INTRAVENOUS SOLUTIONS

Types of Solutions
Osmolarity
pH
Drip Rate Calculations

Type of Solutions Osmolarity/Tonicity

Osmosis

- Osmolality:

Total number of osmotically active particles per liter of solution

- Osmolarity

Concentration of a solute in a volume of solution

Type of Solutions Osmolarity/Tonicity

- Units are in milliosmoles per liter of solution or mOsm/L
- Tonicity reflects the concept and effects of Hypotonic, Isotonic and Hypertonic solutions on body cells

Type of Solutions Osmolarity/Tonicity

- <u>Hypotonic Fluids</u>

Below 240 mOsm/L and lower osmo than plasma

- Fluid shifts move from blood vessels into cells and interstitial spaces
- Hydration of cells
- Depletion of circulatory system

Types of fluids

- 0.45% sodium chloride (NACL) osmo 160 mOsm/L

Hydrates cells, lowers serum sodium levels

Type of Solutions Osmolarity/Tonicity

- Hypotonic Cautions
  - Depletes circulatory system
  - Avoid in hypotensive pts
  - Aggravates hypotensive state
    - Leads to shock

Hypotonic Review

240 mOsm/L or less
Hydration of cells

Ex: 0.45% NaCl 160 mOsm/L
Lowers the osmotic pressure of the blood plasma
Use Caution in hypotensive states

Type of Solutions
Osmolarity/Tonicity

- Isotonic Fluids

  240-375 mOsm/L
  - Expands the extracellular fluid compartment

  Types of Fluids
  - 0.9% NACL (normal saline)
  - 5% dextrose in water (D5W)
    - Can shift to hypotonic once dextrose is metabolized
  - Lactated ringers (balanced electrolyte sol.)

Type of Solutions
Osmolarity/Tonicity

- Isotonic Cautions:

  - Circulatory overload
    - No fluid shifting into other compartments
  - In Congestive Ht Failure
  - Renal disease

Isotonic Review

Expands extracellular fluid compartment
Maintains osmotic pressure
240-375 mOsm/L

Ex: 0.9% saline, 5% dextrose (D5W) and lactated ringer's solution

No fluid shifting therefore may lead to side effects: circulatory overload, caution in CHF and renal diseases

Type of Solutions
Osmolarity/Tonicity

- Hypertonic Fluids

  375 mOsm/L and higher
  - Replacement of electrolytes
  - Most IV vitamin and mineral solutions
  - Shift extracellular fluid from interstitial to the plasma

  Types of solutions
  - 10% dextrose in water (D10W)
  - 20% dextrose in water (D20W)
  - IV pushes aka: Myers Cocktails
    - 600 – 1200+ mOsm/L

Type of Solutions
Osmolarity/Tonicity

- Hypertonic Cautions:

- Circulatory overload
- Irritating to vein wall
- Give cautiously/slow 1-4 ml/min
  - Review, venous type, flow rate and additives osmolarity

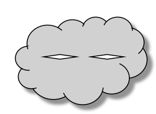
Hypertonic Review

375 mOsm/L expands extracellular compartment
Increases osmotic pressure of the blood plasma

Ex: D10W, D20W, D50W and most IV pushes and infusion of vitamin and minerals are 600-1200+

Circulatory overload

Irritating to vein wall



IV Fluid Dynamics

	Isotonic	Hypotonic	Hypertonic
Effect on intravascular compartment (blood)	**Increases volume**	**Dehydrates – moves fluid to cells**	**Greatly increases volume – dehydrates cells**
Fluid overload potential Incr. in Ki / Li patients, and the elderly	**Moderate potential** **[D5W]** →	**No**	**High potential**

D5W (without other additives) starts Isotonic but can act hypotonic if the patient metabolizes the sugar quickly.

Type of Solutions/ Osmolarity/Tonicity

Summary Of mOsm/L

Normal blood plasma	290 mOsm/L
Isotonic – range 240-375	290 mOsm/L
Hypertonic	> 375 mOsm/L
Hypotonic	< 240 mOsm/l
Red blood cell lysis	<145 mOsm/L

Type of Solutions/ Osmolarity/Tonicity

Tonicity Summary

- EFFECTS ON FLUID BALANCE
- Hypertonic Fluid
  - Expansion: volume of body water is increased by the IV infusion of a hypertonic saline
  - Contraction: (hypertonic dehydration)water loss without corresponding loss of electrolytes

Type of Solutions/ Osmolarity/Tonicity

Tonicity Summary

- Hypotonic Fluid
  - Expansion: increase body fluid volume caused by water alone
    - Water intoxication
    - Dilution hyponatremia
  - Contraction: (hypotonic dehydration) fluid containing relatively more salt than water is lost from the body
    - Sweats, burns, diuretics

Type of Solutions/ Osmolarity/Tonicity

Tonicity Summary

- Isotonic Fluid
  - Expansion: (circulatory overload)fluids of the same tonicity as plasma are infused into the vascular circulation
  - Contraction: loss of fluid and electrolytes to the extracellular fluid
    - whole blood
    - large volumes of fluid, diarrhea, vomiting

TYPES OF IV SOLUTIONS

- **Crystalloid**
- **Colloid**

Crystalloid

- True solutions that are capable of passing through a semipermeable membrane
  - -25% remains in vascular space
- Types of fluids:
- Hypo, Iso or Hypertonic solutions:
- D5W, NaCl, balanced electrolyte solutions, vitamins and minerals

Colloid

- Do Not form true solutions
- Remain in extracellular space
  - -Increasing intravascular osmotic pressure
  - -Plasma volume expanders
- Contain protein or polysaccharide molecules

ELEMENTS IN IV SOLUTIONS

- WATER
- Zero Osmolarity
- Amounts
  - Adults 1000 mL/day for maintenance
  - Sensible loss- average 500-1000 ml/day
    - Respirations >20, low humidity, diaphoresis, loss of kidney concentration in elderly

- Never inject water without appropriate constituents / injectables of appropriate mOsm
  - Avoid RBC hemolysis
  - 145-160 mOsm/L or greater (Normal adults)
    - May require higher mOsm for pts with ↑ RBC fragility

ELEMENTS IN IV SOLUTIONS

- GLUCOSE
- Aka: dextrose
- Improves hepatic function via conversion into glycogen (via liver)
- Uses
  - Replacement
  - Restoration
  - Maintenance therapies

- Glucose
  - Supplies energy for calories
  - Spares protein for individuals unable to eat or digest food
- D5W
  - 5% dextrose in water
  - Every 2 L contains 100 gms of glucose
  - Isotonic
    - 250 mOsm/L

- D10W
  - 10% dextrose in water
  - 100 gms of glucose per liter
  - Hypertonic
    - 500-560 mOsm/L
- D5LR
  - 5% dextrose in Lactated Ringers
  - Isotonic (will review this later)

ELEMENTS IN IV SOLUTIONS

- **Cautions**: Infusions of dextrose can result in:
- Hypokalemia
  - Dextrose and potassium are taken into cells, serum potassium levels decrease
  - Increase insulin levels
- Dehydration
  - Osmotic diuresis
- Hyperinsulinism
  - Rapid infusion of hypertonic carbohydrates result in hypoglycemia post infusion
- Water intoxication

ELEMENTS IN IV SOLUTIONS

- SODIUM CHLORIDE or SALINE

- 0.9% sodium chloride (normal saline)
- Uses
  - Extracellular fluid replacement
  - Metabolic alkalosis with fluid loss (emesis)
  - Sodium depletions

ELEMENTS IN IV SOLUTIONS

- SODIUM CHLORIDE or SALINE

- 0.45% sodium chloride (half- normal saline)
- Uses
  - Replace sodium and chloride
  - Most used for vitamin and mineral IV's protocols
  - Preferable to NS
    - If pt not hypotensive

ELEMENTS IN IV SOLUTIONS

- BALANCED ELECTROLYTE SOLUTIONS

- Prevents complications in emergencies
  - Excess or deficit of electrolytes
  - In house lab testing/know acid-base balance
  - Corrects dehydration, and individual mineral replacement

ELEMENTS IN IV SOLUTIONS

- Lactated Ringers/LR

  - Isotonic similar to NS
  - potassium and calcium (exchanged for Na ions = to blood plasma)
  - Bicarbonate precursor for acidosis

ELEMENTS IN IV SOLUTIONS

- Lactated Ringers/LR
- Uses
  - Dehydration
  - Treatment of diabetic ketoacidosis
  - Metabolic acidosis that occurs with mild renal insufficiency
  - Salicylate overdose
  - Dehydration secondary to infant diarrhea

ELEMENTS IN IV SOLUTIONS

- Cautions/contraindications
  - Liver disease
  - Addison's disease
  - Severe metabolic acidosis/alkalosis
  - Profound hypovolemic shock or cardiac failure

Osmolarity calculations for IV Solutions

- Determining solution protocol
  1. Start with established protocols
     - Gain experience
     - Observe how pts react to various levels of constituents
  2. Caution:
     - when cardioactive minerals are increased
     potassium, magnesium, and calcium (in order of significance)
     - tailor to pts physical state: cardiac and renal
  3. Select appropriate protocol and list all constituents

Osmolarity calculations for IV Solutions

- **QUICK REFERENCE OF OSMOLARITY VALUES**
- Isotonic solution = 290 (240-375) mOsm/L
  - Minimum osmolarity for solution that can be infuse to prevent hemolysis of RBC's is 145 mOsm/L
- Hypertonic solution = > 375 mOsm
  - Possible damage to tunica intima if cellular dehydration > 600 mOsm/L are infused: draws from the cells
- Hypotonic solution = < 240 mOsm/L
  - Fluid invades the cells
  - Water intoxication (the bloated cell)

Osmolarity calculations for IV Solutions

- OSMOLARITIES
- Tables are supplied by each manufacture they supply
  - Many will be similar with small variations
    - Ex: 500mg/ml ascorbic acid is 5.94 mOsm/L (company A) vs: 5.36 mOsm/L (company B)

Osmolarity calculations for IV Solutions

- STEPS FOR CALCULATING OSMOLARITY

1) List each component used
   1) Sterile water
   2) Saline
   3) LR
2) Note the volume of each component
3) List the osmolarity of each component in mOsm/mL
4) Multiply the volume and osmolarity of each component
5) Add the volumes of each component to obtain the total solution volume in mL
6) Add the products of each component under #4 to obtain the total number of mOsm in the mixture
7) Divide the total number of mOsm from #6 by the total solution volume
8) Multiply this value by 1000 to obtain mOsm/L

Example of osmolarity calculation table

Component	Volume, ml	mOsm/ml	Vol x mOsm
Ascorbic Acid 500mg/ml	50	5.8	290
Calcium gluconate, 10%	25	0.72	18.0
Magnesium sulfate, 500mg/ml	4	4.06	16.24
B-Complex 100	2	2.14	4.28
Pyridoxine, 100 mg/ml	3	1.11	3.33
Hydroxocobalamin, 1000 mcg/ml	3	0.31	0.93
Selenium 40 mcg/ml	10	0.0005	0.005
Sodium Bicarb 8.4%	10	2.0	20.0
Sterile water	450	0	0
Total	557		352.75 (353)

Osmolarity calculations for IV Solutions

total amount of volume mOsm divided by Total amount of fluid volume x 1000 = _____mOsm/L

(352.7/ 557) x 1000 = 633 mOsm/L

Note: With an osmolarity this high the solution is infused over 3-4 hours in the largest vein available

Osmolarity Ranges for Infusion

- < 600 mOsm/L normally well tolerated by most patients
- 600-1200 tolerated by most patients if rate is adjusted to their comfort
- > 1200 mOsm/L tolerance is variable; pH becomes very important
- All ranges are patient dependent

pH Considerations for IV Solutions

- USP Standards
  - Requirements: solution pH is in acidic range 3.5-6.2
    - Longer shelf life
  - Compounding pharmacies can and will supply preservative free nutrients at pH values closer to 7 but dating will be shorter
- Body pH
  - Buffering systems of healthy kidneys will compensate effectively in routine IV therapy
  - Blood pH is not a significant concern
  - Buffering systems are:
    - Bicarbonate: works well in both respiratory and renal regulation
    - Phosphate and protein systems
- IV solution
  - pH close to blood will on average be more comfortable

Calculating IV Drip Rate

1.Total Solution Volume vs. Infusion Time

- The type of solution must be taken into consideration
  - Saline or LR
    - For dehydration the infusion rate can safely be infused at 500 ml per hr/ assuming normal cardiac and renal function
  - Irritating solutions to the vein
    - High dose vit C solution with high osmolarities irritate the vein close to the insertion site ↑ discomfort, causing aching, and cramping
    - Keep infusions to 150-200 ml/hr

Calculating IV Drip Rate

- High-dose ascorbic acid formulations > 50 grams exhibit high osmolarity values
  - Best to be infused in a **central line or slowly through a peripheral line**

Calculating IV Drip Rate

- Solutions that act on the cardiac or circulatory systems
  - Those containing calcium magnesium or potassium
  - Magnesium relaxes the peripheral vasculature
    - Hypotension leading to severe conditions
  - Calcium in excess/deficit can cause damage to vessels/cardiac events
  - Potassium in excess/deficit leads to cardiac events
  - Infusion rate should be kept at 150-200 ml /hr
  - Question pt periodically on how they feel
  - Check BP, Pulse and Respirations and reflexes periodically

Calculating IV Drip Rate

- Obtain total volume of infusion by observing bag/ bottle markings or add individual volumes of constituents
- Determine the total infusion time by using the recommended time for a known protocol or by estimating a safe infusion time for similar protocols
- Divide the total volume by the desired infusion time, which will result in "X" mL/min

Calculating IV Drip Rate

- Volume per unit time =

Infusion volume/Total infusion time =
__X__ml/min

Calculating IV Drip Rate

- Note the drops(gtt) /mL listed on the administration set package and multiply that value by the "X" mL/ min obtained above.
- Divide by 4 / and count the number of drops per 15 seconds (easier to count)
- Ex: Using the above solution for which osmolarity was calculated. A 635 mL sol. Infused over 4 hrs using an IV set delivering 20 gtts/mL

Calculating IV Drip Rate

$$Rate = \left(\frac{635ml}{4hours X\, 60\,\text{min}/\,hour}\right)\left(\frac{20drops}{ml}\right) = \frac{53drops}{\text{min}}$$

Calculating IV Drip Rate

- It is easier to count for 15 seconds

53/4 = 13 drops in 15 seconds

- The "real clinic setting": Usually a physician simply wants to infuse a solution at a rate they choose based on experience.
- It is suggested that 20 drops/mL infusion sets are best for all-around use.
- For example: you want to infuse a solution at: 4 mL/min, or 80 drops a minute.
- Since we know that 20 drops is one mL, then 20 drops in 15 seconds is 4 mL/min.

For 20 drop sets: each 5 drops counted in 15 seconds is equal to 1 mL/min, see example table below.

Rate: mL/min	Drops/ 15 seconds
1	5
2	10
3	15
4	20
5	25
Etc	Etc

Calculation of drip rate based on desired drug infusion rate

- If a nutrient or drug needs to be infused at a known rate to achieve therapeutic effects
  - the rate can be calculated in units or mg per hour.

- Example: An I.V. mixture with a total volume of 850 mL contains 200 grams of ascorbic acid (AA). The desired infusion rate for the AA is 30 grams an hour through a 20 drops/mL infusion set. What is the infusion rate in mL/min. and drops/15 seconds?

What volume of mixture contains 1 gram AA?

$$Volume = \frac{850ml}{200grams} = \frac{4.25ml}{gram}$$

What is the infusion rate in ml/min?

$$Rate = \left(\frac{4.25ml}{gram}\right)\left(\frac{\frac{30grams}{hour}}{\frac{60\min}{hour}}\right) = 2.13\frac{ml}{\min}$$

What is the drip rate in a 15 second interval?

$$Rate = \left(\frac{\frac{2ml}{\min}}{\frac{4\,\text{int}\,ervals}{\min}} \right) \left(\frac{20drops}{ml} \right) = 10 \frac{drops}{\text{int}\,erval}$$

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COMPUTATION OF FLOW RATE a Quick method

- Read the drops/cc (drops/ml) of given infusion set on outside of package
- Use following formula:

Drops/ml of given set x total volume being infused
60 min in one hour = drops/min
(min. to be delivered over)

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COMPUTATION OF FLOW RATE

- 20gtts/mL x 1000 ml = 166.67
  60min x 2 hr
  (120 min)
- Divide number of drops per minute by 4
  (42)
- Time that number of drops through drip chamber for 15 sec

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~~DRIP RATE CONVERSION TABLE~~ (based on 20 drops/mL tubing)

mL/HR	Drops/Min	Drops/15 sec
100	32	8
125	42	10-11
150	50	12-13
250	84	21

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IV injection or IV push vs. IV drip

1. An I.V. injection is usually the preferred method when injecting one or two substances with volumes greater 2-3 mL and not greater than ~ 10 mL
   The osmolarity can be as high as 4000 mOsm/L (Mg sulfate or Vit C)
   1-2 mL/min or less
   Watch patient closely.
   Add water to decrease osmolarity

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IV injection or IV push vs. IV drip

2. I.V. pushes usually contain several substances and range in volume from
   10-35 mL.
   The osmolarity ranges from 300-600
   1-2 mL/min are used depending on patient response
   - vein discomfort
   - magnesium heating

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IV injection or IV push vs. IV drip

3. I.V. drips are more convenient for volumes greater than 60 mL. I.V. bags can be obtained in volumes 150 to 1000 mL, osmolarity 600-1400.
   - Lower osmolarities offer greater patient comfort
   - Drip rates 3-8 mL/min can be accomplished depending on solution makeup

REVIEW

- Always calculate your osmolarity
- Know your pH of all solutions
- Preservative vs preservative free solutions
- Patient condition and comfort
- IV Push or IV Infusion
  - Your Time vs volume

Reference

1. Phillips, L.D. Manual of I.V. Therapeutics, 2nd Ed. F.A. Davis Company. Philadelphia. pp. 115-142