Critical Thinking: Nursing Calculations

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Purpose and Objectives

The purpose of this course is to help ensure safe IV medication administration by reviewing calculation techniques.

After successful completion of this course, you should be able to:

1. Identify reasons why nurses need to maintain competency in performing nursing calculations
2. Perform calculations correctly
3. Determine correct dosages

Introduction

With the inclusion of smart infusion pump devices, unit dosing, standardized admixtures, among other technological advances, the need for medication dosing calculations may be seen as an unnecessary task. However, medication safety is still a critical part of your job. Patients' safety and lives depend on receiving the correct dose of medications.

Knowing that the medication dose, concentration, and infusion rate agree with your calculations is the best way to ensure that an overdose/under dose does not occur.

This course offers the healthcare professional the opportunity to practice the most commonly used intravenous (IV) medication dosage calculation formulas. Additionally, due to the use of standardized dilutions available from manufacturers, pediatric drug calculations have been simplified. The calculations in this module can be used by any population. Due to the use of smart pump technology and standardized tubing drip factors, this module will not include drip factor calculation review.

Barriers to Calculation Success

Top ten reasons why healthcare professionals don't think they need to maintain competency in calculations:

1. The computer does it
2. The pharmacy does it
3. The IV infusion pump does it
4. We have charts and tables that do it
5. The drug companies take care of it
6. We use unit dose
7. It's just a nursing school exercise
8. We have a unit-based pharmacist
9. Math is just not one of my strengths
10. It's not a good use of my time

Responsible professionals cannot afford to become complacent with drug calculations as they are accountable for all drugs they administer.

Keys to Calculation Success

To prepare and administer medications safely, healthcare professionals must avoid total dependence on smart technology and pharmacists to perform calculations.

The safe practitioner maintains a state of risk-awareness; continuously evaluating that the nursing action they are about to perform is correct.

Accountability for Medication Calculations

With the advent of smart technology infusion pumps, unit dose preparations and standardized concentrations by drug manufacturers and pharmacists; medication errors have been greatly reduced. Although the use of IV smart pumps has reduced the incidence of IV adverse drug events and medication administration errors, IV infusion continues to be associated with 54% of all adverse drug events, 56% of medication errors, and 61% of serious and life-threatening errors (Giuliano, 2016).

Smart infusion pumps have improved medication delivery using drug libraries, dose limits, hard and soft alarms, and guardrails. Despite these improvements, drug errors still occur. Human error is responsible for many of these errors. Unless the pump is malfunctioning, it will calculate the rate and dose of an infusion correctly, BASED ON USER INPUT. If the data programmed into the pump is incorrect, the pump will deliver incorrect medication doses and rates (Association for the Advancement of Medical Instrumentation (AAMI), 2016 & Giuliano, 2016).

Even when all systems are go – when the technology works well, and pharmacy support is optimal – the nurse remains responsible for safe administration of IV medications directly to patients. To fulfill this responsibility, the nurse must maintain competency in basic medication calculations.

Calculating Flow Rate (mL/hr)

Most commonly the physician will order the mL/hour dose that should be infused. This method of infusion is used for maintenance intravenous (IV) infusions. Should the physician order an amount to be delivered over time, the nurse needs to be comfortable calculating the number of mL per hour that the patient is to receive. Smart technology pumps can do this calculation; however, to ensure that you have entered the data correctly, so the rate of infusion is correct, doing your own calculation before setting up the pump will ensure that you get the right infusion rate.

Your patient's IV orders read: Administer 3000 mL D_5W/24 hours.

The first factor to determine is how many mL/hr you need the pump to deliver. The easiest formula to calculate rate over time is to divide the volume by the time of infusion.

$$\frac{\textbf{Total volume}}{\textbf{\# of hours to infuse}} = \textbf{mL/hour infusion rate}$$

$$\frac{3000}{24} = \text{mL/hr}$$

$$\mathbf{125 = mL/hr}$$

Test Your Knowledge

Your patient's IV orders read: Administer 2.5 L of LR/10 hours

You will adjust the IV infusion pump to deliver _____mL/hr?

Did you get the right answer? Let's check the math.

First, change liters to mL
1 liter = 1000 mL
2.5 (1000) = 2500 mL

$$\frac{2500}{10} = \text{mL/hr}$$

250 = mL/hr

Calculating Critical Medication IV Drip Rates

Most medication infusion rates for critical medications are weight based, using kilograms (kg) not pounds. The different rates are: mg/kg/min; mcg/kg/min; although some are mg/hour or mcg/hour. It is important that the healthcare provider order and calculate the drug accordingly. As the last person to touch the infusion prior to administration, it is critical that you review the order for accuracy and calculate the rate of infusion correctly.

Ensure:

- The order and the bag of medication agree
  - If not, do not hang
  - Consult pharmacist and ordering physician
- Critical medication infusions are labeled with the concentration, dose for patient, rate of infusion
  - The concentration should be the same as in the drug library on your smart pump
    - If not, consult the pharmacist, do not hang
- Independent validation of calculation for dose and rate
  - If the two calculations do not agree, do not program pump
  - Recalculate
- Right patient
- Data programmed into smart infusion pump is correct
  - Compare calculated rate of pump to your calculations
  - If the two calculations agree, start pump
  - If not, review data input
    - Are you in the right library?
    - Are you in the right medication?

These steps will help ensure that the patient gets the right medication at the right rate and dose.

Standard Concentrations

Most of the medication concentrations are presented in mg/mL. For example:

- Dopamine
  - 400 mg/250 mL
  - 800 mg/250 mL
  - 800 mg/500 mL
- Dobutamine
  - 500 mg/500 mL

- Epinephrine
  - 1 mg/250 mL
- Norepinephrine
  - 8 mg/250 mL

As you can see, these drug concentrations are in mg/mL but most often ordered as mcg/kg/min or mcg/min. In order to be sure, the rate calculation is correct you must convert mg/mL to mcg/mL.

Infusion Rate Equation for mcg/min

Order reads: Epinephrine to infuse at 4 mcg/min
Pharmacy provides: Epinephrine 1 mg/250 mL

Step One: Determining mcg/kg concentration
You know that 1 mg = 1000 mcg
So, you determine that there is 1000 mcg/250 mL
To determine the concentration in mcg/mL you would divide 1000 mcg by 250 mL
The concentration is: 4 mcg/mL

Formula:
1 mg = 1000 mcg

$$\frac{x \text{ mcg}}{1 \text{ mL}} = \frac{1000 \text{ mcg}}{250 \text{ mL}} = 4 \text{ mcg/mL}$$

Step Two: Determining the rate of infusion
Formula:

$$\text{Infusion rate (mL/hr)} = \frac{\text{(target dose in mcg/min) x 60 min}}{\text{(Concentration in mcg/mL)}}$$

$$\text{X mL/hr} = \frac{\text{(4 mcg/min) x 60}}{\text{(4 mcg/mL)}}$$

$$\text{X mL/hr} = \frac{\text{240 mcg/hr}}{\text{4 mcg/mL}}$$

X = 60 mL/hr

This is just one way to calculate the mcg/min rate. It is important that you find a calculation method that you like and stick with it. Consistency/standardization = safety

Infusion Rate Equation for mcg/kg/min

Many critical drugs are ordered in mcg/kg/min (such as Dobutamine and Dopamine), you will need to calculate the infusion rate in mL/hr to administer these potent drugs via an IV infusion pump.

Order: Administer Dobutamine 5 mcg/kg/min IV
Pharmacy provides. 500 mg Dobutamine in 500 mL D_5W
Patient weight: 152 pounds

You know that your patient's weight must be in kg.
You know that 1 pound = 2.2 kg
To convert pounds to kg divide the pounds by kg

Step One: Determine kg weight

$$\frac{152 \text{ pounds}}{2.2 \text{ kg}} = x \text{ kg}$$

69.09 kg = x round to 69 kg

If your institution has a protocol for rounding weights, follow it. For this course, we will round to the nearest pound for ease of calculation.

Step Two: Determine the mg/mL concentration

You have 500 mg/500 mL
Divide the mg by the mL to get mg/mL

$$\frac{500 \text{ mg}}{500 \text{ mL}} = \mathbf{1\ mg/mL}$$

Step Three: Determining the rate of infusion

Formula:

$$\text{Infusion Rate (mL/hr)} = \frac{(\text{Weight in kg}) (\text{Target Dose in mcg/kg/min}) \text{ X } 60}{(\text{Infusate concentration in mg/mL}) \text{ X } 1000}$$

NOTE: In a mathematical operation, when 2 quantities appear in parentheses proximate to one another, this means multiply.

You will notice that in this formula, you will NOT separately determine the mcg/mL, but will calculate it within this formula.

$$\text{Infusion Rate (mL/hr)} = \frac{(69 \text{ kg}) (5 \text{ mcg/kg/min}) \text{ X } 60}{(1 \text{ mg/mL}) \text{ X } 1000} = \frac{69 \times 5 \times 60}{1 \times 1000} = \frac{20{,}700}{1000}$$

$$x \text{ mL/hr} = \frac{20700}{1000}$$

x = 20.7 mL/hr round to 21 mL/hr

Test Your Knowledge

You have an order to administer Intropin (Dopamine) 10 mcg/kg/min IV. Your patient weighs 176 lbs. You have infusate labeled 400 mg in 250 mL D_5W. What is your determined rate?

The answer is 30 mL/hr. How well did you do?

Step One: Determine kg weight

1 pound = 2.2 kg

$$\frac{176 \text{ pounds}}{2.2 \text{ kg}} = x \text{ kg}$$

80 kg = x

Step Two: Determine mg/mL Concentration

400 mg/ 250 mL

$$\frac{400}{250} = 1.6 \text{ mg/mL}$$

Step Three: Determine Infusion Rate

$$\text{Infusion Rate (mL/hr)} = \frac{\text{(Weight in kg) (Target Dose in mcg/kg/min) X 60}}{\text{(Infusate concentration in mg/mL) X 1000}}$$

$$\text{Infusion Rate (mL/hr)} = \frac{\text{(80 kg) (10 mcg/kg/min) x 60}}{\text{(1.6 mg/mL) x 1000}} = \frac{80 \text{ X } 10 \text{ X } 60}{1.6 \text{ X } 1000} = \frac{48{,}000}{1{,}600}$$

$$x \text{ mL/hr} = \frac{48{,}000}{1{,}600}$$

x = 30 mL/hr

Pediatric Dosing

Pediatric dosing is based on mg/kg/day. Healthcare practitioners should ALWAYS order medications by weight dosing. Weigh your patients in kgs and save yourself a step.

Double checking all pediatric doses at the beginning of your shift is time consuming but will ensure that when you get busy and under pressure, you will know you are giving the right dose and have decreased the risk of error.

A child who weighs 27 kg has an order for amoxicillin oral suspension 250 mg PO Q8H. According to the drug reference on the unit, the recommended pediatric dose is “20 – 50 mg/kg/day in divided doses every 8 hours.” Does the ordered dose fall within the recommended range of dosage?

Step One: Determine the dose range appropriate for your patient
Multiply the patient weight by the low and high range limits, in this case 20 and 50.
27 X 20 mg/day = **540 mg/day lower limit**
27 X 50 mg/day = **1350 mg/day upper limit**

Step Two: Determine the individual dose range
Divide the upper and lower daily dose by the number of times the medication will be administered. In this case, 3 doses will be given at 8-hour intervals or 24 hours divided by 8 hours = 3 doses

$\frac{540 \text{ mg/day lower limit}}{3}$ = 180 mg/dose

$\frac{1350 \text{ mg/day upper limit}}{3}$ = 450 mg/dose

Individual dose range = 180 to 450 mg/dose

Does the ordered dose lie within or outside of the recommended range?

The dose of 250 mg Q8H lies within the recommended range.

Using Body weight to Calculate Maintenance Fluids

Determining maintenance fluid is an essential task when caring for children. This determination allows you know what the child's baseline fluid needs are. Then you can adjust the rate based on dehydration or fluid overload determination.

With this formula, the child's weight multiplied by a predetermined amount for each weight group to determine the rate per hour needed.

Child's Weight in Kg	IV Drip Rate for Fluid Maintenance
0 – 10 kg	4 mL/kg/hr
11 – 20 kg	40 mL/hr + 2 mL/kg/hr over 10 kg
≥ 21 kg	60 mL/hr + 1 mL/kg/hr over 20 kg

Your patient weighs 9 kg
This weight falls within the first weight category
Multiply the weight by the mL

9 kg X 4 mL = 36 mL/hr

Your patient weighs 19 kg
This weight falls within the second category
Multiply the kgs over 10 kg by the ml/kg/hr rate and add 40 mL
19-10 = 9
9 kg x 2 = 18 kg
18 + 40 = 58 ml/hr

Your patient weighs 38 kg
This weight falls outside of all the categories, now what do you do? Easy
Multiply the kgs over 20 by the mL/kg/hr rate and add 60 mL

18 kg x 1 mL = 18 mL
18 + 60 = 78 mL/hr

Does this logic make sense? Okay, let's try this explanation:
Each weight category builds on the previous category.

Based on the formula, once a patient weighs over 10 kg, the first 10 kg fluid needs have been met and all patients weighing at least 10 kg will need 40 mL/kg/hour of fluid.

Therefore, a 19 kg patient's first 10 kg needs have been met by the set rate of 40 mL/hr. To meet the additional fluid needs of the remaining 9 kgs; the formula requires that you multiply these kg by 2 mL/kg/hour and adding it to the set rate. In this scenario, 9 kg x 2 mL = 18 additional mL/hr needed to meet the patient's maintenance fluid needs or 58 mL/hr

Following this logic, the amount of maintenance fluid a 38 kg patient needs includes the 60 mL/hour determined by the 20 kg in the previous category. To account for the additional needs of the remaining 18 kgs, an additional 1 mL/kg/hour is needed. Therefore, a 38 kg child needs 18 kg X 1 mL or 18 additional mL/hr to meet the patient's maintenance fluid needs or 78 mLs/hr.

10 kg need = 4 mL x 10 kg = 40 mL/kg/hour

20 kg need = 40 mL + kg weight over 10kg X 2 ml/kg/hour
40 mL + 10 X 2 mL/kg/hour
40 mL + 20 = 60 ml/kg/hour

Over 20 kg need = 60 mL + kg weight over 20 kg X 1 mL/kg/hour

Test Your Knowledge

Your patient is a 4-year-old who weighs 22 kg. His physician orders a daily dose of digoxin pediatric elixir 250 mcg PO. The recommended daily maintenance oral dosage for a child age 2- years is 7.5 – 10 mcg/kg.

Calculate the recommended dose for this child:
Did you determine that the daily dose ordered was above the recommended amount? Awesome
If not, let's review:

22 kg X 7.5 mcg = 165 mcg, lower limit recommended
22 kg X 10 mcg = 220 mcg, upper limit recommended

The ordered 250 mcg dose is above the recommended dose

Test Your Knowledge

What rate should this child's maintenance fluid rate be running at?
Answer: 62.7 mL/hr

The child's weight in kg = 22.7 kg.
(4mL x 10 kg) + (2 mL X 10 kg) + (1mL X 2.7 kg) = hourly rate
40 mL + 20 mL + 2.7mL = 62.7 mL/hr

Tips for Calculation Safety

With the advent of unit dosing, standardized concentrations, smart infusion pumps, among other technology, you may think that calculating medication doses is obsolete. However, the evidence is showing that while these approaches to medication safety are reducing medication errors, human error is still responsible for many medication errors even when using this technology.

These findings show how important it is that the healthcare provider know not only which medications the patient is receiving, but the correct dose, concentration, and rate. The only way to do this is to calculate the dose yourself and compare it to the order, the provided medication, and infusion pump.

The biggest pitfalls of medication calculation are performing the calculation under stress, when you are distracted, not using a formula that you are familiar with, and not getting the calculation independently confirmed.

- Find a time to do the calculations when you do not immediately have to give the dose or change the rate
- If your calculation matches what is on the medication package, what the pharmacist has shown on the label, or what has been programmed on the pump…..you will have your independent verification
- If your calculation does not match, get a colleague to review the order and do an independent double check. If both of your calculations match each other, then further investigation is needed to verify the dose and rate.

Conclusion

One of the most important skills you were taught in nursing school was how to complete medication calculations. Do not fall into the common practice of not using this skill. Protect yourself by knowing that you are giving the right medication dose and rate every time you administer a medication or change the rate of a critical medicine infusion. You can prevent errors! You can make technology work for you.

References

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