Fluids, characteristics, influences on physiology , and relevance for emergency care

- **K** p. 1-8
- **B** p. 286-298
- **C** p. 35-36

Objectives

- To understand the basic principles of fluids and electrolytes so as to apply these to resuscitation and therapy in prehospital emergencies
- To understand the basic pathophysiology of common fluid and electrolyte disturbances

Objectives

To understand these basic principles, we 'll look at:

- Body compartments
- Functions of body water
- Homeostasis and movement of body water
- Regulators of Fluid Balance
  - and abnormalities of regulation
  - with an introduction to Naturetic Peptides
- Tonicity and IV Solutions

Body Compartments

- Solid 40 %
- Liquid 60 %
- Water (3)
  - Within blood vessels
  - Within cells
  - Outside of the blood vessels / in between cells

Body Compartments

- Intracellular
- Extracellular
  - Intravascular
  - Interstitial

Body Compartments

- Intracellular - water inside cells
  - 2/3 of total body water
  - or 40% of patient weight
- Extracellular - water outside the cells
  - 1/ 3 of total body water
  - Intravascular - fluid within circulatory system
    - 5% of patient weight
  - Interstitial- fluid outside the cells and
  - outside the circulatory system
    - - 3rd space
      - 15% of patient weight

Body Compartments

- 100 kg patient :

- Intracellular water 40 kg (or 40 kg x 1 L/kg)
- Intravascular : 5 kg (or 5 kg x 1 L/kg)
- Interstitial (3rd space) :15 kg (or 15 kg x 1 L/kg)

Functions of Body Water

- Cellular "ABCs"
- A - transport of O2 to the cells
- B - transport of CO2 from the cells
- C - intravascular volume
- D - transport of fuel (glucose) to cells (brain)
- E - regulation of body temperature

- Transport and homeostasis of waste products, nutrients, enzymes, neurotransmitters, electrolytes
- Lubrication of muscles, joints, mucus membranes (A/B), food

Body Water Intake and Output

- Homeostasis
- Intake = Losses (output)

Body Water Intake and Output

- Intake (total : ~2500mL)
- Liquid 1000+ mL
- Food 1000 mL
- Insensible 500- mL
  - Normal metabolism
    - Oxidation
    - e.g., $H^+ + HCO_3^- \text{ --- } CO_2 + \boldsymbol{H_2O}$

Body Water Intake and Output

- **Losses** (~ total : 2500 mL)
- Excretion 1500 - mL
- Insensible
  - Lungs 500 - mL
  - Skin 500 - mL

Characteristics of Fluids

- Solvent : Water
- Solute : substances mixed into solvent
  - large molecules (e.g., hemoglobin)
  - small molecules (e.g., NaCl, H2O)
- Movement - in living organisms
  - can water go anywhere?
  - can solutes move anywhere?

Fluid and Solute Movement

- Solvent : water
  - can move anywhere
  - "wants to move" to an area of
    - less water
    - less pressure
- Solutes : molecules and ions
  - cannot move anywhere
  - "wants to move" to an area of
    - less solute
    - less ionic charge

Solute Movement

- Selectively permeable membrane
- allows only certain items across:
  - water
  - some selected solutes:
    - ions (Na^+)
    - small molecules (e.g., glucose)
- Solutes not allowed across:
  - Colloids

Fluid and Solute Movement and Gradients

- Gradient
- a difference in :
  - number of solute particles (concentration gradient)
  - water pressure (hydrostatic pressure gradient)
  - ionic charges present (electrical gradient)
  - colloids present (osmotic pressure)

Gradient Units

- Water pressure (hydrostatic pressure)
  - mmHg
- Colloids present (osmotic or "tonic" pressure)
  - mmHg , or
  - mOsm - Osmolality
  - (# of solutes / kg of H2O)
- Ionic charges present (electrical gradient)
  - mEq/L - milliequivalents / L or kg of H2O
  - (# of positive or negative charges/L)

Fluid and Solute Gradients

- Gradient Movements
- From greater to lesser :
  - from high concentration to low (diffusion)
  - from high hydrostatic pressure to low
  - from high ionic charge to "low" [or opposite]
- From lesser to greater :
  - colloidal (osmotic) pulling in of water
  - cellular pulling in of some selected solutes:
    - ions (Na^+) even against an electrical gradient
      - requires extra energy (active transport)

Capillary Gradients

- Gradients and movements across the capillary membrane:
  - high arteriolar hydrostatic pressure
    - pushes water out into the third space
  - high venular osmotic pressure
    - pulls water from the third space
    - back into the vascular space

Osmotic Pressure

- Movement across the capillary membrane, a balance of:
  - arteriolar hydrostatic pressure
  - with
  - venular osmotic pressure
- Net effect:
  - osmotic pressure is
  - equivalent to the blood pressure

Osmotic Pressure

- Osmotic pressure :
  - # of solute particles / kg of H2O
  - (expressed as mOsm - Osmolality)
- Determinants of osmotic pressure :
  - Na^+ (largest contributor to osm. [+ tonicity])
  - glucose
  - urea (BUN - nitrogen)

Osmotic Pressure and Tonicity

- Osmotic pressure (osm) and tonicity :
  - often [clinically] used interchangeably
  - (expressed as mOsm - Osmolality)
- Osmotic pressure determinants :
  - both Na^+ and
  - urea (BUN - nitrogen)
- Tonicity determinants :
  - only Na^+
  - effect on cell volume by the surrounding fluid

Osmotic Pressure and Tonicity

- Osmotic pressure (osm) and tonicity :
  - clinically, in emergency medicine, we are primarily concerned with
    - tonicity:
      - determined primarily by Na^+
    - effects of Na^+ on tonicity (+ osm.)
      - increased Na^+ - increased tonicity
      - decreased Na^+ - decreased tonicity

Tonicity and IV Solutions

Solution	tonicity (mOsm/kg)
blood	290 (240-340)
NS	308
RL	272
D5W	252 (metabolized quickly to hypotonic)
D50W	2520
3%NS	1026

Disorders of Fluid Imbalance

- Volume contraction
  - fluid loss ; hypovolemia (ECF VD)
  - "third-spacing" - fluid loss (ECF VS)
- Volume overload (ECF VE)
  - vascular and third-space overload
- Water "poisoning" or overload (ICF VE)
  - Intracellular volume overload (see p. 35)

Regulators of Fluid Balance and Osmolality

- Kidneys (+ insensible organs)
- ECV stretch-sensors in:
  - renal vessels (renin,…)
  - carotid vessels (SNS/epi)
  - aorta (SNS/epi)
  - hypothalamus (ADH) (thirst)
  - atria + ventricles (ANF;BNP;…)
- Naturetic Peptides
  - ANP ; **BNP** ; C-type ; others

Regulators of Fluid Balance

- Kidneys - primary regulator
  - Increased fluid intake -
    - incr. CO - incr. Na^+ and water excretion
  - ECV stretch-sensors in renal vessels
    - renin - angiotension I + II - BP
    - renin - angiotension - aldosterone - Na^+

+ Regulators of Fluid Balance

- ECV stretch-sensors :
  - vessels
    - carotid
    - aorta
  - Sympathetic Nervous System (SNS)
    - increased epinephrine
      - incr. PVR
      - incr. SV
      - incr. HR
    - BP = CO (HR X SV) X PVR

Other Volume Regulators

- Hypothalamus vessel ECV stretch-sensors
  - decrreased volume - incr. ADH -
    - » - decr. excretion (of Na^+ and H_2O)
    - » - incr. PVR (vasopressin-effect)
- Atrial and Ventricular ECV stretch-sensors
  - ANP
  - BNP
  - CNP ; others

Other Volume Regulators

- Atrium ECV stretch-sensors
  - incr. Volume [stretch] ---> incr. **ANF** -
    - incr. excretion (of Na^+ and H_2O)
    - supresses renin - angiotension-aldosterone
    - vasodilatation
    - thus, lowering the BP
- Ventricular ECV stretch-sensors
  - incr. Pressure [stretch] ---> incr. **BNF** -
    - increases natriuresis (Na^+)
    - increases diuresis (H_2O)
    - decreases renin
    - vasodilatation

Physiologic Effects of ANP , BNP, and Other Volume (and Pressure) Regulators

- Volume (ECV) contraction
- Vasodilation
  - decresed PVR
- Decrease in intracardiac filling pressures
- Decrease in cardiac work / O_2 conumption
- Improved myocardial performance

Causes of Increased BNP

- CHF [BNP blood test aids in the Dx of CHF]
- Aging
- Anything that increases ventricular stretch and volume overload
  - MI
  - Renal failure
  - Liver disease
  - COPD [increased lung resistance / R. afterload]

Causes of Increased ADH (vasopressin)

- Hypotension / hypovolemia
- Increased tonicity (osmolality)
- Ventilator (PPV)
- Medications (morphine, haldol,…)
- Stress
  - Surgery, anesthesia,…
  - Pain
- SIADH

Causes of Inappropriately Increased ADH

- SIADH ["inappropriate" : water retention with salt wasting]
- malignancies
  - brain - pancreas
  - lung - prostate
- CNS
  - head trauma
  - Infection
  - CVA
  - DTs
- Drugs
  - chemotherapy
  - narcotics, phenothiazines

Summary

- We have discussed some basic principles:
- Body compartments
- Functions of body water
- Homeostasis and movement of body water
- Tonicity of body water and of IV Solutions
- Regulators of Fluid Balance and abnormalities of body water regulators , including BNP
- These principles will help us to understand the management of fluids resuscitation and therapy of fluid and electrolyte emergencies