stress.

Medication errors have been identified across acute, community, general practice, learning disability and mental health clinical areas, making key calculation skills applicable to all nurses (National Reporting and Learning System, 2012). Calculation skills are particularly important in children's nursing, since evidence suggests that a disproportionate number of calculation errors are found in children aged 0-4 years (NPSA, 2009b).

Evidence indicates that awareness of potential risks in certain procedures can help nurses to anticipate errors and be more vigilant in preventing them (Vincent, 2012). More recent thinking on medication errors emphasises the need not just to prevent an error in the calculation, but to prevent any error from reaching the patient (Vincent, 2012).

Understanding drug measurements

To calculate and administer the correct dose of a medicine to a patient, nurses need to understand the different measurements used for drug dosages in healthcare and be able to convert between different units of measurement. Drugs are generally measured according to either:

- The weight of a drug (grams, milligrams and micrograms, for example);
- The volume (millilitres and litres);
- Standardised international units;
- Strength of solution, when a weight of a drug is dissolved in a volume of liquid (for example milligrams per millilitre).
- Percentages, when a drug is 100 parts of a product.

Table 1 provides a summary of dosage measurements.

A number of medication errors have been made through not converting between different units of measurement correctly, resulting in doses of 10 or 100 times of those prescribed (NPSA, 2009b). For example, there have been a number of fatalities through not understanding how to measure insulin units, mistakenly measuring this in millilitres and administering large doses of insulin (NPSA, 2010) (Box 1).

Drugs are commonly prescribed and labelled according to their weight or, for solutions, their strength – the weight dissolved or suspended in a specific volume (weight per volume or 'w/v').

Box 1 Drugs measured in units

- Some drugs such insulin are measured in units
- Insulin is most commonly supplied as 100 units/ml
- Insulin is administer using an insulin syringe which is calibrated in units
- Some manufacturers are now producing a 200 unit/ml strength
- Units should never be abbreviated to U because of confusion with 0, which can result in error

Fig 1. Converting units of measurement

Unit of measurement	Relationship
Kilograms	Largest
Grams (1kg = 1000g)	
Milligrams (1kg = 1000 000mg)	
Micrograms (1kg = 1000 000 000 micrograms)	
Nanograms (1kg = 1000 000 000 000 nanograms)	Smallest

Converting to different units of weight

The main weight measurements that nurses must be familiar with, and confident converting between, are grams, milligrams, micrograms and nanograms. The relationship between each of these measurements is a factor of 1,000 (Fig 1), so conversions require nurses to multiply or divide dosages by 1,000.

The prescribed dose is always converted to the units of the available drug dose, so that it is easier to compare the prescription with how the medicines is labelled. For example, if the prescription given for benzylpenicillin is 1.8g, but the available vials for this drug are 600mg, to compare the dosages, the same unit of measurement is required.

Table 1. Units of measurement used in medicine dosage

Unit of measurement	Abbreviation	Description
Grams	g	These measure the weight of a drug
Milligrams	mg	
Micrograms	Do not abbreviate	
Nanograms	Do not abbreviate	
Litres	L (must be a uppercase)	These measure the volume of a solution
Millilitres	ml	
Standardised units	U or IU, however guidance recommends 'units' should be written in full (NRLS, 2010)	The unit is a measure of a specific therapeutic effect of a drug. The therapeutic effect has been standardised for each drug so they can be prescribed as unit dosages
Millimols	mmol	The smallest part of a chemical is an atom. When different chemical atoms are combined together to make a chemical substance this is called a molecule. A mol is a standardised number of molecules of a substance. A millimol is 1,000 times smaller than a mol (1mol = 1000mmol)
Ratio	For example, 1:1000	Ratios refer to a relationship between two quantities; this relationship always remains constant. For example, 1:1000 adrenaline refers to 1g adrenaline contained in 1000ml solution
Percentages	%	Percentages refer to an amount of a substance out of a possible 100. For example, in 5% glucose each 100ml of water contains five parts glucose

To convert 1.8g to the equivalent milligram dose, it must be multiplied by 1,000 to get 1800mg. It is important that conversions are checked carefully, through repeating the calculation or asking a colleague if unsure.

Once the conversion has been checked, the prescribed dose can be compared with the available dose to calculate how much of the medicine to administer.

In this example, we would need three 600mg vials of benzylpenicillin to get 1800mg.

For solid oral doses such as tablets or capsules, this type of calculation is usually quite straightforward, as the prescribed dose can be divided by the available drug dose to work out how many tablets to give. For example, if the prescription is for 30mg prednisolone, and the available tablets are 5mg, then the number of tablets to administer would be six. You can check this by adding up the dosage of each tablet and making sure the total is 30mg.

Converting between dose required and strength of available solution

When the medicine is a solution of a specific strength, calculations can become more complicated. Liquids (solutions and suspensions) are frequently used in children's nursing – for example for children who find swallowing tablets difficult or patients who have medicines administered via a percutaneous endoscopic gastrostomy (PEG) tube. These factors may be partly responsible for the higher error rate of errors in children's nursing (NPSA, 2009b; DH, 2004).

The strength of a medicine solution is expressed as the weight of the drug that is dissolved in a specific volume of solution, for example amoxicillin suspension 125mg/5ml. You will need to work out what volume needs to be administered to give the prescribed dose. So if 250mg amoxicillin is prescribed, the amount of suspension to administer would be two x 125mg, which would be 10ml.

Nurses use different methods to calculate the volume of solutions or number of ampoules to administer, depending on several factors, and do not necessarily stick to one method (Wright, 2013). The most important thing is finding a method that you feel comfortable and confident with.

The most commonly taught method is the 'nursing formula' (commonly quoted as the mantra 'what you want, over what you've got, multiplied by what it is in' (Fig 2). Although there is some criticism of this method (Wright, 2008) it can be a useful tool if you are tired, stuck or need to check a calculation.

Fig 2. The nursing formula

$$\text{Volume to administer} = \frac{\text{Dose required by patient} \times \text{volume of solution}}{\text{Dose available}}$$

In the amoxicillin example above, the nursing formula gives:

Volume to administer = (250/125) x 5 = 10ml

The evidence is beginning to suggest that methods used to manipulate the available weight/volume strength to find the required weight/volume strength could be less error-prone (Wright, 2013). More experienced and confident nurses seem to work easily in this way, but those who are less confident with numbers may find the formula safer.

Whatever method you use it is important to be able to explain your methods and how you arrived at an answer so you can participate in double-checking calculations with colleagues.

Double-checking

Double-checking is recommended for all complex calculations (NMC, 2010; DH, 2004). Checking must involve each nurse doing the calculation independently, then checking the answer together.

There is some evidence that double-checking can increase the risk of error, as each nurse relies on the other to pick up any error (Alsulami et al, 2012). This is why it is important that each nurse does the calculation independently before comparing.

Once the calculated answer is agreed; it is important to relate this back to clinical practice, to ensure that the calculated answer makes logical sense from your clinical and medicine knowledge. For example, is this an appropriate dose/volume for this medicine, this route or this age of patient?

Weight-based dosages

Medicines can also be prescribed according to the weight of the patient in kilograms, and this requires an additional calculation step to work out the dose for the patient's weight, before the administration dose can be calculated.

An example would be a prescription for ciclosporin of 10mg/kg. To calculate the child's prescription you need to know an accurate weight for the child in kilograms and then multiply this by the dosage specified.

For example, if the child's weight was 12kg then the dose required would be 10mg/kg x 12kg = 120mg.

Complexity increases risk

Calculations become more complex when they involve all of the skills we have covered so far.

For example, what proportion of an ampoule would you draw up if alfacalcidol of 50 nanograms/kg was prescribed intravenously for a child who weighs 8kg and the available ampoules were 1ml, at a strength of 2 micrograms/ml?

To calculate this you need to:

1. Calculate the dose for the individual child (50 nanograms/kg x 8kg = 400 nanograms)
2. Convert 2mcg/ml to nanograms/ml (2mcg/ml x 1,000 = 2000 nanograms/ml) (converting the available dosage to the prescribed dose avoids having a decimal point in the wrong place and so reduces risk of error in the calculation)
3. Calculate the volume of alfacalcidol required = 400/2,000 = 0.2ml

Alternatively, use the nursing formula:

400/2,000 x 1 = 0.2ml

This particular calculation would be considered to be a high-risk calculation because it has multiple stages in which errors can be introduced, and because of the small dosage involved and the conversion required between different units of measurement (NPSA, 2009b). Such calculations must be checked carefully with a second nurse to reduce the risk of error.

Calculating infusions correctly

Medications can also be prescribed in doses that need to be administered continuously for a specified period of time. An infusion is therefore administered at a flow rate that will give the required dosage per hour or minute for the patient.

Generally, clinical areas will have standardised infusion strengths that are always used for specific medications, with the rate varied according to the prescribed dose for that patient. For example, aminophylline is often prescribed as 500 micrograms/kg/hour and is infused using a solution of 500mg in 500ml sodium chloride.

Fig 3. **Formulas for calculating dosage per weight prescribed per minute**

Formula 1

$$\frac{\text{Dosage per kg* x Patient weight (kg) x 60}}{\text{What you have available (dosage* in syringe)}} \times \text{Volume it is dissolved in} = \text{rate per hour (ml/hr)}$$

Formula 2

$$\text{Dosage/kg* x Patient weight (kg) x 60} \div \frac{\text{Dosage* in infusion}}{\text{Volume of infusion}} = \text{ml/hr}$$

* Dosages need to be converted to the same unit of measurement

To administer the correct dose, the dose for the patient's weight (dose x kg) must be calculated, then the number of millilitres of the infusion to be administered per hour to give this dose can be calculated. This can be done in stages:

1. To calculate the millilitres/hour we first need to work out what dose is contained in one millilitre of the infusion dosage. We can do this by dividing the volume of the dosage by the weight of the medicine it contains. In this case 500ml/500mg = 1ml/mg. Therefore, 1ml of this infusion solution contains 1mg of aminophylline;
2. We then need to calculate (as we have done previously) the dosage per weight of the patient and convert this into milligrams (since the infusion strength available is in milligrams/millilitre). For a 45kg patient the dose required would be 45kg x 500 micrograms/kg = 22 500 micrograms. Converting this into milligrams would give 22.5mg (22,500/1,000);
3. Using the infusion strength, you know that 1ml would administer 1mg of aminophylline, so 22.5ml would administer 22.5mg. We would therefore set the infusion rate as 22.5ml/hour (22.5mg/1, where 1 is the strength of the dosage in ml/mg).

Converting dosages

Other complex calculations can give the prescribing dose for dose/kg/min. There are formulas that can help with these calculations to reduce the number of steps needed in converting dosages into the volume required per hour (Fig 3).

You will notice that these calculations include many of the skills introduced already; it is imperative that you are secure in all the basic calculation skills before moving on to more complex calculations.

Percentages

A percentage means 'out of 100', so a percentage concentration can be defined as the amount of drug in 100 parts of the product. For example, patients are frequently prescribed intravenous glucose 5%. This means that each 100ml of water in the infusion contains five parts of glucose.

The most common percentage you will encounter is the weight of a drug in a volume (number of grams in 100ml). An example is the local anaesthetic lidocaine, which comes in different percentage solutions, most commonly 0.5% to 2%:

- 1% lidocaine contains 1g of lidocaine in 100ml or 1000mg in 100ml;
- To find the number of milligrams in a millilitre you need to divide by 100;
- 1ml of 1% lidocaine contains 10mg per ml.

You can apply the same calculation to 0.5% lidocaine:

- 0.5% lidocaine contains 500mg of lidocaine in 100ml;
- To find the number of milligrams in a millilitre you need to divide 500mg by 100;
- 1ml of 0.5% lidocaine contains 5mg per ml.

Conclusion

This article has provided an overview of how to calculate drug doses but it is important to practise these skills regularly to help avoid errors that can result in patient harm.

After reading this article you can undertake the Nursing Times Learning unit Drug Calculations in Practice, which gives you an opportunity to work through clinical scenarios and test your knowledge. **NT**

Box 2. **Tips on avoiding error**

- Check abbreviations for example, prescribers should not abbreviate micrograms (mcg) as this can be confused with milligrams (mg)
- Use the British National Formulary (BNF) to check the usual dose and method of administration if you are unfamiliar with the drug
- Always double check any calculations
- Ask a colleague to carry out the calculation independently to verify that your answer is accurate

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