PHYSIOLOGY

Lec: 8 + 9

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Physiology Lecture 8 & 9

Movements of fluids between body fluid compartments

&

Clinical abnormalities of fluid volume regulation

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Lecture Objectives:

- Describe the changes in body fluids compartment volume and osmolarity following the intravenous infusion of normal saline.
- Calculate changes in body fluids compartment volume and osmolarity following the intravenous infusion of normal saline after osmotic equilibrium.
- Describe changes in body fluids volumes and osmolarity following the infusion of hypoosmotic and hyperosmotic solutions.
- Define hypo and hypernatremia.
- List the main causes of hypo and hypernatremia.
- Describe and explain the shift of fluids between ECF and ICF in conditions associated with hypernatremia and hyponatremia.
- Describe changes in body fluids compartments volume and osmolarity associated with hypernatremia and hyponatremia.
- Outline methods of fluid therapy (glucose and other solutions administration).

Changes in volumes and osmolality (fluid therapy)

Factors that can cause changes in the extracellular and intracellular volumes are:

3 factors can change the volume of ICF & ECF

- Excess ingestion or renal retention of water.
- Intravenous infusion of different types of solutions. Salines change cell volume → hypertonic / hypotonic
- Loss of large amounts of fluid from the gastrointestinal tract, by sweating, or through the kidneys.

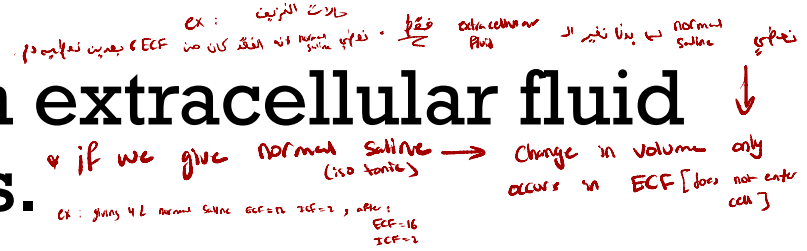
ex: cholera, diarrhea

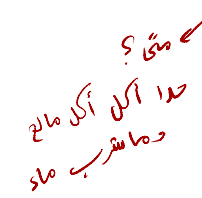
Principles:

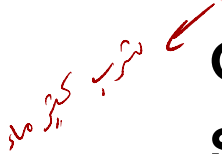
1. Water administration does not create a change in osmolalities between the intracellular and extracellular compartments.
2. Adding or removing impermeable solute from the extracellular compartment (such as NaCl) will cause fluid shift between the intracellular and extracellular compartment.

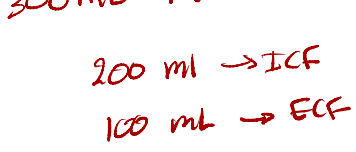
Effect of adding saline solution to the extracellular fluid:

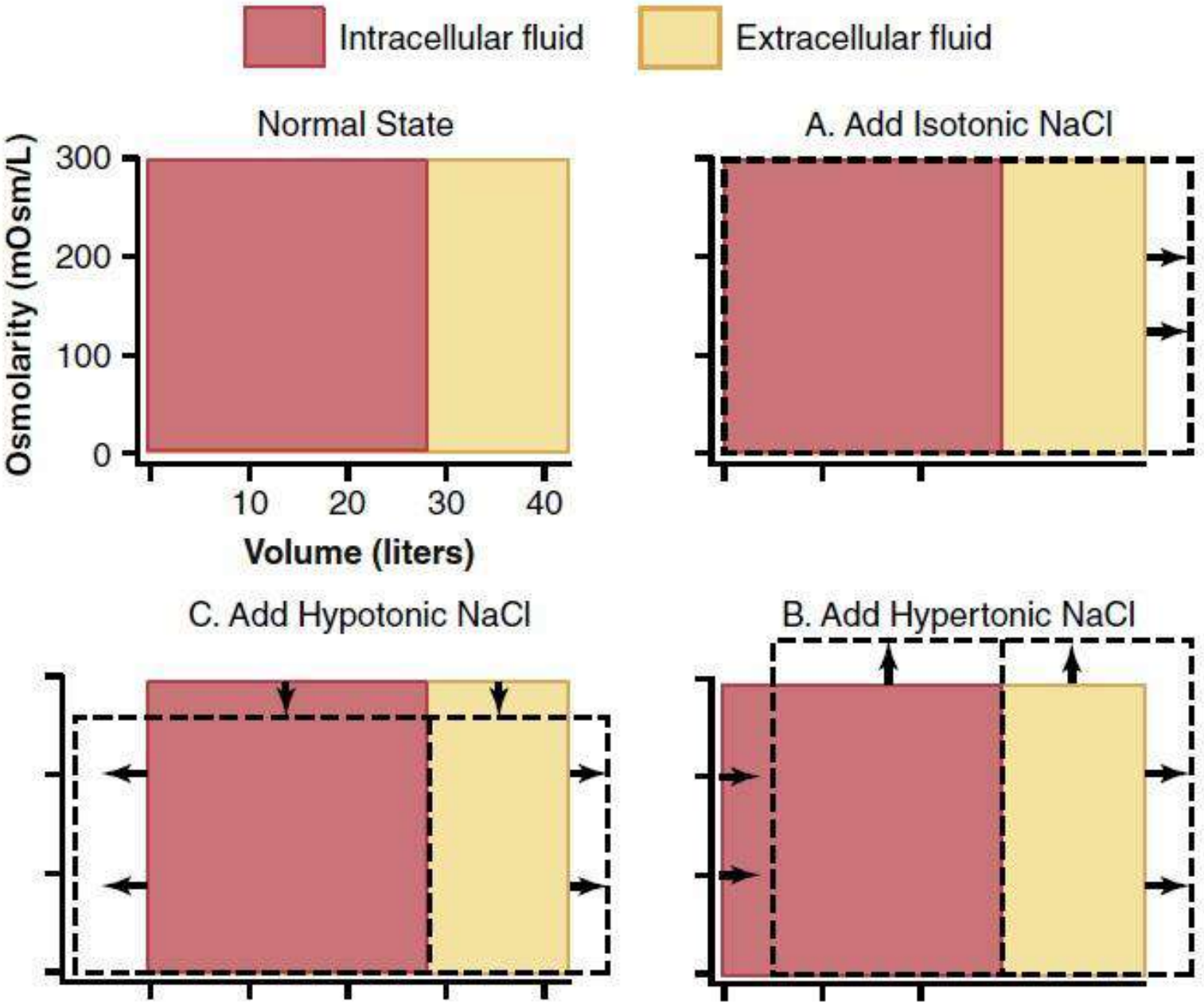
1. Isotonic solution → ↑ in extracellular fluid volume with no osmosis.
2. Hypertonic solution → osmosis out of cells into the extracellular compartment → ↑ in extracellular volume and ↓ in intracellular volume.
3. Hypotonic solution → osmosis into the cells → both compartments increase in size, although the intracellular volume increases to a greater extent.










Intracellular fluid
Extracellular fluid
Normal State
Osmolarity (mOsm/L)
300
200
100
0
10
20
30
40
Volume (liters)
A. Add Isotonic NaCl
C. Add Hypotonic NaCl
B. Add Hypertonic NaCl

Effect of administering glucose (or nutritive) solution:

* Comatose patients are not given water, instead water with glucose, glucose enters cells & is used up, and water is left for absorption

- Almost always these solutions are usually adjusted nearly to isotonicity.
- Normally after the glucose or other nutrients are metabolized, the kidneys excrete excess of water in the form of dilute urine.
- A 5% glucose solution is often used to treat dehydration. After the glucose being metabolized, the remaining water helps correct the increase in extracellular fluid osmolarity associated with dehydration.

Abnormalities of fluid volume regulation

Important note:

Na^+ ion and its associated anions (mainly Cl^-) account for more than 90% of the solute in the extracellular fluid, therefore plasma Na^+ is a reasonable indicator of plasma osmolarity under many conditions.

Dehydration (volume contraction)

A clinical state caused by a decrease in ECF volume (contraction) especially by loss of Na^+ (*negative Na^+ balance*). Physical signs include;

- dry tongue with loss of skin turgor
- increased heart rate
- flat neck veins
- increased arterial pulse pressure
- decreased blood pressure (in severe cases)
- increased hematocrit
- decreased urine outflow
- increased urine osmolality
- decreased body weight (due to fluid loss)

Hyponatremia:

A state where plasma Na^+ concentration is less than 135 mOsm (or meq)/L. It results from NaCl ***loss*** or ***addition*** of excess water to the extracellular fluid.

1. Dehydration with loss of NaCl can be precipitated by renal loss of NaCl as in primary hypo-adrenocorticalism (Addison's Disease), overuse of diuretics, diarrhea and vomiting with pure water replacement can precipitate this condition too.

The ECF volume is decreased, The ICF volume is increased with reduced osmolality. Salt and water intake or intravenous saline administration is essential to restore the extracellular compartment.

Hyponatremia (cont.):

↳ almost always, the problem is with ADH

2. Hyposmotic overhydration may result from ingestion of a large volume of water and renal retention of water due to the syndrome of inappropriate antidiuretic hormone (ADH) secretion (SIADH).

secreted from pituitary gland ← لحبس الماء في الكليتين // ↳ syndrome of inappropriate ADH secretion

The ECF and ICF volumes increase and osmolality of both major fluid compartments decreases.

* ADH only affects water reabsorption with NO effect on sodium

* What stimulates the secretion ADH? ⇒ ↑ serum osmolarity, ↓ Blood pressure [heart failure, cirrhosis], ↘ Angiotensin II

Hyponatremia

SIADH

↳ inappropriate ↑ ADH ⇝ Volume expansion ⇝ appropriate inhibition of tubular Na^+ reabsorption ⇝ ↑ urine $[Na^+]$

* Causes cerebral edema
  ↳ fluid [ECF → ICF]
* Caused by loss of sodium containing fluids [diarrhea & vomiting]
* Treated with isotonic solutions
* Women have ↑ chance of hyponatremia

Hypernatremia:

A state where plasma Na^+ concentration is more than 145 mOsm (or meq)/L. It can be either due to ***loss of water*** from extracellular fluid or to an ***excess of Na^+*** in the extracellular fluid.

1. Hyperosmotic dehydration occurs in decreased water intake, diabetes insipidus, diabetes mellitus, alcoholism, fever, excessive sweating during heavy exercise (sweat is hypotonic; 75 mEq/L).

   ECF and ICF volumes both are decreased, and the osmolality of both major fluid compartments is increased. Juice or water intake is essential. The administration of glucose (dextrose) solutions is physiologically equivalent to the administration of distilled water.

Hypernatremia (cont.):

2. An increase in extracellular Na^+ ion concentration with no water loss is associated with hyperosmotic over hydration as with hyperaldosteronism, oral intake of large amounts of salt, or IV infusion of a hypertonic saline solution.

There is a decrease in the volume of the ICF and an increase in the volume of the ECF.

Hypernatremia

* causes dehydration [brain]

[fluid from ICF to ECF]

* Hypernatremia caused by
  - ↑ Na^+ gain
  - ↓ water intake [impaired thirst mechanism] — mainly in elderly
  - ↑ water loss / excretion [most common]
    - kidney:
      1. impaired vasopressin [ADH] release
         - ↓ADH → no reabsorption of water → urine rich in water → osmolality ↓
      2. renal dysfunction
      3. certain diuretics
         - inhibit Na^+ K^+ pump ← urine rich in water ← osmolality ↓
    - not kidney related:
      - vomiting
      - diarrhea

* treated by hypotonic fluids

Compensation mechanism in hypernatremia :

↓ plasma osmolality ← relative Na^+ ↓ ← ↑ H_2O ← reabsorbtion of water in ducts to bloodstream ← bind to a receptor in kidneys ← option ①

① ↑ Na^+ → ↑ osmolality → ↑ tonicity [hypertonic] → stimulation of pituitary gland → pumping of ADH ↑↑

or ↓ H_2O

option ②

↓ plasma osmolality ← relative ↓ in Na^+ ← ↑ H_2O ← ↑ thirst [drink water]

Consequences of hypernatremia:

↑↑ Na^+ in blood stream → cells lose water causing them to shrink

fluid ICF → ECF

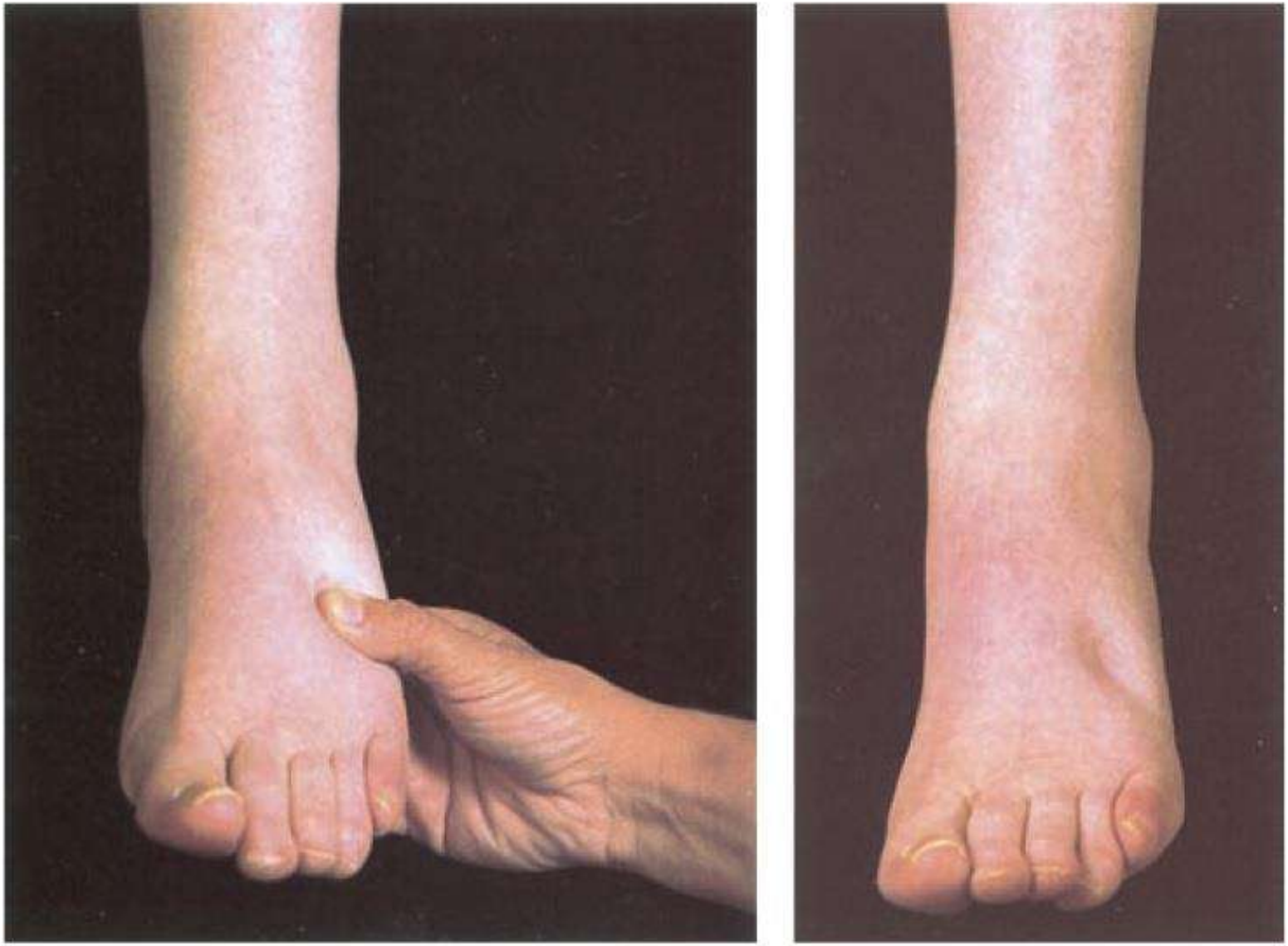
Edema:

in hyponatremia

↳ ECF, fluid excess → edema → 95%

ICF, fluid excess → edema → 5%

A state in which there is excess fluid in the body tissues. Although it occurs mainly in the extracellular fluid compartment, yet it can involve intracellular fluids as well.



Pitting edema of the left foot

- *Intracellular edema* – results from either depression of the cellular Na^+-K^+ pump or because of inflammation that increases the permeability of cell membranes.
- *Extracellular edema* – the two general causes of extracellular edema are;
  1. Abnormal leakage of fluid from the plasma to the interstitial spaces across the capillaries. <u>This is the most common cause</u>.
  2. <u>Failure of the lymphatics</u> to return fluid from the interstitium back into the blood.

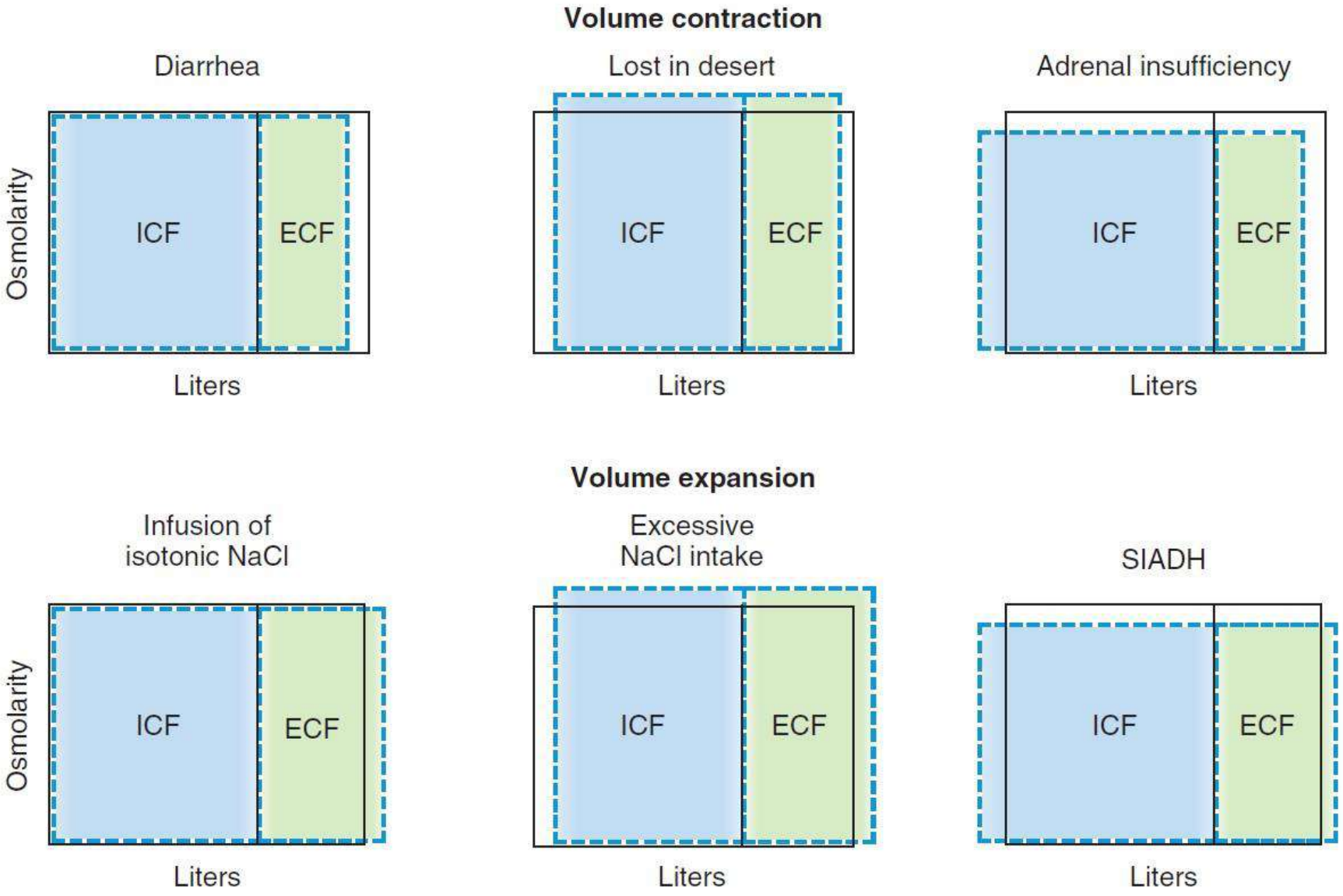


FIGURE Shifts of water between body fluid compartments. Volume and osmolarity of normal extracellular fluid (ECF) and intracellular fluid (ICF) are indicated by the *solid lines*. Changes in volume and osmolarity in response to various situations are indicated by the *dashed lines*. SIADH = syndrome of inappropriate antidiuretic hormone.

Table . Changes in Volume and Osmolarity of Body Fluids

Type	Key Examples	ECF Volume	ICF Volume	ECF Osmolarity	Hct and Serum [Na^+]
Isosmotic volume expansion	Isotonic NaCl infusion	↑	No change	No change	↓ Hct – [Na^+]
Isosmotic volume contraction	Diarrhea	↓	No change	No change	↑ Hct – [Na^+]
Hyperosmotic volume expansion	High NaCl intake	↑	↓	↑	↓ Hct ↑ [Na^+]
Hyperosmotic volume contraction	Sweating Fever Diabetes insipidus	↓	↓	↑	– Hct ↑ [Na^+]
Hyposmotic volume expansion	SIADH	↑	↑	↓	– Hct ↓ [Na^+]
Hyposmotic volume contraction	Adrenal insufficiency	↓	↑	↓	↑ Hct ↓ [Na^+]

– = no change; ECF = extracellular fluid; Hct = hematocrit; ICF = intracellular fluid; SIADH = syndrome of inappropriate secretion of antidiuretic hormone.

Test Question:

B) A 1% solution of dextrose is hypotonic, and when infused, it would increase both intracellular and extracellular fluid volumes while decreasing the osmolarity of these compartments.

Q. Which diagram represents the changes (after osmotic equilibrium) in extracellular and intracellular fluid volume and osmolarity after the infusion of 1% dextrose?

A. Diagram A.
B. Diagram B.
C. Diagram C.
D. Diagram D.
E. No diagram is matching