

Clinical Mathematics

<http://healthprofessions.udmercy.edu/academics/na/agm/mathweb09.pdf>

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Objectives

My overall objective is a collection of mathematical tools useful in clinical anesthesia practice.

1. Name six basic units in SI measurement.
2. Convert fractions to ratio, fraction to decimal, decimals to percent, ratios to mg/mL or mcg/mL, percent solutions to mg or mcg/mL.
3. Know common SI prefixes and be able to convert.
4. Perform temperature conversions in any scale.
5. Calculate desired rate setting for IV drips given patient weight, drug dilution, and desired dose.
6. Convert weights in pounds to kilograms.
7. Calculate FIO₂ when air is being used rather than N₂O.
8. State ideal weight when given actual weight and height in any units.
9. Calculate how long an E tank of oxygen will last at a given liter flow.

Math Tools Review

Further Reading

- Waugaman et al. *Nurse Anesthesia* 2nd ed. Chapter 4 on Metric medical mathematics by Marian Waterhouse. ISBN 0-8385-7962-0 1992 Appleton Lange.

- Kee JL, Marshall SM. *Clinical Calculations*. 2nd ed. Philadelphia: WB Saunders; 1992 (or newer editions).
- Drug Calculations for Health professionals- Quiz page (<http://www.testandcalc.com/quiz/index.asp>)
- Shubert D, Leyba J. *Chemistry and physics for nurse anesthesia*. New York: Springer; 2009.

Basic Approaches

Four basic techniques for solving any math problem are: Dimensional analysis, proportions, desired & available, and Lester's Rule for drips. These are explained below.

Dimensional analysis

To **convert units**, multiply by an identity (these are sometimes called *conversion factors* and are shown in parentheses in the formulae below). Examples:

$$760\text{mmHg} \times \left(\frac{14.7\text{psi}}{760\text{mmHg}} \right) = 14.7\text{psi} \quad (1.1)$$

$$29.9\text{inHg} \times \left(\frac{1013\text{mBar}}{29.9\text{inHg}} \right) = 1013\text{mBar} \quad (1.2)$$

$$454\text{gm} \times \left(\frac{2.2\text{lb}}{1000\text{gm}} \right) = 1\text{lb} \quad (1.3)$$

$$\frac{50\text{microgm}}{\text{mL}} \times \left(\frac{1\text{mg}}{1000\text{microgm}} \right) = \frac{0.05\text{mg}}{\text{mL}} \quad (1.4)$$

In each example, the fraction is an identity (14.7 psi and 760 mm Hg are equivalent in formula 1.1). Multiplying any quantity by an identity doesn't change the underlying quantity, only the label. For example, in formula 1.2, inches of Hg are changed to mBar.

Proportions

Proportions are used to determine the answers to questions like "How far can I go on a half tank of gas, if a full tank will let me drive 300 miles?" or, more pertinently, "How many mL of 0.75% bupivacaine do I need to draw up to give the patient 12 mg?" To solve this question, you calculate that 0.75% bupivacaine contains 7.5 mg/mL (see "Percentage solutions" below on this page), then set up and solve a proportion:

$$\frac{1\text{mL}}{7.5\text{mg}} = \frac{x\text{mL}}{12\text{mg}} \quad (2.1)$$

$$(12mg) \times \frac{1mL}{7.5mg} = \frac{x mL}{12mg} \times (12mg) \quad (2.2)$$

$$\frac{12}{7.5} mL = x \quad (2.3)$$

And $1.6mL = x$

Desired & Available

Working from what you have, to what you need. If you desire **remifentanil** 50 mg/mL, and have 1 gm available, how many mL of diluent are needed?

The first proportion (step 3.1) cannot be solved yet, since the denominator is in grams (on the left) and milligrams (on the right). So, in step 3.2, we multiply the right side by an identity (a conversion factor) which changes the denominator on the right side of the equation to grams, like the left.

$$\frac{x mL}{1gm} = \frac{1mL}{50mg} \quad (3.1)$$

$$\frac{x mL}{1gm} = \frac{1mL}{50mg} \times \left(\frac{1000mg}{1gm} \right) \quad (3.2)$$

$$\frac{x mL}{1gm} = \frac{1000mL}{50gm} \quad (3.3)$$

$$(1gm) \times \frac{x mL}{1gm} = \frac{1000mL}{50gm} \times (1gm) \quad (3.4)$$

And thus, $x = 20$ mL. Take the gram of remifentanil and dissolve in 20 mL diluent.

Another example. You have **ketamine** 500 mg in 5 mL. You want to prepare a 10 mL syringe with 10 mg/mL.

$$\text{Available} \quad \frac{500 mg}{5 mL} \times \frac{0.2}{0.2} = \frac{100 mg}{1 mL} \quad (3.5)$$

$$\text{Desired} \quad \frac{10 \text{ mg}}{1 \text{ mL}} \times 10 \text{ mL} = 100 \text{ mg (total drug in 10 mL)} \quad (3.6)$$

Therefore take ketamine 1 mL from the vial (which gives the 100 mg total drug you want in your 10 mL syringe) and add 9 mL of diluent.

Another example. **Epinephrine** is available, marked "1/1,000" and "1 mg/mL." You are asked to "double-dilute" it, so you take 1 mL of the epinephrine 1:1,000, and add 9 mL diluent. Then you discard all but one mL of the new mixture, and add 9 mL diluent. What is the resulting concentration of epinephrine in micrograms/mL?

- Epi 1:1,000 contains 1 mg/mL (= 1,000 mcg/mL). Taking 1 mL and adding 9 mL diluent yields a syringe with 1,000 mcg/10 mL (100 mcg/1 mL).
- Taking 1 mL of this mixture (containing 100 mcg/mL) and adding 9 mL diluent to it yields a syringe containing 100 mcg/10 mL. Each mL of the "double-diluted" new mixture contains 10 mcg/mL.

Another example: **Epidural syringe preparation.** Available: bupivacaine 0.25% (2.5 mg/mL), fentanyl 50 mcg/mL, and sterile diluent. Desired: A 60 mL syringe, containing 0.0625% (this is often called 1/16 %) bupivacaine with fentanyl 5 mcg/mL.¹

Here's Method 1: First, what is the total drug mass that you will end up with in the 60 mL syringe?

- Bupivacaine: 0.0625% contains 0.625 mg/mL.
 - How do we know this? "0.0625 %" means 0.0625 **grams** of drug in **100 mL of solution.**

$$\frac{0.0625 \text{ g}}{100 \text{ mL}} \times \frac{1,000 \text{ mg}}{1 \text{ g}} = \frac{62.5 \text{ mg}}{100 \text{ mL}} = \frac{0.625 \text{ mg}}{1 \text{ mL}} \quad (3.7)$$

- We want a 60 mL syringe with 0.625 mg/mL. The syringe will contain a total mass of bupivacaine of 37.5 mg (= 60 mL * 0.625 mg/mL).
- The total mass of fentanyl in the syringe is desired to be 5 mcg/mL * 60 mL = 300 mcg.

¹ Please keep in mind that these doses are for learning mathematics only. Please check with your colleagues to determine an appropriate concentration to give to your patients!

Now we are ready to prepare the 60 mL syringe:

- The total drug mass of bupivacaine is 37.5 mg/60 mL. Take the bupivacaine 0.25% (2.5 mg/mL) and draw up 15 mL ($37.5/2.5 \text{ mg} = 15$) in the 60 mL syringe.
- The total drug mass of fentanyl is 300 mcg/60 mL. Take the fentanyl (50 mcg/mL) and draw up 6 mL in the 60 mL syringe. The total volume you have drawn up so far is 15 mL (bupivacaine) + 6 mL (fentanyl) = 21 mL.
- Add 39 mL diluent to achieve a total volume of 60 mL.

What if, for some reason, you had to prepare a 20 mL syringe? The method is the same, if the same final concentration is desired.

- Bupivacaine: 0.0625% contains 0.625 mg/mL.
 - We want a 20 mL syringe with 0.625 mg/mL. The syringe will contain a total mass of bupivacaine of 12.5 mg ($= 20 \text{ mL} * 0.625 \text{ mg/mL}$).
- The total mass of fentanyl in the syringe is desired to be $5 \text{ mcg/mL} * 20 \text{ mL} = 100 \text{ mcg}$.

Now we are ready to prepare the 20 mL syringe:

- The total drug mass of bupivacaine is 12.5 mg/20 mL. Take the bupivacaine 0.25% (2.5 mg/mL) and draw up 5 mL ($= 12.5/2.5 \text{ mg}$) in the 20 mL syringe.
- The total drug mass of fentanyl is 100 mcg/20 mL. Take the fentanyl (50 mcg/mL) and draw up 2 mL in the 20 mL syringe. The total volume you have drawn up so far is 5 mL (bupivacaine) + 2 mL (fentanyl) = 7 mL.
- Add 13 mL diluent to achieve a total volume of 20 mL.

Here's Method 2: Some find it (much) easier to make the calculation of total drug mass for bupivacaine in the 60 mL syringe in another way.

It is easy to see that the same drug mass is present in two solutions, the second of which is twice as concentrated as the first, but contains only half the volume. Therefore, all the rows below contain the same total mass of drug. The first row starts with what you want to end up with, and proceeds down to what you need to start with.

“Bupivacaine 60 mL of 1/16% contains the same mass of drug as 30 mL of 1/8%.
Bupivacaine 30 mL of 1/8% contains the same mass of drug as 15 mL of 1/4%.”

Concentration of bupivacaine	Volume	Total mass of drug present
1/16 % (= 0.0625% = 0.625 mg/mL)	60 mL	37.5 mg
1/8 % (= 0.125% = 1.25 mg/mL)	30 mL	37.5 mg
1/4 % (= 0.25% = 2.5 mg/mL)	15 mL	37.5 mg

So, draw up bupivacaine (1/4 %) 15 mL, add 6 mL fentanyl, and finally add 39 mL of diluent as we did before. This yields a 60 mL syringe with bupivacaine 1/16%, and fentanyl 5 mcg/mL.

Lester's No-Math Rule for Intravenous Infusions

Lester's No-Math Rule for intravenous infusions is:

The number of milligrams in 250 mL comes out in micrograms in 1 min. at a setting of 15mL/hr, (and) The number of grams in 250 mL comes out in milligrams in 1 min. at a setting of 15mL/hr.

- Why? At 15 mL/hr, the volume delivered is 0.25mL per minute.

$$\frac{15\text{mL}}{1\text{hr}} \times \left(\frac{1\text{hr}}{60\text{min}} \right) = \frac{15\text{mL}}{60\text{min}} \quad (4)$$

And by division, $15\text{mL}/60\text{min} = 0.25\text{mL}/\text{minute}$

- 0.25 mL is 1/1,000 of a 250 mL intravenous bag. Therefore it contains 1/1,000 of the mass of drug in the 250 mL bag.



If this whole bag contains **Dopamine 400 mg in 250 mL...**

Then in each **1/1,000th** of the bag, there is **400 mcg in 0.25 mL**

- $400 \text{ mg} \times 0.001 = 0.4 \text{ mg} = 400 \text{ mcg}$
- $250 \text{ mL} \times 0.001 = 0.25 \text{ mL}$

■ 1 mcg is 0.001 of 1 mg (and 1 mg is 0.001 of 1 gm). Therefore, (as Lester states), the number of milligrams in 250 mL comes out in micrograms in one minute, at a setting of 15mL/hr.

Examples:

- What is the dose per minute of lidocaine (1 gm in 250 mL) running at 15 mL/hr?
 - *Answer: 1 mg/min.*
- What rate should you set to deliver dopamine 3 mcg/kg/min for a patient who weighs 70 kg? The dopamine is 400 mg per 250 mL.
 - *Answer: 7 mL/hr will deliver 200 microgm/min, which is approximately 3 microgm/kg/min.*

Fraction to ratio

Fractions and ratios are *nearly* identical except when the numerator and denominator are small. For example, 1/3 signifies 0.33, but 1:3 signifies a ratio of 1 part to 3 parts (and thus 4 parts in total) or 0.25.

Fraction to decimal

$$1 \div 3 = 0.3333 \quad (5)$$

Decimals to percent

Divide numerator by denominator, then multiply by 100.

$$(1 \div 3) \times 100 = 33.33 \% \quad (6)$$

Ratios in anesthesia

The ratio 1:100,000 is the one to remember. Ratios are expressed in grams/mL (it's easy to recall if you remember that 1 mL of H₂O weighs 1 g). So (starting with 1 gm in 100,000 mL), take the following steps to determine the number of microgm/mL in a 1:100,000 solution. The fractions in parentheses are conversion factors:

$$\frac{1gm}{100,000mL} \times \left(\frac{1000mg}{1gm} \right) = \frac{1000mg}{100,000mL} \quad (7.1)$$

$$\frac{1000mg}{100,000mL} \times \left(\frac{0.001}{0.001} \right) = \frac{1mg}{100mL} \quad (7.2)$$

$$\frac{1mg}{100mL} \times \left(\frac{1000microgm}{1mg} \right) = \frac{1000microgm}{100mL} \quad (7.3)$$

$$\frac{1000microgm}{100mL} \times \left(\frac{0.01}{0.01} \right) = \frac{10microgm}{1mL} \quad (7.4)$$

So a solution containing epinephrine 1:100,000 has 10 microgram of epinephrine per mL. By the same logical steps, a solution marked 1:200,000 has 5 microgram epinephrine per mL.

Percentage Solutions

The "number of parts of drug in every hundred" is the percentage of a solution, which is conventionally expressed as number of grams per 100 mL.

The shortcut is "To determine mg/mL in a % solution, you just move the decimal point one place to the right".

- *Example:* A 1% solution has 1 gm/100 mL, the same as 0.01 gm/1 mL, or 10 mg/mL (0.01 gm = 10 mg).

Metric System

The metric system is also known as "SI" (Système Internationale). The NIST Metric System Teaching Site (<http://physics.nist.gov/cuu/Units/index.html>) has a wealth of information on every aspect of the metric system, very clearly presented. It's easier to learn if you start thinking of all your everyday quantities metrically- your height, your soda can, a jar of salsa- what is their volume and weight expressed in metric system units?

Remember that a gram is 1000 mg, a mg is 1000 mcg, and a mcg is 1000 ng.

Metric Prefixes

Prefix	Associated quantity	In scientific notation
mega (M)	1,000,000	10^6
kilo (k)	1000	10^3
hecto (h)	100	10^2
centi (c)	0.01	10^{-2}
milli (m)	0.001	10^{-3}
micro (mc)	0.000001	10^{-6}
nano (n)	0.000000001	10^{-9}

Metric pressure units (the first two below), based on the Pascal, are a little unfamiliar to most of us.

1 atmosphere equals	1 Bar 1000 hPa = 1,019 cm H ₂ O = 1,013 mBar 760 torr = 760 mm Hg 100 kPa 29.9 in Hg 14.7 psi
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Temperature Conversions

$$^{\circ}\text{C} = 5/9 (^{\circ}\text{F} - 32) \quad (8.1)$$

$$^{\circ}\text{F} = (9/5 \times ^{\circ}\text{C}) + 32 \quad (8.2)$$

Or (better yet) remember the two together with:

$$9 \times ^{\circ}\text{C} = (5 \times ^{\circ}\text{F}) - 160 \quad (8.3)$$

Also,

$$\text{Degrees Kelvin} = ^{\circ}\text{C} + 273 \quad (8.4)$$

Figuring oxygen concentration when air or N₂O are used

It is useful as a backup to your oxygen analyzer to know what it "should" read. You can calculate the percent composition of the oxygen as compared to the total fresh gas flow. The total volume of oxygen includes all volume from the oxygen flowmeter, 21% of the volume indicated on the air flowmeter, and none of the rest of the flowmeters. Examples:

- What is the percent oxygen when 2 L/min oxygen and 2 L/min air are flowing?

- Answer: 60.5%, derived by:

$$2000\text{mL } O_2 + (0.21 \times 2000\text{mL Air}) = 2420\text{mL } O_2 \quad (9.1)$$

$$(2420\text{mL } O_2)/(4000\text{mL total FGF}) = 60.5\% O_2 \quad (9.2)$$

- What percent oxygen is inspired when flows are 2 L/min oxygen? 1 L/min oxygen? 8 L/min oxygen? *Answer: 100% in each case*
- What percent oxygen is inspired when flows are 2 L/min oxygen and 2 L/min nitrous oxide? *Answer: 50%*
- What percent oxygen is inspired when flows are 1 L/min oxygen and 2 L/min nitrous oxide? *Answer: 33%*

Hopefully the method of solving the last three is obvious.

DOT-123

A clinical rule useful in (quick and dirty) estimation of respiratory parameters for infants and children:

- Dead space = 1 mL per lb,
- O₂ consumption = 2 mL per lb, and
- Tidal Volume = 3 mL per lb.

Pilchak's No-Math Rule (convert pounds to kg)

To quickly convert pounds to kilograms (a formula that's easy to do in your head): *"Take the weight in pounds, subtract 50%, then subtract another 10%."*

$$(Weight(lbs))/2 - 10\% = Weight(kg) \quad (10)$$

Ideal Weight Estimation- three methods

Regardless of which method you choose, keep in mind that *none of these work well at extremes of height* (particularly poor for females of short stature [< 60 in.]). There's a good discussion of IBW online.²

1. **Simple rule** Easy to remember, since we most often think of height in inches and feet:

$$Females = 105lb + (5lb/inch \text{ over } 5 \text{ ft}) \quad (11.1)$$

$$Males = 106lb + (6lb/inch \text{ over } 5 \text{ ft}) \quad (11.2)$$

² <https://halls.md/ideal-weight-formulas-broca-devine/>

- **Devine** (1974) converted this simple rule to metric. Epic (electronic medical record) uses this formula at the hospital where I work to calculate desired tidal volume for mechanical ventilation. Note- also called **Predicted Body Weight (PBW)**.³

$$\text{Females IBW kg} = 45.5\text{kg} + (0.9\text{kg}/\text{Height cm} - 152) \quad (11.3)$$

$$\text{Males IBW kg} = 50\text{kg} + (0.9\text{kg}/\text{Height cm} - 152) \quad (11.4)$$

2. **Broca's Index** is useful if you can get comfortable thinking of height in centimeters. Five feet is ≈ 150 cm, six feet is ≈ 180 cm. This is very handy if your electronic medical record gives height in meters, e.g. 1.57 m height has an IBW of 57 kg. As compared to the simple rule, this formula overestimates IBW for males (by 2.4 to 5 kg over heights from 60-72 in.) and for females- more drastically (by 6.9 to 9.6 kg for heights of 60-72 in.).

$$\text{Ideal weight (kg)} = \text{Height(cm)} - 100 \quad (11.5)$$

3. **Body Mass Index (BMI)** is a way to relate the actual weight to the ideal. Be sure to specify height in meters. Normal BMI is less than 25, obese is less than 28, morbid is more than 35. To use this to find IBW, set BMI to 25 and solve for weight.

$$\text{BMI} = \frac{\text{Weight(kg)}}{\text{Height (meters)}^2} \quad (11.6)$$

Lean Body Weight

Lean BW is a way to determine the percentage of the obese weight that is metabolically active (also known as “adjusted” BW). We want to calculate fluids and tidal volumes based on metabolically-active tissue weight – the Lean BW- in morbidly obese individuals.

This is also important because the basis for drug dosages differs:⁴

- Dose based on Ideal BW: **propofol (induction)**, vecuronium, **rocuronium**, remifentanyl, **Tidal Volume** for mechanical ventilation (based on IBW or predicted body weight- see below).
- Dose based on Total BW: **propofol (maintenance infusion)**, thiopental, midazolam, **succinylcholine**, cisatracurium, fentanyl, and sufentanyl

³ N Engl J Med. 2000;342:1301–8

⁴ AANA Journal April 2011: 79 (2):147; Br J Anaesth 2010;105(Suppl_1):i16–i23

Lean BW First Method

- The multiplier is between .25 and .5 of the difference between Actual and Ideal BW (median .32)⁵. Miller uses 0.2⁶

$$LBW = IBW + 0.2(ActBW - IBW) \tag{12.1}$$

- For example, a male 6 ft 0 in. (1.83 m) and 270 lbs. (122.7 kg)
 - $BMI = \frac{122.7 \text{ kg}}{3.34 \text{ Ht (m}^2\text{)}}$ and BMI = 36.7
 - $IBW \text{ (using 25 BMI)} = 25 * 3.34 = 83.5 \text{ kg (183.7 lbs)}$
 - $Lean \text{ BW}$ (using formula above) is 91.34 kg (200.9 lbs)
 - $Lean \text{ BW} = 83.5 \text{ kg} + 0.2(122.7 - 83.5 \text{ kg})$

Lean BW Second Method⁷

$$Lean \text{ BW} = BMI * Height \text{ (m}^2\text{)} \tag{12.2}$$

	Males	Females
For Normal Body mass, Lean BW = Ideal BW	IBW=23*Ht (m ²)	IBW=21*Ht (m ²)
Morbidly Obese	IBW Same	IBW Same
Lean BW	LBW=26*Ht (m ²)	LBW=22*Ht (m ²)

- For example, a male 6 ft 0 in. and 270 lbs.
 - $BMI = \frac{122.7 \text{ kg}}{3.34 \text{ Ht (m}^2\text{)}}$ and BMI = 36.7
 - $IBW \text{ (using 23 BMI)} = 23 * 3.34 = 76.8 \text{ kg (169 lbs)}$
 - $Lean \text{ BW}$ is 86.8 kg (191 lbs)
 - $Lean \text{ BW} = 26 * 3.34$

⁵ Nutr Clin Pract 2005;20(4):468-73

⁶ Miller's Anesthesia 7th Ed. 2009. p. 2099. Nagelhout Nurse Anesthesia 4th ed agrees.

⁷ Br J Anaesth 2012;109(5):829-30.

Calculating how long a cylinder will last

A perennial Board-type question with clinical importance. Use a proportion to solve (there are approximately 660 L in a full E tank of oxygen, at a service pressure of 2000 psi). Don't forget to consider fresh gas flow (FGF).

- *Example:* Your oxygen tank pressure gauge reads 200 psi. How long can a flow of 2 L/min be maintained?

$$\frac{x L}{200psi} = \frac{660L}{2000psi} \quad (13)$$

- $x = 66L$. Thus the tank will last 33 min, if the 66 L in the tank flows out at 2 L/min.

Drips by drops method for drug infusions

Works for dopamine, dobutamine, isoproterenol, epinephrine, norepinephrine, phenylephrine, theophylline, sodium nitroprusside, nitroglycerin, trimethaphan, lidocaine, procaineamide, bretyllium. Requires no calculations or tables. From Donenfeld RF. *Anesth Analg* 1990;70:116-7.

- Method: Dilute 1 ampule of drug in one 250 mL bag of IV fluid. Infusion rates of 60, 30, and 15 mL/hr give high, medium, and low dose rates of any of the above agents (for a 70 kg person). If a controller pump is unavailable, these rates are easy to set with microdrop tubing (1 gtt/sec, 1 gtt/2sec, 1 gtt/4sec).
- If the patient's weight differs from 70 kg, the drop rate needs adjustment accordingly, ie:

$$\frac{\text{Actual kg}}{70kg} \times \text{Desired rate (mL/hr)} = \text{Adjusted rate} \quad (14)$$

- Delivered dose is easily calculated as follows: (mg/250 mL) x 4 = mcg/mL.
 - *Proof?* The number of mg/250 mL x 4 = mg/1000 mL. The number of mg/1000ml multiplied by 0.001/0.001 equals mcg/mL. Note: this is also a method some use to calculate continuous IV infusion doses.

Acceptable blood loss (ABL)

There are online calculators on the web (http://manuelweb.com/nrs_calculators.htm just in case you have internet connectivity in your OR!). I found that one by Googling "allowable blood loss".

EBV (mL/kg) differs with age and gender

- Males 75 mL/kg
- Females 65 mL/kg
- Premature infants 90 mL/kg
- Neonate at term 85 mL/kg
- Children 1-2yr 75 mL/kg

Then calculate [allowable blood loss](#)

$$ABL = \frac{Hct_{initial} - Hct_{final}}{Hct_{initial}} \times EBV \quad (15)$$

Fluid maintenance

Pediatric fluid balance:

1. For the first 10 kg, give 4mL/kg/hr, then
2. For the next 10 kg (10-20 kg), give 2mL/kg/hr, then
3. Give 1mL/kg/hr for kg greater than 20 kg.

For example, a 12 kg child gets $(10 \times 4) + (2 \times 2) = 44\text{mL/hr}$
 And a 22 kg child gets $(10 \times 4) + (10 \times 2) + (2 \times 1) = 62\text{mL/hr}$

Endotracheal tube size, length

$$\text{Lip line} = \frac{\text{Age}}{2} + 12 \quad (16.1)$$

$$\text{ET internal diameter (mm)} = \frac{\text{Age} + 16}{4} \quad (16.2)$$

Alveolar air

$$pAO_2 = F_1O_2(p_B - p_{H_2O}) - 1.2 \times paCO_2 \quad (17.1)$$

Note how alveolar (and thus arterial) oxygenation can suffer if arterial CO_2 is elevated. Normal alveolar oxygen is

$$101.73\text{torr} = 0.21(760 - 47) - 1.2 \times 40 \quad (17.2)$$

But, if CO_2 increases to 60 torr, alveolar oxygen must fall to 77.7!

This simplified equation from Martin (http://www.globalrph.com/martin_4_most2.htm) assumes that $p_{H_2O} = 47$ torr at body temperature, P_B is barometric pressure, and R is normal (R is the respiratory quotient, found by dividing CO_2 excreted by O_2 consumed)

Arterial oxygen content

$$CaO_2(\text{mL}/100\text{mL blood}) = (1.39 \times Hb \times SaO_2) + (paO_2 \times 0.003) \quad (18)$$

Expected pO2 for changes in FIO2

A rough estimator based on Henry's Law. If you change FIO_2 10%, expect paO_2 to increase 50 torr (starting values FIO_2 21%, paO_2 100 torr approximately).

Time constant

$$\text{Time Constant} = \frac{\text{Capacity}}{\text{Flow}} \quad (19)$$

- A system reaches 63% of equilibrium in one time constant; 86% of equilibrium in 2 time constants; 95% of equilibrium in 3 time constants. Applications are wash-in and washout of gases, or time to complete denitrogenation at varied fresh gas flow rates.

Remembering drug doses

It's always advisable with a family of drugs **to work out their relative doses per 70 kg**. That way, you have a baseline for comparison and can increase or decrease your starting dose in proportion to the patient's weight. Also, you're less likely to choose a much too big (or much too small) dose for a patient when you have memorized what the "average weight" patient would typically receive.

- For example, reasonable intubating doses for the muscle relaxants (assume 70 kg weight) are vecuronium 7 mg, rocuronium 42 mg, cis-atracurium 14 mg, and pancuronium 7 mg. (Of course you would modify these doses based on body habitus and past history.)

Remember "same as..." doses. For example, vecuronium and pancuronium. Or similar doses like the pair esmolol (bolus 0.5 mg/kg) and rocuronium (roughly the same for a low-range intubating dose).

Work out doses for a typical person

Dose mg/kg	Dose/70kg
1	70 mg
0.5	35 mg
0.1	7 mg
0.05	3.5 mg
0.01	0.7 mg

Again, that way you have a concept of what those numbers mean for the "average" patient. You can then use this concept as a means of double-checking your answer derived from the electronic calculator, or for mental math done in haste.

Keep in mind the expected volume (number of mL) for drugs, especially narcotics and muscle relaxants. If you are drawing up and preparing to administer more than 3 to 10 mL of muscle relaxant as an intubating dose, it is likely your math is faulty (provided the patient is anywhere near normal weight).

Spinal (intrathecal) doses

1. **Have somewhere to start for a reasonable level (T10) for each drug.**
 - For example tetracaine 10 mg (1 mL of 1%)
 - A reasonable lidocaine dose for the same effect is 50 to 60 mg (1 to 1.2 mL of 5%).
 - A reasonable bupivacaine dose is 12 mg (1.6 mL of 0.75%).

2. **Know the range of doses found to be useful at your institution, in your patients.** Modify the dose based on height, medical history, pregnancy, or whatever other factors you like.
 - When you add or subtract, remember the amount of drug in some usefully-small quantity (spinal syringes are marked every 0.2 mL)
 - lidocaine 5% has 10 mg per 0.2 mL,
 - tetracaine 1% has 2 mg per 0.2 mL , and
 - bupivacaine 0.75% has 1.5 mg per 0.2 mL.
3. **Alter the baricity of the drug, if needed, for the effect you want.** Typically, hyperbaric spinals are given. The spinal medications may or may not come mixed in hyperbaric 7-10% dextrose. If they do *not* come so mixed, add an equal volume of dextrose solution to the local anesthetic.
4. **Add any extras, have someone double-check your figures if you have the SLIGHTEST doubt** (once given, the medication is irretrievable and has profound effects), *then administer.*
 - Epinephrine (1:1000) 0.2 mL is a common additive.
 - Preservative-free morphine 0.5-0.7 mg (0.5-0.7 mL of Duramorph 0.1%) is also common.
 - Please don't ask me how I know about the "irretrievable and profound" part.

Epidural doses

1. The rule of thumb is **With a lumbar epidural placement, 10 mL of drug will generally produce a T7 to T9 level in the average size patient, 20 mL will result in a T4 level.**
2. Larger volumes of drug will be required for higher blocks, more concentrated drugs for more intense motor block, and more dosage (total mass of drug) for increased sensory block (Reese CA. Spinal and epidural blocks. 2nd ed. Park Ridge, Illinois: AANA; 1996 p. 104-5).

[Questions?](#)

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