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Nursing Children and Young People :Continuing Professional Development Article

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This is the second of two articles that aim to provide children's nurses with an opportunity to develop their knowledge and skills of medicines management when caring for infants and children. The first article considered the processes associated with effective medicine management, including the concept of human error. This second article addresses essential numeracy and calculation skills, which have been identified as an important risk factor associated with medication errors in children (Manias et al 2014). The range of activities throughout the article will help you develop and practice numeracy skills, with the answers for each activity at the end of the article.

Aim and intended learning outcomes:

To refresh your knowledge of essential numeracy and calculation skills. By reading the article and completing the time out activities you will be able to:

- Describe the International System of Units used in the clinical environment.
- Convert units of measure by manipulating decimal points.
- Apply the common medicine calculation formula in order to complete a range of medicines calculations.

Nursing interventions often involve the application of essential numeracy skills. Medicines management is a fundamental role of the nurse that requires them to have the ability to understand and calculate drug doses. Nurses are directly accountable for ensuring medicines are prescribed, dispensed and administered safely, and within their limits of training and competence (NMC 2015, NMC 2010). Prescribing and administering medicines to infants and children is challenging because children vary in weight, body surface area, and their ability to metabolise and excrete medications changes as body systems develop, which require all involved to be competent in essential numeracy skills (Blair and Standing 2011). Medication doses must be calculated specifically for each individual child, which result in greater potential for errors compared to adult patients (Manias et al 2014). In addition, advances in technology and treatments have resulted in care and interventions being more complex with greater accuracy in prescribed doses required (Wilson 2003, Blair and Standing 2011). In order to undertake calculations accurately nurses must be able to add, subtract, divide, multiply, covert units of measure and work with fractions (Hutton 1998). Age and the decade of the nurse's education can have an influence on how numeracy skills were taught (Pentin and Smith 2006). Therefore nurses may apply different methods when undertaking a calculation, which needs to be recognised when nurses are being supported to develop their calculation skills and maintain their confidence. Now undertake Time Out 1.

TIME OUT 1
Reflect on your own practice.
What are your strengths and weaknesses in relation to undertaking calculations?
List which types of calculations you find the most challenging, you may wish to discuss with your colleagues what calculations they find challenging.

International System of Units (SI) of measure made simple

The most common measurements used in calculations are weight (essential when calculating drug dosage), length (required to calculate body mass) and volume (required when calculating volume and rates of infusions). The SI, sometimes referred to as the metric system, is the most widely adopted system for units of measure and was standardised in the United Kingdom in 1975. Failure to use SI units can lead to potentially life threatening errors. Prior to the introduction of SI units, imperial measurements were used and parents sometimes use pounds and ounces when referring to their child's weight. Nevertheless, as medicines and fluids administered to children require calculations based on weight, weight must always be recorded in SI units. In rare situations where a child is unable to be weighed, parents may be able to provide an up to date weight, if this is in pounds and ounces the weight must be converted to SI units (Hutton and Gardner 2005). The SI system is a metric system based on powers of 10 which enables numbers to be manipulated to make them more manageable for example *one thousandth* of a gram could be written as 0.001g or 1mg (Box 1).

Box 1: SI units explained

Weight	kilogram	Kg	1000 grams
	gram	g	1000 milligrams
	milligram	mg	1000 micrograms
	microgram	Never abbreviate	1000 nanograms
	nanogram	Never abbreviate	
Length	Meter	M	1000 centimeters
	centimeter	cm	1000 millimeters
	millimeter	mm	
Volume	Litre	L	1000 millilitres
	milliliter	mL	

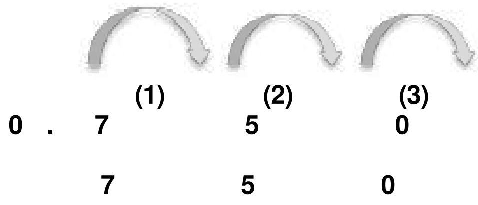
Note that small measurements should be written in full, particularly micrograms and nanograms, because micrograms misread as milligrams could result in giving a drug 1000 times the strength intended, the consequences of this could be catastrophic.

Converting units of measure by manipulating decimal points

When converting measures of weight between grams, milligrams, micrograms and nanograms, divisions or multiplications between each unit of measure occur in 1000's. To convert from a larger unit to a smaller unit e.g. grams to milligrams, multiply by 1000. One way to do this is to move the decimal point 3 places to the right. It can be useful to ensure there are 3 numbers after the decimal point which is achieved by adding '0' to the end of the number. To convert a smaller unit to a larger unit e.g. milligrams to grams, divide by 1000. Again one way to do this is to move the decimal point, this time 3 places to the left. The same principles apply when converting liquid measures between litres and millilitres. Think logically, multiplying makes numbers bigger whereas dividing makes numbers smaller. Box 2 provides examples of moving decimal points.

Box 2: Moving decimal points

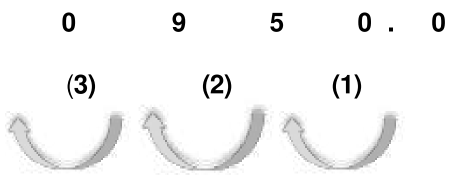
To covert 0.75g to mg move the decimal point three places to the right
(NB 0.75 is the same as 0.750)



0.75g = 750mg

Note the unit of measurement is changed from grams to milligrams

To convert 9500mg to g move the decimal point three places to the left (NB 950 is the same as 950.0)



950.0 mg = 0.95g

Note the unit of measurement is changed from micrograms to grams

Poorly written numbers can be misinterpreted and are a common cause of medication error (Pryce-Miller and Emanuel 2010). When working with decimal points errors are easy to make. Prescriptions should not be written using fractional numbers (numbers less than a whole) (Health Education Yorkshire and Humber 2015). For example 0.6g should be written as 600mg and 0.7mg should be written as 700micrograms. Where possible avoid using decimal point for example write 3mg NOT 3.0mg (if the decimal point was not noticed 30mg could be given instead of 3mg). Now complete Time Out 2.

TIME OUT 2: Converting units of measure	
a. How many grams are in 700mg?	
b. How many micrograms are in 0.6mg?	
c. How many milligrams are in 1.56g?	
d. How many grams are in 2.87kg?	
e. How many litres are in 1670 mL?	
f. How many nanograms are in 1.24 micrograms?	

In Time Out 2 it is important that the decimal point was moved the required number of places and that the unit of measure was recorded correctly. There is a potential for error when using decimal points, misplacing a decimal point can result in a significant change in the amount of drug prescribed and given. For example, if 7.5mg of intravenous diclofenac sodium was prescribed but because of a misplaced decimal point this became 75mg, the infant would receive 10 times more the recommended dose. It is important to consider what is a reasonable dose of a medication for the age of child, use your intuition and experience. Ensure your knowledge about medications is current and use the resources available to you, never make assumptions.

Medication calculations

Every year medication errors occur, many of which are attributable to incorrect medication doses with unit conversion errors being the most common (Department for Education and Skills /Department of Health 2004, National Patient Safety Agency 2007). All children's nurses must be able to accurately calculate medication doses. The most common formula to calculate medications is:

$$\frac{\text{What you want}}{\text{What you've got}} \times \text{What volume the drug is in}$$

However, other formulae are available and the safest method to use is the one you understand (Health Education Yorkshire and Humber 2015).

Whichever formula is used understanding the mathematical principles of fractions is essential for many nursing calculations; Box 3 briefly explains fractions and Box 4 presents examples of medication calculations.

Box 3: Fractions explained
In simple terms fractions state the number of parts of a whole, for example a half is two parts of a whole. Fractions can be written as two numbers separated by a forward slash, for example half would be written as $^{1}/_{2}$ but when undertaking calculations with fractions it can be useful to write the numbers above each other: the top number (1) is referred to as the numerator the bottom number (2) is referred the denominator. Fractions are easer to work with when they are in their simplest form, so $^{2}/_{4}$ is the same as $^{1}/_{2}$. These fractions are equivalent because they can be converted from one to the other by multiplying (or dividing) the numerator and the denominator by the same number, in this case 2. Dividing numerators and denominators is often referred to as 'cancelling fractions', making them easier to manipulate particularly when we multiply and divide them. To multiply 2 fractions, multiply the numerators (and denominators) of the fractions: $\frac{1}{2} \times \frac{1}{2} = \frac{1 \times 1}{2 \times 2} = \frac{1}{4}$ think of this as half of a half which is intuitively smaller.

Box 4: Medication calculation examples
Poppy requires Flucloxacillin 375mg. Oral Flucloxacillin is dispensed as 500mg in 5mL, applying the formula: $\frac{\text{What you want}}{\text{What you've got}} = \frac{375}{500}$ $\frac{375}{500}$ = 0.75 x What it's in (5mL) = 0.75 x 5 = 3.75mL In this example if the decimal point had placed in the wrong place the child could have received 37.5 or 0.375 again it is about what is reasonable and 0.375 of flucloxacillin is not reasonable.
Jason is 4 years old and weighs 15 Kg. He has been prescribed Cefaclor 8 hourly. The dose is 20mg/kg daily, given in 3 divided doses. 15 (kg) x 20 (mg/kg) = 300mg This is the dose required in a 24 hour period - Jason has been prescribed the drug 8 hourly, 24 divided by 8 gives a total of 3 doses per day: 300/3 = 100mg per dose In this example if the total daily dose was given as an individual dose instead of dividing the answer by 3, the child would have received a significant overdose.

The registered nurse is responsible for ensuring the correct dose of medication is administered (NMC 2010). Before undertaking the drug calculation ensure the correct dose has been prescribed; do not presume the prescriber has prescribed correctly. You will become familiar with the doses of drugs you use regularly, however if you are uncertain of the dose you must check the dose with a recognised resource such as the British National Formulary for Children (BNFC) (2015). If you are still unsure that the dose is correct refer back to the prescriber. You may wish to revisit article 1 which highlights your responsibility when administering medicines.

Once you are sure the correct dose has been prescribed use your experience to estimate what is the likely amount you will be administering. This is a useful internal safety check in identifying potential errors and ensuring patient safety (Ramjan et al 2013). For example if you require 2.7mg and the drug is dispensed as 2.5mg/5mL, your estimate would suggest you need slightly more than 5mL. Next calculate the volume required using the formula you are familiar with and check it against your estimation and with the second checker, depending on local trust guidelines, who should calculate the volume required independently. In the above example 5.4mL in is the correct amount. Now undertake the calculations in Time Out 3.

TIME OUT 3: Medication calculations	
a. Rebecca requires 40mg of prednisolone, which is available in 5mg tablets. How many tablets does Rebecca require?	
b. Sophie requires 730mg of vancomycin, which is prepared as a solution of 500 mg/100mL. How many mL of the solution does Sophie require?	
c. Harry requires 450 micrograms/day of digoxin administered in 2 divided doses. How many micrograms should be prescribed per dose?	
d. Zoe requires 120mg of ranitidine, which is available as a solution of 75mg/5mL. How many mL of the solution does Zoe require?	

You will note in Time Out 3 that all of the drugs prescribed are in the same unit of measure to the dispensed unit. Therefore the formula presented in Box 4 can easily be applied to calculate how much of the drug needs to be administered. However, care must be taken if a drug is prescribed in a different unit of measure to the dispensed unit. For example if 400 micrograms of a drug is prescribed and is only available in ampoules containing 4mg/mL, calculating the amount to be administered requires both the dose and drug strength to be converted to the same unit of measure, here 1mL solution contains 4000 micrograms. In this example first you need to convert mg to micrograms (4mg = 4000 micrograms), the calculation is now 400/4000 x 1 = 0.1mL; 0.1mL of the drug would be administered. Now undertake the calculations in Time Out 4.

TIME OUT 4: Medication calculations requiring measure conversions	
a. Joshua requires 2.1g of Benzylpenicillin sodium, which is available as a solution of 600mg/10mL. How many mL of the solution does Joshua require?	
b. Sam requires 600 micrograms of Morphine which has been prepared as a solution of 10mg/5mL. How many mL of the solution does Sam require?	
c. Grace requires 1.2g of Cefuroxime, which is available as a solution of 750mg/20mL. How many mL of the solution does Grace require?	
d. Lauren requires 1200 nanograms/hour of Alprostadil which is available as a solution 600micrograms/50mL. How many mL/hour of the solution does Lauren require?	

The first 3 questions in Time Out 4 can be calculated by taking the same steps as in the worked example, ensuring that you used the same unit of measure for the prescribed and dispensed units. The last question is a calculation related to an infusion. This should not cause any additional difficulty as it is calculated in the same way, because the amount of drug Lauren is prescribed and the dispensed units are both mL/hour. Fluid calculations are explored in more detail in the next section.

Fluid and infusion calculations

The ability to correctly calculate fluid requirements for infants and children is an important nursing skill (Blair and Standing 2011). In addition to the calculation skills already outlined other factors that should be considered when calculating fluid requirements or administering infusions in children are presented in Box 5.

Box 5: Factors to consider when deciding fluid requirements
Weight Age Fluid type Any fluid restrictions/ fluid replacement requirements The child's condition/ underlying disease Results of blood tests in particular urea and electrolytes

Although a range of guidelines exist for calculating fluid requirements in children in the United Kingdom the British Medical Association guidance is widely used (BMA 2015) (Box 6).

Box 6: Calculating fluid requirements	
Body Weight	**24 hour replacement**
First 10kg	100ml/kg
Second 10kg	50ml/kg
Subsequent kg	20ml/kg
Anya is 32 kg and is unable to take oral fluid and therefore requires standard intravenous fluids	
First 10kg	10 x 100mL = 1000mL
Second 10kg	10 x 50mL = 500mL
Subsequent kg	12 x 20 = 240mL
Total 24 hour requirement = 1740mL	
Hourly fluid requirement = 1740/24 = 72.5mL/hour	

When calculating fluid infusions there is final step to the calculation process as fluid infusions are given over a prescribed time, often this is a 24 hour period. Consequently, the total volume of fluid required needs to be divided by 24 before the hourly infusion rate on the infusion pump can be set, as outlined for Anya in Box 6. However, some intravenous fluids and drugs may require administering over a shorter period of time, for example an intravenous antibiotic may be prescribed to be administered over 30 minutes. Calculating short infusion times are presented in Box 7. Infusion pumps are programmed to deliver mL/hour, when calculating rates ensure time is converted to the same units.

Box 7: Calculating short infusions times
Sarah requires 17mL of a drug to be administered over 30 minutes (pump programmed in mL/hour) The drug needs to be administered over 30 minutes: 60 divided by 30 = 2 Therefore the volume to be infused needs to be multiplied by 2 Pump infusion rate: 17mL x 2 = 34mL/hour
Asyah requires 372mL of packed cells to be administered over 4 hours Divide the volume to be infused (372) by the number of hours the packed cells are to be infused over (4) Pump infusion rate: 372 ÷ 4 = 93mL/hour
George requires 27mL of a drug to be administered over 15 minutes (pump programmed in mL/hour) The drug needs to be administered over 15 minutes: 60 minutes divided by 15 = 4 Therefore the volume to be infused needs to be multiplied by 4 Pump infusion rate: 27mL x 4 = 108mL/hour

Fluid Restrictions

Some children's underlying condition may necessitate fluid intake being restricted. If restricted, fluids are likely to be prescribed as a percentage of the standard fluid regime. For example Sophie is four and weighs 18kg, she is admitted to hospital with renal failure. Sophie's fluids are restricted to 75% of standard fluids.

1. Calculate the usual fluid requirement for a child of Sophie's age and weight:

   10 kg x 100 = 1000mL

   8 kg x 50 = 400mL

   Total daily fluid = 1400mL

2. Calculate 75% of 1400mL to meet Sophie's specific requirements:

   $\frac{75}{100} = 0.75$

   0.75 x 1400 = 1050mL in 24 hours

3. Hourly fluid requirement = 1050 ÷ 24 = 43.8mL/hour

Where a child has a restricted daily fluid requirement but has oral fluids, IV infusions and medications, all these fluids must be included and recorded.

Benjamin weighs 5kg and is restricted to 65% of standard fluids. Benjamin's can have milk as part of his fluid intake and usually has 6 feeds a day, his full fluid requirement can be calculated in the following way

a. 5kg x 100mL/kg = 500mL
2. 65% of 500mL

$$\frac{65}{100} = 0.65$$

3. Hourly fluid requirement = 0.65 x 500 = 325mLs in 24 hours

Benjamin also has an IV infusion running at 2mL/hour and is receiving medication that is a total of 6mL every 12 hours, both need to be included in his daily total:

1. Infusion: 2mL/hour x 24 = 48mL
2. Medication: 6mL x 12 hourly = 12mL
3. 24 hour total: 48mL + 12mL = 60mL
4. Deduct this from the daily total 325mL – 60mL = 265mL
5. Divide this total by the number of feeds in 24 hours 265 ÷ 6 = 44mL per feed.

Now undertake Time Out 5.

TIME OUT 5: Fluid restriction calculations	
a. Lizzie weighs 13 kg and is restricted to 70% of standard fluid requirement and she requires an intravenous infusion. Calculate the pump infusion rate in mL/hour.	
b. George weighs 7kg and is restricted to 75% of standard fluid requirement. He is receiving 5 feeds per day. Calculate how much milk he should receive for each feed.	
c. Charlotte weighs 15kg and is restricted to 80% of standard fluid requirement. She is receiving a drug infusion of 240mL/day. How much fluid is she able to drink in a 24 hour period?	
d. Faizal weighs 36kg and is restricted to 80% of his standard fluid requirement. His medication fluids are 224mL in 24 hours, he also requires intravenous fluids. Calculate the pump infusion rate in mL/hour.	

The questions in Time Out 5 require more complex calculation skills, however if you follow the steps in the worked examples and undertake each stage systematically you should be able to calculate how much oral or intravenous fluid each child requires.

Percentage Concentrations

A final point for consideration relates to that solutions used in practice may be expressed as percentages, for example 0.9% sodium chloride, a frequently used intravenous fluid. Percent means 'per 100', for example 0.9% means that every 100mL of water contains 0.9 grams of sodium chloride and 5% dextrose means there are 5 grams of dextrose in every 100mL of water. Therefore a 500mL bag of 5% dextrose contains 25 grams of dextrose, 5g of dextrose in 100mLs multiplied by 5 = 25g dextrose in 500mL.

Conclusion

Essential numeracy and calculation skills underpin safe and effective medicines and fluid management in children. This article and associated activities will have assisted you to develop your ability to undertake a range of calculations by outlining the underpinning processes. Calculations in children's nursing are complex requiring practice and ongoing development to remain a competent practitioner. Now undertake Time Out 6.

TIME OUT 6
Now you have completed the activities in this article, test your knowledge and complete the questions on page X.

TIME OUT ANSWERS

Time Out 2

a 0.7g, b 600micrograms, c 1560mg, d 2870g, e 1.67L, f 1240 nanograms

Time Out 3

a 8 tablets, b 146mL, c 225 micrograms, d 8mL

Time Out 4

a 35mL, b 0.3mL, c 32mL, d 0.1mL/hour

Time Out 5

a 33.5mL/hour, b 105mL, c 760mL, d 51.3mL/hour

Resources

If you need more help with your calculation skills there are a wealth of resources available both on and off line. Below are some examples from basic to advanced level skills.

Health Education Yorkshire and Humber (2015) *Medicines Calculations: Student Pack.* Leeds, University of Leeds. https://www.networks.nhs.uk/nhs-networks/medslearning/documents/calculations-training-booklet-1

Hutton M, Gardner H (2005) *Paediatric Nursing Calculation Skills*. London, RCNi.

Starkings S Krause L. Passing Calculations Test for Nursing Students (2010) Learning Matters Exeter

Safety in numbers - numeracy refresher can be found in the Royal College of Nursing (RCN) Professional Development Section under personal skills, you will need your RCN to log-in https://www2.rcn.org.uk/development/learning/learningzone

Mathis is fun has useful section on percentages and can be found at www.Mathsisfun.com

The maths 'dude' covers a range of skills and can be found at www.quickanddirtytips.com

Although aimed at children 'cool math' is simple but fun way to start learning the basics of mathematical principles and can be found at www.coolmath4kids.com

Mathematical principles are covered in basic mathematics including percentages, fractions, division and multiplication can be found www.basic-mathematics.com and www.Math.com

Two useful web links with some child specific examples can be found at www.testandcalc.com and http://www.uhs.nhs.uk/Media/suhtideal/TopNavigationArticles/SkillsForPractice/ClinicalSkills/Paediatricdrugcalculationsforthirdyearmedicalstudents.pdf

A useful step by step guide to drug calculations for nurses, doctors and all other healthcare professionals with adult and child examples can be found at http://www.baxterhealthcare.co.uk/downloads/healthcare_professionals/therapies/pharmacy_services/ps_calc_guide.pdf

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Test your knowledge

1. How are fractions multiplied?
   a) Add the numerators and denominators
   b) Multiply the denominators
   c) Multiply the numerators and multiply the denominators
   d) Divide the numerator by the denominator

2. How would $\frac{8}{32}$ be written in its simplest form?
   a) $\frac{1}{3}$
   b) $\frac{2}{8}$
   c) $\frac{1}{2}$
   d) $\frac{1}{4}$

3. To change a unit of measure which number do you need to multiply or divide by?
   a) 10
   b) 100
   c) 1000
   d) 10000

4. What is the most common reason an incorrect medication dose is administered?
   a) Unit conversion error
   b) Incorrect use of a drug calculation formula
   c) Administering the wrong drug
   d) Giving the incorrect number of doses in a 24 hour period

5. Ellie requires 3.5g of a drug every 24 hours. The drug is prescribed 6 hourly, how much of the drug should Ellie receive for each dose?
   a) 1750mg
   b) 1.17g
   c) 583mg
   d) 875mg

6. Liam requires 320 nanograms of a drug. The drug is available as a solution of 2mg/mL, how many mL of the solution does Liam require?
   a) 0.016mL
   b) 1.6mL
   c) 16mL
   d) 0.16mL

7. Ikram requires 275mL of an antibiotic to be administered by infusion over 20 minutes, how many mL/hour should the infusion pump be set at?
   a) 275mL/hour
   b) 1100mL/hour
   c) 825mL/hour
   d) 550mL/hour

8. Georgia requires 282mL of packed cells to be administered over 6 hours, calculate the pump infusion rate in mL/hour:
   a) 47mL/hour
   b) 70.5mL/hour
   c) 32.3mL/hour
   d) 50mL/hour

9. Holly weighs 23kg and is restricted to 75% of the standard fluid requirement, how much fluid can she have in a 24hour period?
   a) 1248mL
   b) 1560mL
   c) 1170mL
   d) 1872mL

10. A 500mL bag of 0.45% sodium chloride contains how much sodium chloride?
    a) 0.45g
    b) 2.25g
    c) 225g
    d) 45g

Answers: 1-C, 2-D, 3-C, 4-A, 5-D, 6-D, 7-C, 8-A, 9-C, 10-B