MEDICATION ADMINISTRATION · CHAPTER 21

Part 3

Intraosseous Infusion

The Metric System · Medical Calculations

Part 3

Intraosseous Infusion and Medical Mathematics

Why a Bone Works Like a Vein

The question students always ask, answered before they ask it

What an IO actually is

Intraosseous infusion involves inserting a rigid needle into the cavity of a long bone or into the sternum.

Within the diaphysis — the shaft of the bone — the medullary canal contains bone marrow, and that marrow is richly vascular.

The answer to the question

Marrow is drained by a network of venous sinusoids that empty into the central circulation. A drug pushed into the marrow is in the great vessels in seconds.

And because those sinusoids are held open by the bone around them, they cannot collapse — which is exactly why they are still there in the patient whose peripheral veins have shut down.

Three consequences worth stating out loud

1 Onset is effectively IV

Drug and fluid delivery times through an IO closely approximate those through a peripheral IV. Nothing about a dose or a push rate changes because the route is IO.

2 It works when nothing else does

Peripheral vasoconstriction in shock empties the veins you can see. The marrow space is scaffolded by bone and stays patent. The sicker the patient, the greater the relative advantage.

3 It needs pressure to run

A marrow sponge has resistance a vein does not. Gravity alone will not deliver a fluid bolus — which is why the Region X procedure ends with applying a pressure bag.

4 Peripheral IV is still preferred

The text is explicit: peripheral IVs are preferred, and IOs are reliable in the absence of other available sites. This is a route you choose when the alternative has failed or is not worth the time.

Access Sites and the Anatomy Behind Them

Into the diaphysis, away from the growth plate

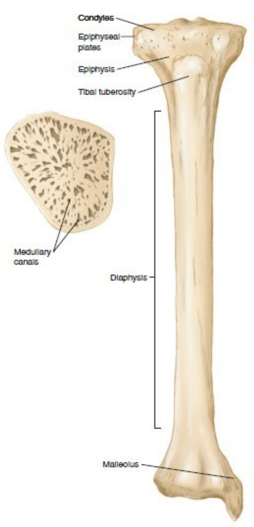

Figure 21-59 Anatomy of the tibia.

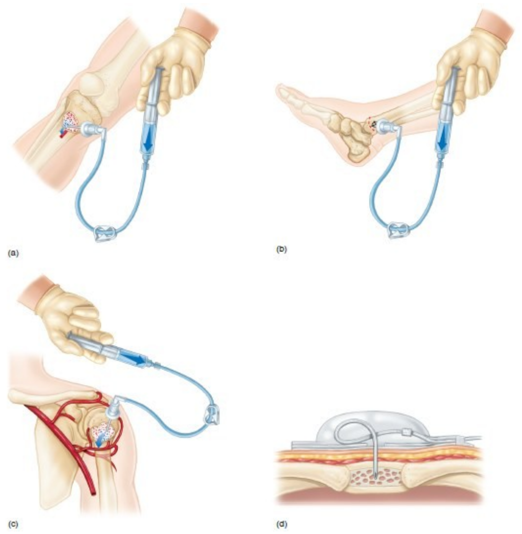

Figure 21-58 IO placement sites by device.

Finding the proximal tibia — the landmark sequence

Pediatric

Palpate the tibial tuberosity. Move 1 to 2 fingerbreadths below it, onto the flat expanse medial to the anterior tibial crest.

Adult and geriatric

Find the medial location — the flat, broad plate of bone on the inner aspect of the proximal tibia, clear of the joint.

The sites

The proximal tibia is the bone most used in both pediatric and adult patients.

In adults the medial malleolus, the humeral head and the sternum are also used. Which of them is available to you depends on the device your service carries — not every device reaches every site.

The anatomy that keeps you out of trouble

The needle goes into the diaphysis, the shaft, where the medullary canal is. Avoid the epiphysis — the end of the bone, where the growth plate sits in a child.

Understanding bone anatomy is how you both find the site and avoid the complication. Growth plate damage is the complication that is unique to this route.

Rotate the leg outward to expose the medial, proximal aspect of the tibia before you go looking for landmarks. Positioning is half of finding the site — an internally rotated leg hides the flat surface you need.

When to Go to the Bone

The textbook gives you the principle; your SOP gives you the trigger

Region X indications — Intraosseous Infusion, SOP p. 85

Who

Shock, arrest or impending arrest. An unresponsive — or conscious — critical patient.

When you stop trying for a vein

Two unsuccessful IV attempts, or 90 seconds of duration, or no visible sites.

Any one of the three is enough. They are alternatives, not a sequence you must exhaust.

The textbook's fourth contraindication is the honest one

The text lists "establishment of a peripheral IV line" as a contraindication to IO placement. Read plainly: if you can get a vein, get a vein. The IO is not a shortcut around a difficult stick on a stable patient.

Contraindications — the SOP list, and why each one is there

1. **Fracture in the same extremity, or infection at the insertion site**
   A fractured bone leaks — fluid infused below a fracture extravasates into the limb instead of reaching the circulation. An infected site seeds the marrow, and osteomyelitis is a serious infection to have caused.

2. **Previous orthopedic procedures — knee replacement, or a previous IO within 48 hours**
   Hardware may occupy the space you are aiming for. A recent IO leaves a hole the new infusion leaks straight back out of.

3. **Pre-existing conditions — tumour near the site, peripheral vascular disease**
   Both mean the marrow cavity or its drainage may not be what you are assuming it is.

4. **Inability to locate landmarks — significant edema**
   If you cannot find the flat medial plate with confidence, you cannot drive a needle perpendicular to it with confidence. Do not guess at a bone.

The Intraosseous Needle

A needle inside a needle — rigid enough to be driven through cortex

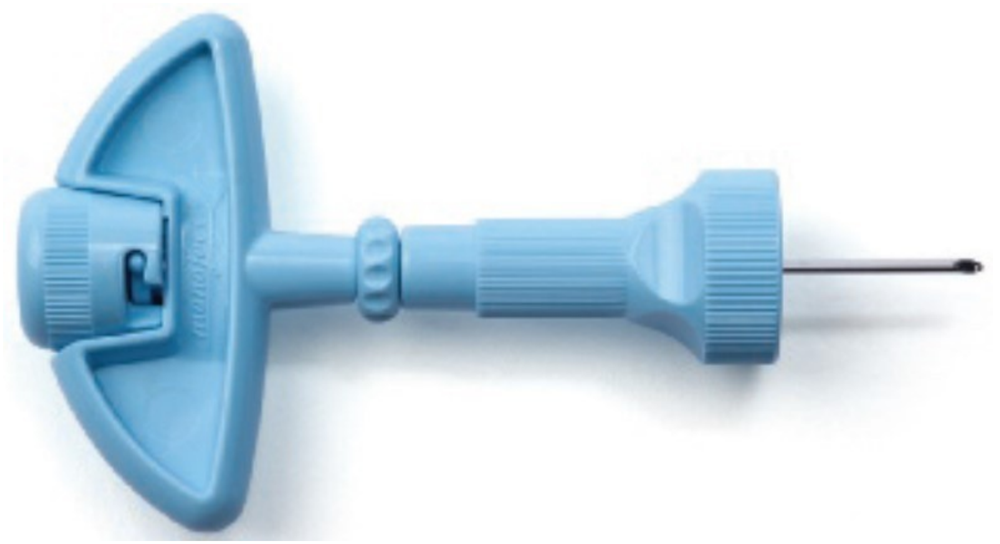

Figure 21-60 Intraosseous needle.

Bledsoe, Porter & Cherry, Paramedic Care: Principles & Practice, 6th ed. © Pearson Education, Inc.

Why there is a trocar inside it

The IO needle is a hollow cannula — the text gives 14- to 18-gauge — with a sharp metal trocar inside it.

The trocar provides strength and rigidity, and it plugs the lumen so the needle does not core a plug of skin, fat and bone and carry it into the marrow. It comes out once you are through; the cannula stays.

What else you need laid out before you start

1. **IV fluid with a pressure infuser** — Gravity will not overcome marrow resistance. The pressure bag is equipment, not an optional extra.
2. **Administration tubing** — Plus, on a commercial device, the short connector set that primes separately.
3. **A 10 mL syringe** — For aspiration to confirm placement and then for the flush that opens the marrow space.
4. **Tape and a securing device** — The needle is short and stands proud of the skin. Securing it is the difference between a working line and a dislodged one.
5. **Antiseptics and gauze** — Same aseptic discipline as any vascular access — you are opening a direct path into the marrow.

Commercial Intraosseous Devices

Three mechanisms — spring, hand-driven, and drill

Figure 21-61 The bone injection gun.

Figure 21-62 The FAST1: sternal placement.

Figure 21-63 The EZ-IO drill.

Bone Injection Gun

Spring-loaded. The device is set to a depth, placed against the site and triggered; the spring drives the needle in.

Adult and pediatric models are separate devices.

FAST1

Places intraosseously in the sternum of an adult or adolescent. A cluster of probes finds the depth for you and a single needle enters at the calculated depth.

Carried mainly where extremity access is unavailable or unreliable.

EZ-IO

A small battery-powered drill. Approved for adult and pediatric use, and the device Region X carries.

Drilling produces a cleaner channel with less risk of the needle bending or the trocar binding — which is why it displaced the others.

Placing an Intraosseous Line

The general technique — device-independent, and the shape every procedure follows

1 Confirm the indication

Determine that intraosseous infusion is indicated for this patient. Assemble and check all equipment before you touch the leg.

2 Position

Rotate the leg toward the outside to expose the medial, proximal aspect of the tibia. Support it — never hold the leg in the palm of your hand with the needle coming toward it.

3 Locate the site

Pediatric: 1 to 2 fingerbreadths below the tibial tuberosity, medial to the anterior tibial crest. Adult and geriatric: the medial location.

4 Cleanse outward

Start at the puncture site and work outward in an expanding circular motion — the same discipline as any vascular access.

5 Puncture

Hold the needle perpendicular to the site and insert with a twisting motion until you feel a decrease in resistance or a distinct pop. That change is the cortex giving way to marrow.

6 Confirm

Remove the trocar, attach the syringe, and slowly pull back the plunger. Easy aspiration of bone marrow and blood confirms correct medullary placement.

7 Connect and run

Rotate the plastic disk down toward the skin, remove the syringe, attach the prepared administration tubing and solution, and set the flow rate.

8 Secure like an impaled object

Surround the needle with bulky dressings and tape them securely in place. It stands proud of the skin and it will catch on everything.

The Region X EZ-IO Procedure

The general technique, as your system performs it — SOP p. 85

1	**Locate and prep**	Proximal medial tibia or proximal humerus. Prep the site.
2	**Prime the connector**	Prime the EZ-Connect tubing, leaving 9 mL of fluid in the syringe. That 9 mL is the confirmation flush — it is measured out before you start for a reason.
3	**Select the needle**	Prepare the driver and choose the needle set by patient weight and site.
4	**Insert to bone**	Insert at 90 degrees through skin until the needle stops at bone. The line on the needle closest to the hub must remain visible — if it is not, remove the needle, place a bandage, and do not use the EZ-IO at that site.
5	**Drive, then stop**	Depress the trigger. Release it at decreased resistance or when the flange reaches skin — whichever comes first.
6	**Separate**	Stabilise the needle hub, remove the driver, then remove the stylet by rotating it counterclockwise.
7	**Confirm**	Connect the primed EZ-Connect tubing. Aspirate, then flush with the remaining 9 mL of normal saline to confirm placement.
8	**Run it and hold it**	Attach IV tubing and begin the infusion. Apply a pressure bag. Tape the tubing to the extremity. If you used the humerus, immobilise the arm. Reassess bag pressure, volume infused, site and patient frequently.

Needle selection

15 mm · Pink
Patient 3 to 39 kg.

25 mm · Blue
Patient 40 kg and above.

45 mm · Yellow
Humeral site, and the bariatric patient.

The visible-line rule
If the black line nearest the hub is not visible once the needle rests on bone, the soft tissue is deeper than the needle is long. A longer needle — not more force.

The Pain Problem

The reason this skill gets hesitated over — and what your SOP does about it

Be honest about it

Insertion in a conscious patient is uncomfortable; infusion under pressure into a marrow cavity is worse, and patients describe it as a deep, severe ache in the whole limb.

The IRM names the consequence directly: this is a skill many paramedics are reluctant to perform because it causes a great deal of pain.

Why the hesitation is the bigger risk

The patient who meets the indications — shock, arrest, or impending arrest — is the patient for whom delay is measured in organ perfusion.

A provider who spends four more minutes hunting for a vein to avoid causing pain has chosen a certain delay over a treatable discomfort.

Region X lidocaine for IO pain — supplied 100 mg/5 mL, concentration 20 mg/mL, slow IO push over 1–2 minutes

Adult

LIDOCAINE 1 mg/kg, maximum 50 mg, over 1 to 2 minutes. Wait 60 seconds before beginning the fluid infusion. May be repeated once for pain control.

Pediatric

LIDOCAINE 0.5 mg/kg, maximum 40 mg, over 1 to 2 minutes. Wait 60 seconds before infusing. May repeat at 0.25 mg/kg over 30 to 60 seconds, maximum 20 mg.

The 60-second wait is the whole point of the drug. Lidocaine has to occupy the marrow space before pressurised fluid arrives, or the anaesthetic is simply washed ahead of the pain it was meant to prevent.

A worked example for later: a 70 kg adult at 1 mg/kg calculates to 70 mg — but the maximum is 50 mg. At 20 mg/mL that is 2.5 mL. The ceiling, not the arithmetic, sets the dose.

Complications of Intraosseous Access

Most of them are one error — the needle is not where you think it is

Unique to this route

1. **Fracture** — Driving a large needle into bone can fracture it, particularly in the very young, the very old, and in structurally abnormal bone.
2. **Growth plate damage** — The complication that exists only in children, and the reason the pediatric landmark is measured away from the epiphysis.
3. **Complete insertion** — The needle passes through the far cortex. Fluid then goes into the tissue on the other side of the bone, and the line reads as patent while delivering nothing.
4. **Infiltration** — Fluid escaping the marrow cavity into the surrounding limb — from a partly seated needle, a leaking previous hole, or a fracture above the site.

Shared with every vascular access route

Infection

A direct path into marrow. Osteomyelitis is the serious version.

Pulmonary or air embolism

Marrow contents or air entering the central circulation.

Thrombophlebitis

Inflammation and clot in the draining vessels.

Circulatory overload

Same as any line — fluid given faster than the patient can take it.

Allergic reaction

To the solution, the drug or the antiseptic.

Local pain

Expected rather than unexpected — and treatable, as the last slide showed.

Look at the limb, not just the line. Compare circumferences, feel the calf, and check that the site is not tightening — infiltration into a leg is silent until it is a compartment problem, and a pressure bag is pushing fluid in the whole time.

THE SECOND HALF

Medical Mathematics

Where the right dose stops being a principle and becomes a number

1. The metric system
2. One formula, four uses
3. Weight-based doses
4. Infusion rates

The Metric System

Pharmacology's principal system of measurement — and the only one your protocols use

Grams · mass

How much drug there is. A gram is not a prefixed unit — it is the thing the prefixes multiply.

Liters · volume

How much liquid it is dissolved in. Same status: the base, with a multiplier of 1.

Meters · distance

The third fundamental unit, and the one you will use least in this chapter.

Table 21-2, with the base unit put back — every step is ×10, except the one that is not

kilo	hecto	deka	BASE UNIT	deci	centi	milli	micro
k	h	da	g · L · m	d	c	m	mc
1,000	100	10	1	0.1	0.01	0.001	0.000001

× 10 · × 10 · × 10 · × 10 · × 10 · × 10 · **× 1,000**

two decades have no prefix

The three you will actually use

Kilograms for patient weight. Milligrams and micrograms for drug dosing. Milliliters and liters for volume.

Watch the abbreviations: mc is the prefix, mcg is the unit — one microgram.

Hecto, deka and deci are on the ladder because the system is regular, not because you will draw up a decagram.

Where the ladder is not a ladder

The printed table leaves out two things. The base unit is a rung of its own, with a multiplier of 1 — without it, deka to deci looks like one step when it is two.

And milli to micro is a thousandfold jump, not tenfold: the two decades between them have no prefix in clinical use.

Why it still comes out simple

Every rung is a power of ten, so every conversion is a decimal point moving — not a fraction, not a ratio, not a lookup.

And the three jumps you will make at speed are all the same size, three rungs each:
1 kg = 1,000 g · 1 g = 1,000 mg · 1 mg = 1,000 mcg

Converting Between Prefixes

Two rules, and a sanity check that catches almost every error

To a smaller unit — multiply

Multiply by how many of the smaller units make one of the larger. There are 1,000 milligrams in a gram, so multiply by 1,000. Smaller units, more of them.

To a larger unit — divide

Divide by that same number. There are 1,000,000 micrograms in a gram, so divide by 1,000,000. Larger units, fewer of them.

Example 1 · Convert 3 grams to milligrams

Milligrams are smaller than grams, so multiply.

3 g × 1,000 = 3,000 mg

Sanity check: the number got bigger. Correct.

Example 3 · Convert 1,600 micrograms to grams

Grams are larger than micrograms, so divide.

1,600 mcg ÷ 1,000,000 = 0.0016 g

Sanity check: the number got smaller. Correct.

The sanity check, stated as a rule you can apply without thinking

1 Smaller unit, bigger number

Going from grams to milligrams, the count must go up. If your answer went down, you divided when you should have multiplied.

2 Larger unit, smaller number

Going from micrograms to grams, the count must go down. An answer larger than what you started with is wrong before you check anything else.

3 The error is always direction

Almost nobody gets 3 × 1,000 wrong. What people get wrong is whether to multiply or divide — so check the direction first, every time.

4 Say the units out loud

"Three grams is three thousand milligrams." If the sentence sounds absurd when spoken, it is absurd on paper too.

When Neither Unit Is the Fundamental One

Route through grams rather than trying to jump

The rule

When converting a measurement to or from a prefix that is not the fundamental unit, first convert the existing measurement to the fundamental measurement.

Then convert that fundamental measurement to the desired unit.

Why not just jump?

You can — milligrams to micrograms is a single multiplication by 1,000. But the jump requires you to know the relationship between two prefixed units.

Routing through the fundamental unit requires you to know only each prefix's own multiplier, which is what the table gives you. Fewer facts, fewer errors.

Example 4 • Convert 5.6 milligrams to micrograms

Step 1 — milligrams to grams. Grams are larger, so divide.

5.6 mg ÷ 1,000 = 0.0056 g

Step 2 — grams to micrograms. Micrograms are smaller, so multiply.

0.0056 g × 1,000,000 = 5,600 mcg

The same answer, jumped in one step

Micrograms are 1,000 times smaller than milligrams.

5.6 mg × 1,000 = 5,600 mcg

Use whichever route you trust. Both are correct;

only one of them is correct when you are tired.

The chapter summary makes this point for the whole session: medical calculations can be completed by a variety of methods, and what matters is finding a method that works for you and gets the right answer every time you work a problem.

Fentanyl is supplied at 50 mcg/mL. A label reading 0.05 mg/mL is the same drug at the same strength — and a provider who does not see that instantly is one decimal point from a problem.

The Systems You Will Meet but Not Use

Household measures, apothecary measures, and the things that cannot be converted at all

Why they are still in the chapter

Pharmacology traditionally used the household and apothecary systems. The metric system has gradually replaced them, but you may occasionally encounter them — usually in a patient's own account of what they took.

Table 21-3 • Metric equivalents — note how many say "approximately"

1 gallon	4 quarts	**3.785 L**
1 quart	1 quart	**0.946 L**
16 ounces	about 1 pint	**473 mL**
1 cup	about ½ pint	**about 250 mL**
1 tablespoon	—	**about 16 mL**
1 teaspoon	—	**about 4 to 5 mL**

Units — the ones that convert to nothing

Some medications are measured in units, and units cannot be converted. A unit is a measure of biological activity, not of weight, mass or volume.

Insulin and heparin are the ones students will meet.

The table does not quite agree with itself

Three teaspoons make a tablespoon. At 4 to 5 mL each that is 12 to 15 mL — not the 16 the table prints. Both figures are approximations of kitchenware, not instruments.

Use 5 mL and 15 mL in practice. That imprecision is the whole argument for the metric system, and it is why nothing you administer is measured in spoons.

Where this actually matters on a call

It matters in history taking, not in administration. A parent says they gave two teaspoons of children's acetaminophen; a patient says they drank half a cup of an unknown liquid.

Your job is to translate that into something the receiving physician can use — roughly 10 mL, roughly 120 mL — and to say "approximately" when you report it.

Weight and Temperature Conversion

Two conversions you will do on real calls — one of them constantly

Pounds to kilograms — divide by 2.2

Every weight-based order in your protocols is written in milligrams per kilogram. Every patient tells you their weight in pounds. That conversion is the first step of most calculations you will ever perform.

Worked · a patient who reports 165 pounds

165 lb ÷ 2.2 = 75 kg

Estimate first: halve it, then take a bit off.

165 halved is 82; 75 is in that neighbourhood.

The estimate is not the answer — it is the check.

The error that matters

Using pounds where the order says kilograms gives a dose 2.2 times too large. That is not a rounding difference; it is a serious overdose, and it is the single commonest weight-based error.

The IRM asks the question directly: how much of a difference in dosage can be related to weight conversion? Answer it with this number.

Fahrenheit and Celsius

The international thermometric scale measures temperature in degrees Celsius, and clinical thresholds are increasingly written that way.

°C = 5/9 (°F − 32)　　°F = 9/5 °C + 32

Worked · the exertional heat stroke threshold

Region X uses a rectal temperature above 104°F.

°C = 5/9 (104 − 32) = 5/9 × 72

°C = 40°

So the threshold is 104°F, or 40°C exactly.

Anchors worth memorizing instead

Most providers never use the formula, because four anchor points cover clinical practice: 98.6°F is 37°C, 100.4°F is 38°C, 104°F is 40°C, and 95°F is 35°C — the hypothermia threshold.

Know the formula for the examination; know the anchors for the ambulance.

The Basic Formula

Three facts, one equation, and everything else in this session is a variation on it

Desired dose

The specific quantity of medication needed — what the protocol or the physician ordered. Expressed in mass: grams, milligrams, micrograms.

Dosage on hand

The weight of drug in the container you are holding — read off the label, never from memory.

Volume on hand

The amount of liquid that dosage is dissolved in. Together with the line above it, this is the concentration.

$$\text{Volume to administer} = (\text{Desired dose} \times \text{Volume on hand}) \div \text{Dosage on hand}$$

The four things it is used for — the same equation each time

1 Oral medications

A liquid drug in a bottle. Desired dose over what is in the bottle, times the volume it is in.

2 Liquid parenteral medications

The commonest use — how many millilitres to draw into the syringe.

3 Intravenous fluid administration

There is no concentration to divide by — the order is already a volume. Divide it by the time and you have a rate.

4 Intravenous medication infusions

The formula, plus a drip factor at the end to turn millilitres into drops.

Worked Examples · Straight Doses

Every drug on this slide is in your SOP — check your answers against it

Naloxone · adult depressant overdose

Ordered: 2 mg IV/IO.

Supplied: 2 mg/mL preload syringe.

$(2\ \text{mg} \times 1\ \text{mL}) \div 2\ \text{mg} = 1\ \text{mL}$

Answer: 1 mL — from the 2 mg/mL preload.

Midazolam · adult sedation

Ordered: 2 mg IV/IO.

Supplied: 10 mg/2 mL vial — that is 5 mg/mL.

$(2\ \text{mg} \times 2\ \text{mL}) \div 10\ \text{mg} = 0.4\ \text{mL}$

Answer: give 0.4 mL.

Midazolam · the other vial

Ordered: 2 mg IV/IO. Same order, same drug.

Supplied: 1 mg/mL vial.

$(2\ \text{mg} \times 1\ \text{mL}) \div 1\ \text{mg} = 2\ \text{mL}$

Answer: give 2 mL — five times the volume.

Region X stocks midazolam in two concentrations and prints CHECK VIAL CONCENTRATION PRIOR TO ADMINISTRATION in capitals on the drug page. The two examples above are why. Same order, same drug, same patient — and a provider working from habit rather than from the label gives either 20 percent or 500 percent of what was intended.

Two more, worked the same way

Verapamil · adult SVT

Ordered: 5 mg IV/IO, slow push over 5 minutes.

Supplied: 10 mg/4 mL — concentration 2.5 mg/mL.

$(5\ \text{mg} \times 4\ \text{mL}) \div 10\ \text{mg} = 2\ \text{mL}$

Magnesium sulfate · adult torsades

Ordered: 2 g IV/IO.

Supplied: 1 g/2 mL vial — concentration 0.5 g/mL.

$(2\ \text{g} \times 2\ \text{mL}) \div 1\ \text{g} = 4\ \text{mL}$ to draw

Converting Before You Calculate

The formula only works when both mass figures are in the same unit

The rule

When a drug is expressed in a different prefix — grams on the label, milligrams in the order — the dosage on hand must be converted into the appropriate prefix before it goes into the formula.

Convert first. Then calculate. Never both at once.

Why doing it in one step fails

Because the formula has no way of noticing. Put 2,000 over 1 into it and it will confidently return a number — the wrong one, with a plausible-looking unit attached.

The equation cannot protect you from a unit error. Only the check beforehand can.

Magnesium sulfate · the same problem, written differently

Ordered: 2,000 mg IV/IO.   Supplied: 1 g/2 mL.

Step 1 — convert. 1 g on the label = 1,000 mg.

Step 2 — now the formula, both sides in mg:

(2,000 mg × 2 mL) ÷ 1,000 mg = 4 mL

Same answer as the last slide. Same drug, after all.

Push dose epinephrine · mg on the label, mcg in the order

The preload label reads 1 mg/10 mL. The order says 50 mcg.

Step 1 — convert. 1 mg = 1,000 mcg, so the preload is 100 mcg/mL.

Step 2 — 1 mL of that plus 9 mL of saline gives 10 mcg/mL.

Step 3 — (50 mcg × 1 mL) ÷ 10 mcg = 5 mL

The 100 mcg maximum is the whole 10 mL syringe.

The habit worth building: before you write anything down, look at the unit on the order and the unit on the label and say whether they match. If they do not, convert, write the converted figure down, and then start.

Weight-Dependent Dosages

One multiplication at the front — and one ceiling at the end that catches people

The three steps, in this order, every time

1 Get the weight in kilograms

Divide pounds by 2.2. Write the kilogram figure down before you do anything else with it.

2 Multiply to get the desired dose

Dose per kilogram × kilograms = the desired dose in milligrams or micrograms.

3 Check it against the maximum

If the calculated dose exceeds the protocol maximum, the maximum is the dose. This is the step that gets skipped.

4 Then the formula, as normal

Desired dose × volume on hand ÷ dosage on hand = millilitres to give.

Lidocaine for IO pain · a 70 kg adult

Ordered: 1 mg/kg IO, maximum 50 mg.

1 mg/kg × 70 kg = 70 mg calculated.

But the maximum is 50 mg — so the dose is 50 mg.

Supplied 100 mg/5 mL, so 20 mg/mL.

(50 mg × 5 mL) ÷ 100 mg = 2.5 mL

Fentanyl · a child who weighs 44 pounds

44 lb ÷ 2.2 = 20 kg.

Ordered: 1 mcg/kg. 1 × 20 = 20 mcg.

Supplied: 50 mcg/mL.

(20 mcg × 1 mL) ÷ 50 mcg = 0.4 mL

Check it: the SOP page for 20 kg prints 20 mcg, 0.4 mL.

A dose that is 2.2 times too large looks exactly like a dose that is correct, right up until the patient responds to it. The pounds-for-kilograms error produces no absurd number and no obvious warning — which is why the conversion gets written down first, not held in your head.

Infusion Rates

Turning a volume and a time into drops you can count

What you need to know first

Three facts: the volume to be administered, the drip factor of the set in drops per millilitre, and the total infusion time in minutes.

The drip factor is printed on the tubing package — macrodrip sets are typically 10, 15 or 20; microdrip sets are always 60.

Why drops at all

Because a gravity set has no display. The only thing you can observe and control is how fast fluid falls through the chamber.

With a pump you enter a volume and a time and the machine does this arithmetic. Without one, you do it — and you still need it to sanity-check the pump.

Drops per minute = (Volume to be administered × Drip factor) ÷ Time in minutes

Reading it, and using it

1 Volume × drip factor = total drops

If you are giving 100 mL through a set that makes 10 drops per millilitre, the whole infusion is 1,000 drops. That is the number you are spreading over the time.

2 Divide by the minutes

1,000 drops over 5 minutes is 200 drops a minute. The division is the only step, and it is the step that turns a plan into something you can watch.

3 Convert to drops per second

Counting 200 drops in a minute is impractical. Divide by 60 — about 3.3 a second, which you can set by eye against a watch.

4 Microdrip changes the number, not the method

A 60 drop set makes six times as many drops as a 10 drop set for the same volume, so the count is six times higher. Same formula.

Worked Infusions · Deriving Your Own Protocol Tables

The rates printed in your SOP are this formula, already run

Magnesium sulfate · torsades · 100 mL over 5 minutes

Macrodrip set, 10 drops per millilitre.

(100 mL × 10 gtt/mL) ÷ 5 min = 200 gtt/min

200 ÷ 60 = 3.3 drops per second.

The SOP prints 200/min and 3.3/sec. They match.

The same order, a different set

A 15 drop set: (100 × 15) ÷ 5 = 300 gtt/min.

A 20 drop set: (100 × 20) ÷ 5 = 400 gtt/min.

The SOP prints 300/min and 400/min for those sets.

Same fluid, same time — the tubing changed the count.

Magnesium sulfate · asthma · 100 mL over 15 minutes

10 drop set: (100 × 10) ÷ 15 = 66.7 gtt/min.

Round to 67 drops a minute — about 1.1 a second.

15 drop set: (100 × 15) ÷ 15 = 100 gtt/min.

Every one of these is in the SOP table. Check them.

Tranexamic acid · 1 g in 100 mL over 10 minutes

10 drop set: (100 × 10) ÷ 10 = 100 gtt/min.

100 ÷ 60 = 1.67, so about 1.7 drops per second.

The SOP prints 1.6/sec here — and 1.7/sec for the same

100/min on the magnesium page. Note the 1 g never entered.

The last line of the TXA example is the one to dwell on. Once a drug is mixed into a bag, the infusion calculation stops caring what is in it — it is now a volume, a time and a drip factor. The dose was decided when you injected it into the bag, which is why the labelling step from Part 2 matters so much.

And the practical point: these tables exist so that nobody performs this arithmetic at 3 a.m. Learn to derive them so that you can check one, recover when the page is missing, and recognise instantly when a printed rate cannot be right.

Calculating for Infants and Children

The population with the least margin and the most arithmetic

Why the stakes are different

It is imperative to calculate medication accurately for infants and children, because they cannot tolerate underdoses or overdoses of medications.

An adult has physiological reserve to absorb a modest error. A 10 kg child does not, and almost every pediatric dose is weight dependent — which means almost every pediatric dose is calculated.

Aids exist — and the textbook's warning about them

Aids for calculating pediatric doses and rates are available, but the text is explicit that you should not rely on them exclusively.

They fail in predictable ways: a weight outside the chart, a drug not listed, a page that is missing, and the situation where the number printed does not match the order you were given.

Three worked pediatric doses for a 20 kg child — all from the Region X pages

Fluid bolus

Ordered: normal saline 20 mL/kg.

20 mL/kg × 20 kg = 400 mL

No concentration involved — the

order is already a volume.

Ondansetron

Ordered: 0.1 mg/kg. Supplied 2 mg/mL.

0.1 × 20 = 2 mg desired.

(2 mg × 1 mL) ÷ 2 mg = 1 mL

The SOP page for 20 kg prints 1 mL.

Dextrose 10%

Ordered: 0.5 g/kg. Supplied 0.1 g/mL.

0.5 × 20 = 10 g desired.

10 g ÷ 0.1 g/mL = 100 mL

A hundred millilitres, pushed slowly.

Notice the third one. A correct pediatric calculation can produce a large volume, and a provider expecting a syringe-sized answer may assume they have gone wrong. Dextrose 10% at 0.5 g/kg genuinely is 100 mL in a 20 kg child — the plausibility check has to be against the drug, not against a general sense of how big a dose should be.

Region X prints a page per weight: dose and volume for every drug, energy settings, tube sizes and vital sign ranges. Know where it is and how it is laid out before the call, not during it.

Chapter 21 in Summary

Three sessions, one responsibility

1 A fundamental skill

Medication administration is a fundamental skill used in the treatment of the sick and injured. For medications to be effective they must be safely delivered into the body by the appropriate route.

2 Route is not interchangeable

Many routes are available to the paramedic, but specific medications require specific routes. The route determines onset, and onset determines whether the drug arrives in time to matter.

3 The arithmetic is part of the drug

You must accurately calculate many medication dosages. A correctly chosen drug at an incorrectly calculated dose is not a partial success.

4 The consequences are real

Dosage errors and inappropriate medication administration can result in serious side effects or even death for the patient. That sentence is in the textbook for a reason.

5 Find a method that works

Medical calculations can be completed by a variety of methods. What matters is finding one that works for you and gets you the right answer every time you work a problem.

6 It is your responsibility

It is your responsibility to be familiar with all routes of administration and the techniques for establishing and using them. Nobody else on the scene will check your arithmetic.

Part 3 — Key Takeaways

1. **Bone is a vein that cannot collapse.**

   Marrow drains through venous sinusoids held open by the bone around them. That is why IO onset approximates IV, and why the route still works in the patient whose peripheral veins have shut down.

2. **Two attempts, ninety seconds, or no sites.**

   Any one of the three is enough to go to the bone. And if the black line nearest the hub is not visible on bone, the answer is a longer needle — never more force.

3. **The pain has an answer.**

   Reluctance is the bigger risk. Lidocaine 1 mg/kg to a maximum of 50 mg for adults, half that for children, then wait a full 60 seconds before the fluid or you have washed it away.

4. **One formula, four uses.**

   What I want, over what I have, times the volume it is in. Weight-based orders add a multiplication at the front; infusions add a drip factor and a division at the end.

5. **Match the units before you calculate.**

   The formula cannot detect a unit error — it will return a confident wrong answer. Check the order against the label first, convert, write it down, then start.

6. **Calculate, then check the ceiling.**

   1 mg/kg for a 70 kg adult is 70 mg, and the maximum is 50. And divide pounds by 2.2 on paper — that error produces no absurd number to warn you.