Fluid Balance – normal and disturbed
Mammalian Pathobiology
PATB 4130/5130
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Maintenance of total body water and fluid balance is critical

Water as a percentage of total body weight, changes from fetal to adult life

In late term fetuses and neonates, % total body water is approximately 80%

In adults, % total body water = approximately 65%
Which fluid compartment contains the extra 15% in fetuses?
Fluid compartments

- **Intravascular (4%)** – the fluid component of blood and lymphatics, varies by body size and species
- **Interstitial (15%)** – the fluid component in the tissues and between, not in, cells
- **Transcellular (5%)** – fluid in the body cavities
- **Intracellular (41%)** – the fluid within cells. Varies by cell type

% given on assumption of 65% fluid (approximately 14-16 gallons for a 200 lb person based on lean body mass).

Hormones in the Control of Total Fluid Volume

- Renin – Angiotensin system
- Mineralocorticoids - aldosterone
- Antidiuretic hormone (vasopressin)
- Atrial natriuretic factor
Hormones in the Control of Total Fluid Volume

- Renin – Angiotensin
- Mineralocorticoids
- Antidiuretic hormone
- Atrial natriuretic factor
  - Produced by atrial muscle
    - ↓ Arterial blood pressure
    - Diuresis, natriuresis
    - Inhibits renin, aldosterone, and ADH

Abnormal fluid ‘accumulations’
(redistribution of fluids, there is often no net increase in total fluid volume)

Intracellular – hydropic change
(degeneration); intracellular edema
Mechanisms underlying hydropic change

Extracellular Fluid Accumulation

Edema is accumulation of fluid in the extracellular spaces within tissues, i.e. interstitial compartment

Accumulation of fluid in body cavities =
- Hydro + cavity (hydrothorax, hydropericardium)
- Ascites – fluid accumulation in abdominal cavity
Fluid redistribution occurs due to events at the level of the microcirculation.

Forces Regulating Fluid Balance

**Intravascular**
- Arterial Capillary Forces
  - Hydrostatic = 25 mmHg
  - Colloidal Osmotic = 28 mmHg
- Venous Capillary Forces
  - Hydrostatic = 10 mmHg
  - Colloidal Osmotic = 28 mmHg

**Extravascular**
- Interstitial Capillary Forces
  - Hydrostatic = -6.3 mmHg
  - Colloidal Osmotic = 5.0 mmHg
- Interstitial Forces
  - Hydrostatic = -6.3 mmHg
  - Colloidal Osmotic = 5.0 mmHg

Drained via lymphatics.
Abnormal fluid distribution -
Mechanisms

- Increased vascular permeability
- Increased intravascular hydrostatic pressure
- Decreased intravascular colloidal osmotic pressure
- Increased tissue colloidal osmotic pressure
- Decreased lymphatic drainage

Disturbances in these forces leading to edema – increased hydrostatic pressure

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- Arterial Capillary Forces
  - Hydrostatic = 25 mmHg
  - Colloidal Osmotic = 28 mmHg

- Venous Capillary Forces
  - Hydrostatic = 10 mmHg
  - Colloidal Osmotic = 28 mmHg

**Extravascular**
- Interstitial Forces
  - Hydrostatic = -6.3 mmHg
  - Colloidal Osmotic = 5.0 mmHg

Drained via lymphatics
Disturbances in these forces leading to edema – decreased colloidal osmotic pressure

**Intravascular**
- Arterial Capillary Forces
  - Hydrostatic = 25 mmHg
  - Colloidal Osmotic
- Venous Capillary Forces
  - Hydrostatic = 10 mmHg
  - Colloidal Osmotic

**Extravascular**
- Interstitial Forces
  - Hydrostatic = -6.3 mmHg
  - Colloidal Osmotic = 5.0 mmHg
  - 31.3 mmHg Drained via lymphatics

Disturbances in these forces leading to edema – increased colloidal osmotic pressure

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**Extravascular**
- Interstitial Forces
  - Hydrostatic = -6.3 mmHg
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  - 31.3 mmHg Drained via lymphatics

Disturbances in these forces leading to edema – decreased lymphatic drainage

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Ascites

Edema of the bowel wall

Palpebral edema
Mesocolonic edema

Pulmonary Edema

Lymphatic obstruction from a metastasizing basal cell carcinoma of the paw pad - cat
Congenital lymphedema in a dog.

Consequences of Edema

Consequences of Edema
Hypervolemia / Overhydration –
too much total body water

Natural occurrence is rare
1) Syndrome of inappropriate ADH secretion
2) Iatrogenic – IV fluid administration
3) Idiopathic / idiosyncratic water drinkers

Hypovolemia / Dehydration

Too little total body water

As long as the mechanisms for stimulating thirst in the brain (osmoreceptors) and kidney function remain intact, the body is able to maintain total fluid volume
Causes of dehydration

- Insufficient water intake
- Increased loss due to kidney disease
- Vomiting / diarrhea
- Hyperhidrosis / hyperpnea
- Drugs
- Diabetes insipidus
  - Pituitary dependent
  - Nephrogenic
- Hypoadrenocorticism (Addison’s disease)

Sequence of Events

- There is initially a loss of interstitial fluid to maintain blood volume
- This is followed by a loss of intracellular fluid in a further attempt to maintain blood volume
- Eventually, these mechanisms fail if total body water is not replenished resulting in hyperviscosity of blood and a hyperosmolar state

The brain and ultimately the cardiovascular system are most severely affected

The brain during dehydration

- **Acute phase (1-2 days)**
  - Elimination of ions to balance osmotic forces
  - Brain shrinkage
- **Chronic phase (3+ days)**
  - Endogenous production or organic osmolytes
  - Re-establish more normal [ion]
- **The dangers of rehydration**
  - The brain cannot rapidly eliminate organic osmolytes
  - If rehydration occurs rapidly brain swelling
SAMPLE QUESTION #1

Briefly explain how congestive heart failure causes abnormal fluid redistribution.

SAMPLE QUESTION #2

Which of the following statements is/are true concerning hormones involved in regulation of fluid balance.

1. Renin, produced by the lung, converts angiotensin I to angiotensin II.
2. Aldosterone, produced by the adrenal gland, inhibits the production and release of angiotensinogen.
3. Angiotensin II stimulates secretion of aldosterone from the adrenal gland.
4. Antidiuretic hormone, produced mainly in the supraoptic nucleus of the hypothalamus, enhances resorption of water and sodium from renal tubules.