Good practice for drug calculations

A step-by-step guide for nurses, doctors and all other healthcare professionals

Pharmacyservices

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Introduction

Calculation errors are listed as one of the main risks with injectable medicines, outlined in the National Patient Safety Agency (NPSA) alert 20.[1*]

Of all medication errors successfully reported to the National Patient Safety Agency's National Reporting and Learning system between January 2005 and June 2006, wrong dose, strength or frequency was the most common type of error (28.9%).[1]

The aim of this pocket guide is to reduce patient safety incidents related to drug calculations by providing clear instructions and examples for healthcare professionals who perform such calculations.

Paediatric calculations have also been included and are highlighted with a green heading.

Double-checking calculations

When double-checking a calculation, perform the calculation **independently** and then compare your answer with your colleague's answer. The answers should be the same. If the answers are different, both practitioners should repeat the calculation **independently** and compare answers again.

If they are still different, contact a more senior colleague or a pharmacist for advice before prescribing or administering the dose.

* Note that the NPSA is now part of NHS England.

Commonly used abbreviations

NOTE: Many Trusts' drug policies state that certain abbreviations should not be used in prescriptions because they are a source of errors if misunderstood.

	Usually accepted abbreviations
kilogram	kg
gram	g
milligram	mg
microgram	should always be written as microgram
nanogram	should always be written as nanogram
litre	L
millilitre	ml or mL
units or international units	should always be written as units or international units
millimoles	mMol or mmol

The use of fractional doses is unsafe and should be avoided e.g.
0.1g should be written as 100mg
0.5mg should be written as 500 microgram

The unnecessary use of decimal points should be avoided e.g. 3mg not 3.0mg.

Top tips

- Drugs are formulated into medicines in such a way that most adult doses are easily calculated and predictable, e.g. 1 or 2 tablets, 1 or 2 capsules, 1 vial or ampoule of an injectable medicine, 1 suppository
- Before doing a calculation, it is sensible to estimate the dose you are likely to require so that you know whether your calculated answer seems reasonable, i.e. roughly what you expected
- To check doses use a reliable reference source, such as the BNF or BNF for Children
- For recommended administration methods, see local drug policies or national guides such as The IV Guide
- Dose volumes of oral liquid medicines are typically 5-20ml for adults and 5ml or less for children
- Crushing tablets should be avoided wherever possible. Some tablets, such as 'modified release' products should never be crushed. Always ask your pharmacist's advice before crushing tablets. If it must be done, a pestle and mortar or tablet crusher should be used and the tablet ground to as fine a powder as possible
- Always check children's and babies' weights carefully. Make sure they are weighed in kg and that their weight is recorded in kg
- If a calculation using weight or surface area gives an answer equivalent to or greater than the normal adult dose, reconfirm that it is what is really required
- If you are in any doubt about a calculation, stop and contact the ward pharmacist, an on-call pharmacist or the prescriber

Converting units of weight and volume

Metric units of measurement

Weight		Volume	
1kg	= 1000g	1L	= 1000ml
1g	= 1000mg	1ml	Weighs 1g
1mg	= 1000 micrograms	1000ml	Weighs 1000g or 1kg
1 microgram	= 1000 nanograms		

10- or 100-fold errors can occur if dosing units are converted incorrectly.

Principles

Doses may be calculated by bodyweight or body surface area.

For body surface area calculations in paediatrics, see BNF for Children.

Converting units of weight and volume

Example 1

A prescription for metformin 1g. How many milligrams is this?

To convert grams to milligrams multiply by 1000
1g = 1 x 1000 = 1000mg

Example 2

A patient is prescribed 0.0625mg digoxin. How many micrograms is this?

To convert milligrams to micrograms multiply by 1000
0.0625mg = 0.0625 x 1000 micrograms = 62.5 micrograms

Example 3

Amiodarone 5mg per kg body weight in 100ml 5% glucose over 20 mins is prescribed.
The patient weighs 60kg.

To calculate the dose
Dose = 5(mg) x 60(kg) = 300mg

See also pages 14 and 15 for examples of this type of calculation.

Calculating concentrations

Principles

The way the strength of a drug in a solution is described will affect the way a dose calculation is carried out. Doses may be expressed in a number of different ways:

1. Mass (weight) per volume of solution, e.g. mg in 10ml, mMol/L.
2. Units of activity per volume of solution, e.g. units per ml.
3. Percentage. This is the weight of the drug in grams that is contained in each 100ml of the solution. Common examples are 0.9% sodium chloride; 5% glucose.

% strength of solution	1ml of solution contains	100ml of solution contains	250ml of solution contains	1000ml of solution contains
1%	10mg of drug	1g of drug	2.5g of drug	10g of drug
10%	100mg of drug	10g of drug	25g of drug	100g of drug
20%	200mg of drug	20g of drug	50g of drug	200g of drug

- If you know the number of grams in 1000ml, divide by 10 to convert to % strength
- If you know the % strength, multiply by 10 to give the number of grams of drug in 1000ml
- If you know the % strength, divide by 100 to calculate the amount of drug in 1ml

Calculating concentrations

Example 1

The prescribed dose is 1g magnesium sulphate. Magnesium sulphate 50% injection is available.
50% = 50g in 100ml.
How many ml contains 1g magnesium sulphate?
Number of ml containing 1g = $\frac{100\text{ml} \times 1\text{g}}{50\text{g}}$ = 2ml

Another way of thinking about this is: 50g in 100ml = 5g in 10ml = 1g in 2ml

Example 2

Thiopentone 2.5% infusion is prescribed. What volume is required to administer a dose of 100mg?
2.5% = 2.5g in 100ml
100mg is contained in $\frac{100\text{mg} \times 100\text{ml}}{2500\text{mg}}$ = 4ml

Another way of thinking about this is:
Thiopentone 2.5% = 2.5g in 100ml = 2500mg in 100ml = 25mg in 1ml = 100mg in 4ml

See also pages 14 and 15 for examples of this type of calculation.

Ratios

Strengths of some drugs such as adrenaline (epinephrine) are commonly expressed in ratios.

Strength as a ratio	= Weight in volume	= Weight per ml
= 1 in 1,000,000	= 1g in 1,000,000ml	= 1 microgram in 1ml
= 1 in 100,000	= 1g in 100,000ml	= 10 micrograms in 1ml
= 1 in 10,000	= 1g in 10,000ml	= 100 micrograms in 1ml
= 1 in 1000	= 1g in 1000ml	= 1000 micrograms in 1ml = 1mg in 1ml
= 1 in 100	= 1g in 100ml	= 10mg in 1ml = 0.01g in 1ml
= 1 in 10	= 1g in 10ml	= 100mg in 1ml = 0.1g in 1ml

1 in 1000 solution of adrenaline contains 1g in 1000ml = 1000mg in 1000ml = 1mg in 1ml

1 in 10,000 solution of adrenaline contains 1g in 10,000ml = 1000mg in 10,000ml = 1mg in 10ml

Ratios

Example 1

Adrenaline (epinephrine) 1 in 1000 injection is available.
The prescribed dose is 1ml.

How many mg in 1ml?

Use a two-step process:

The solution contains 1g in 1000ml

Step 1: 1g in 1000ml = $\frac{1g}{1000ml}$ in 1ml

Step 2: Convert this to mg by multiplying by 1000

$\frac{1g \times 1000}{1000ml}$ = 1mg in 1ml

Another way of thinking about this is: 1g in 1000ml = 1000mg in 1000ml = 1mg in 1ml

Calculating oral doses in tablets

Principles

1. Check the strength of (amount of drug in) each tablet or capsule.
2. Make sure you are clear about the dose units used, most commonly prescribed are milligrams or micrograms.
3. Check the dose on the prescription and that it is expressed in the same units as on the medicine label.
4. If the prescription and the medicines label use different units of strength, refer to the conversion table and calculation examples on page 4 and 5.
5. Once you are sure that the units are the same, divide the required dose by the strength of the tablet or capsule.
6. The answer is the number of tablets/capsules needed for each dose.

$$\text{Number of tablets} = \frac{\text{Dose}}{\text{Strength of tablet}}$$

Extra safety tip

If your first calculation gives a dose of more than two tablets, double-check the calculation <u>and</u> confirm that the dose doesn't exceed the manufacturer's recommended maximum. If it does, or if you are still unsure that the dose is correct, <u>check</u> with the prescriber or pharmacist.

Calculating oral doses in tablets

Example 1

Amoxicillin 500mg three times a day p.o. is prescribed.
Amoxicillin capsules 250mg are available.

The number of capsules needed for each dose = $\frac{500mg}{250mg}$ = 2 capsules

Example 2

Levomepromazine 6.25mg three times a day p.o. is prescribed.
Levomepromazine tablets 25mg are available.

The number of tablets needed for each dose = $\frac{6.25mg}{25mg}$ = 0.25 or ¼ of a tablet

Another way of looking at this is:

Half a tablet = $\frac{25mg}{2}$ = 12.5mg

Quarter of a tablet = $\frac{25mg}{4}$ = 6.25mg

Calculating oral doses for children and neonates

Principles

1. Always use the smallest oral syringe that will hold the volume you need to measure.
2. If the dose prescribed means that less than a whole tablet or capsule is required, check with the pharmacy that it is appropriate to break a tablet or split a capsule before doing so.
3. If it is essential, dissolve or disperse the powder/crushed tablet in an accurately measured amount of water (e.g. 5ml). Stir and draw up the required volume immediately.

   $$\text{Volume required} = \frac{\text{Dose in mg x Volume of solution}}{\text{Amount of drug (mg) in tablet}}$$

4. If the result cannot be accurately measured, e.g. 0.33ml, it is generally acceptable to round the dose up or down. However, the actual dose given must be within 10% of the calculated dose. If this cannot be achieved, discuss with the prescriber and pharmacist.

Calculating oral doses for children and neonates

Example 1

2mg amlodipine p.o. is prescribed. 5mg amlodipine tablets are available.
Crush one tablet and mix the powder thoroughly in 5ml of water.

The dose required is: $\frac{2mg \times 5ml}{5mg} = 2ml$

Another way of thinking about this is: 5mg in 5ml = 1mg in 1ml = 2mg in 2ml

Example 2

14mg ranitidine p.o. is prescribed.
15mg per ml ranitidine oral suspension is available.

The dose required is: $\frac{14mg \times 1}{15mg} = 0.933ml$

0.933ml cannot be accurately measured but 0.9ml or 1ml could be.

1ml is the easiest to measure, which equates to 15mg ranitidine.

To work out the % increase: $\frac{15mg \times 100}{14mg} = 107\%$

A 7% increase is less than 10% above the prescribed dose of 14mg so is acceptable.
15mg (1ml) can be accurately measured and should be given.

Calculating IV drug doses

Principles

1. For drugs already in solution, check the amount of drug in each ml and the total amount of drug in the container.
2. Make sure you are clear about the dose units used. Most commonly prescribed are milligrams (mg) or micrograms.
3. Beware of drugs such as insulin and heparin, for which doses are prescribed in international units (which is sometimes, but should never be, abbreviated to i.u. which can be misread as 10).
4. Check the dose on the prescription and that it is expressed in the same units as on the medicine label.
5. If the prescription and the medicines label use different units of strength, refer to the conversion table and calculation examples on pages 4 and 5.
6. Once you are sure that the units are the same, divide the required dose by the amount of the drug in the ampoule and multiply by the volume of solution in the vial or ampoule.
7. The answer is the volume needed for each dose.

$$\text{Volume required} = \frac{\text{Dose x Volume of solution in ampoule}}{\text{Amount of drug in ampoule}}$$

Calculating IV drug doses

Example 1

Digoxin 125 microgram in 100ml sodium chloride 0.9% is prescribed over 1 hour.
500 microgram digoxin in 2ml ampoules are available.

The volume to be added to 100ml sodium chloride 0.9% is:

$$\frac{125 \text{ micrograms} \times 2\text{ml}}{500 \text{ micrograms}} = 0.5\text{ml}$$

Example 2

300mg aminophylline injection is prescribed. 250mg in 10ml ampoules are available.

The volume of injection required is:

$$\frac{300\text{mg} \times 10\text{ml}}{250\text{mg}} = 12\text{ml}$$

Calculating drip rates for gravity flow infusions

Principles

1. Without a flow control device such as a pump, infusion rates depend entirely on gravity. Rate of flow is measured by counting drops per minute.
2. Administration sets deliver controlled amounts of fluid at a predetermined fixed rate, measured in drops per minute.
3. It is also important to check the number of drops per ml delivered by the administration set (which is printed on the outer packaging). This may vary between sets, between manufacturers and between different infusion fluids or drug solutions.
4. A (drug) solution administration set will usually deliver 20 drops per ml of clear infusion fluid such as 0.9% sodium chloride injection.
5. A blood administration set will deliver 15 drops per ml of blood.
6. A burette administration set will usually deliver 60 drops per ml of infusion fluid or drug solution.
7. Number of drops per minute = $\frac{\text{Volume in ml x Number of drops per ml}}{\text{Intended duration of infusion (in minutes)}}$

Calculating drip rates for gravity flow infusions

Example 1

1000ml sodium chloride 0.9% infusion over 8 hours using a solution set is prescribed. 8hr = 8 x 60min.

The drip rate needs to be set at:

$$\frac{1000\text{ml} \times 20 \text{ drops per ml}}{8 \times 60\text{min}} = \frac{20000 \text{ drops}}{480\text{min}} = 42 \text{ drops per minute}$$

Example 2

1 unit of blood over 4 hours using a blood set is prescribed. (1 unit of blood = 350ml.) 4hr = 4 x 60min.

The drip rate per minute should be set at:

$$\frac{350\text{ml} \times 15 \text{ drops per ml}}{4 \times 60\text{min}} = \frac{5250 \text{ drops}}{240\text{min}} = 22 \text{ drops per minute}$$

Example 3

100ml glucose 5% infusion over 6 hours using a burette set is prescribed. 6hr = 6 x 60min.

The rate per minute should be set at:

$$\frac{100\text{ml} \times 60 \text{ drops per ml}}{6 \times 60\text{min}} = \frac{6000 \text{ drops}}{360\text{min}} = 17 \text{ drops per minute}$$

Calculating infusion rates for infusion devices

Principles

1. Also see the principles on page 18.
2. All infusions require rate control. This can be achieved using a roller clamp (gravity flow), an infusion pump, a syringe driver, a syringe pump or a disposable device.
3. When using any sort of rate control device, check at least the following parameters at regular intervals in accordance with local policy:
   - Volume given
   - Volume remaining
   - Administration rate
   - Condition of the patient including the administration site
4. Before and after transfer of care between units or teams, make sure you repeat the above checks.
5. You should always check the manufacturer's instructions or refer to local policy to ensure you use the correct administration set for the device and that the device is programmed correctly.
6. An administration device should only be used by practitioners who have been trained and are competent in the use of the particular device.

See also the advice on page 3 about double-checking calculations.

Calculating infusion rates for infusion devices

The rate may be prescribed in terms of:

Volume: For example ml per hour or ml per min. OR:

Amount of drug: For example mg per min or international units per hour.

Volume in ml per hour: $\frac{\text{Total volume of infusion (ml)}}{\text{Duration of infusion (hour)}}$ = ml per hour

Amount of drug in mg per hour: $\frac{\text{Total dose in mg}}{\text{Duration of infusion (hour)}}$ = mg per hour

Example 1

To calculate the amount of infusion to be given in ml per hour.

500ml sodium chloride 0.9% is prescribed to be given over 4 hours using a volumetric pump.

The rate of infusion should be set at:

$$\frac{\text{500ml}}{\text{4 hour}} = \text{125ml per hour}$$

Calculating infusion rates for infusion devices

Example 2

Diamorphine 30mg in 60ml 0.9% sodium chloride over 24 hours using a syringe pump is prescribed. To be given at 1.25mg per hour. How many ml per hour should be given?

The number of mls containing 1mg = $\frac{\text{Volume of infusion (ml)}}{\text{Amount of drug (mg)}} = \frac{\text{60ml}}{\text{30mg}}$ = 2ml

The number of mls containing 1.25mg = 2 (ml) x 1.25 (mg) = 2.5ml

Therefore, 2.5ml per hour will deliver 1.25mg per hour.

Example 3

A similar method can also be used to calculate the rate of an insulin infusion.

Insulin 50 international units in 50ml 0.9% sodium chloride is prescribed for administration from a syringe pump, starting at 4 international units per hour.

The rate should be set at:

$\frac{\text{Volume infusion x Dose of drug per hour}}{\text{Amount of drug}} = \frac{\text{50ml x 4 international units per hour}}{\text{50 international units}}$ = 4ml per hour

Another way of thinking about this is:
50 international units in 50ml = 1 international unit in 1ml = 4 international units in 4ml

Calculating rates for syringe drivers

Principles

1. A syringe driver pushes the plunger of a syringe forward at an accurately controlled rate.
   - For most syringe **pumps** the rate is set according to the volume of solution injected per hour, i.e. in **ml per hour**
   - For some syringe **drivers** the rate is set according to the distance travelled by the plunger in **mm per hour** or **mm per 24 hour**
2. If the rate is to be set in mm, the volume to be adminstered by a syringe driver depends on the diameter of the syringe barrel as well as on the rate setting. Different makes of syringe may have different barrel sizes. It is essential that the brand of syringe to be used is specified and the stroke length is measured.
3. **Serious errors have occurred when settings in mm per hour and ml per hour have been confused.**
   - Prepare prescribed infusion
   - Prime the extension set with fluid
   - If using a syringe driver, measure the stroke length (the distance the plunger has to travel) in mm. See diagram for example

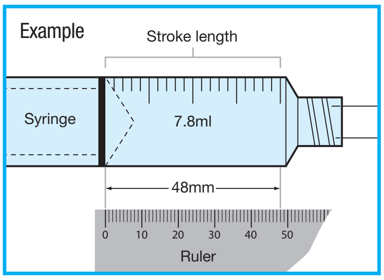

Diagram adapted from Sarpal. 2003.[2]

Calculating rates for syringe drivers

Principles continued

4. Check carefully the units of time in which the syringe driver operates: Is the rate set in mm per hour or mm per day (24 hours)?

mm per hour

$$\text{Rate} = \frac{\text{Stroke length (mm)}}{\text{Infusion period (hours)}}$$

mm per 24 hours

$$\text{Rate} = \frac{\text{Stroke length (mm)}}{\text{Infusion period (days)}}$$

Example 1

Diamorphine 20mg over 12 hours is prescribed. The stroke length is measured as 48mm.

The rate setting needed on a mm per hour syringe driver is: $\frac{\text{48mm}}{\text{12 hours}}$ = 4mm per hour

Example 2

Diamorphine 20mg over 1 day (24 hours) is prescribed. The stroke length is measured as 48mm.

The rate setting needed on a mm per 24 hour driver is: 48mm = $\frac{\text{48mm}}{\text{1 day}}$ per 24 hour

Calculating IV drug doses for children and neonates

Principles

1. Remember that many injections are made for adults. For children's doses, you may need as little as one tenth (1/10) or even one hundredth (1/100) of the contents of one ampoule or vial.
2. When calculating infusions, consider the child's total daily fluid allowance. More concentrated individual infusions may be required. Discuss with the pharmacist or prescriber.
3. Ensure the prescribed infusion fluid/diluent is appropriate for the child e.g. the sodium content of an infusion contributes to the child's total daily sodium requirement.
4. For many injections presented as powders for reconstitution, the powder adds to the volume of the final solution after the diluent has been added. This 'displacement value' must be taken into account when the dose needed is less than the full contents of the vial or ampoule.

The displacement value can be found on the package insert. It may vary with brands, so it is crucial to check the package insert for the product you are actually using.

5. For the above reasons, the calculations involved in preparing and administering infusions for children are often particularly complex. It is most important that these calculations are independently checked (see page 3).
6. See also the principles outlined on pages 14 and 18.

Calculating IV drug doses for children and neonates

Example 1

A brand of amoxicillin 250mg vials has a displacement value of 0.2ml per vial.

This means that for this brand, 250mg of the powder occupies a volume of 0.2ml. Therefore, if you add 5ml to the vial, the resulting solution contains 250mg amoxicillin in 5.2ml. To make a solution containing 250mg in 5.0ml, you must add 4.8ml of WFI.

Example 2

How many mmols of Na would a child receive from an infusion of sodium chloride 0.9% given at a rate of 1ml per hour over 24 hours?

0.9% sodium chloride contains 150mmol Na per litre (1000ml) = $\frac{150\text{mmol}}{1000\text{ml}}$ per ml

Number of mmol per 24 hours = $\frac{150\text{mmol}}{1000\text{ml}}$ x 24 hour = 3.6mmol Na in 24 hours

This is normally acceptable for a 6-year-old child, but may not be for a neonate.

Calculating IV drug doses for children and neonates

Example 3

0.5 microgram per kg per minute midazolam is prescribed for a 1kg baby, to run at 0.1ml per hour. The prescription asked for 7.5mg midazolam in 25ml glucose 5%. Ampoules of midazolam 5mg in 5ml are available.

To prepare the syringe as prescribed:

The volume needed for a dose of 7.5mg = $\frac{\text{Dose x Volume in ampoule}}{\text{Amount of drug in ampoule}} = \frac{\text{7.5mg x 5ml}}{\text{5mg}}$ = 7.5ml

To make up 7.5mg to 25ml in a syringe:

Draw up 7.5ml midazolam injection into a 10ml syringe and transfer to a 25ml syringe.

The volume of glucose required = 25ml – 7.5ml = 17.5ml

Add 17.5ml glucose 5% injection to the 25ml syringe to make a total volume of 25ml.

The syringe now contains 25ml of solution containing 7.5mg midazolam.

Further reading

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Lapham R. & Agar H. Drug Calculations for Nurses: A Step-by-step Approach (2nd Edition) Hodder Arnold, London, 2003.

Rees J, Smith I. & Smith B. Introduction to Pharmaceutical Calculations. Pharmaceutical Press, London, 2005.

Pickstone M. A Pocketbook for Safer IV Therapy (Drugs, Giving Sets & Infusion Pumps), Scitech Educational Ltd, 1999.

British National Formulary, No 67 BMJ Group and RPS Publishing, March 2014

British National Formulary for Children, Paediatric Formulary Committee, July 2014

Online resources

The IV Guide. www.injguide.nhs.uk Full access by subscription. (Accessed June 2014)

Test and Calc. www.testandcalc.com (Accessed June 2014)

BNF and BNFC www.bnf.org (Accessed June 2014)

NHS Education South Central (NESC) www.learning.nesc.nhs.uk Compatibility of Injectable Medicines. Site registration required (Accessed June 2014)

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2. Sarpal N. Drug administration: delivery (infusion devices). In Dougherty L & Lister S (Eds). The Royal Marsden Hospital Manual of Clinical Nursing Procedures (7th Edition) Wiley Blackwell, 2008, chapter 13, page 302.

If you would like to know more about how Baxter can help you, contact:
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Adverse events should be reported. Reporting forms and information can be found at www.mhra.gov.uk/yellowcard

Any adverse events relating to Baxter products can also be reported direct to Baxter Pharmacovigilance on +44 (0)1635 206360, or by email to vigilanceuk@baxter.com

Any drug product quality complaints (including suspected defective medicines) relating to Baxter products can be reported directly to the Baxter Country Quality Assurance Team on 01604 704603, or by e-mail to shs_qad_uk@baxter.com. Alternatively please report directly to your Baxter Representative, who will take the details and forward to the Baxter Country Quality Assurance Team.

Any suspected defective medicines, should be reported to the MHRA. Reporting forms and information can be found at: www.mhra.gov.uk/safetyinformation/reportingsafetyproblems/index.htm

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