Extracellular Water and Body Osmolarity

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As knowledge of physiologic regulation of the composition and distribution of body fluids has grown, the importance of disorders of extracellular fluid volume and body osmolarity in fluid and electrolyte disturbances has emerged. Most problems of fluid and electrolytes present with one or both of these disorders. The following discussion attempts to outline the physiological and pathological considerations regarding extracellular fluid volume and body osmolarity, and to indicate a few diagnostic and therapeutic points of interest in this respect.

Distribution of H_2O and Electrolytes

A lean adult male is composed of approximately 60% water. This water is distributed between two chief compartments. The larger is within the cells or intracellular (ICW) and the other is extracellular (ECW) and is composed primarily of the plasma (P) and the interstitial fluid (ISF). The distribution of water in an average man (70 kg. or 154 lbs.) would be:

	Volume	% Body Weight
Total Body Water	45L.	60
Intracellular Water	33L.	44
Interstitial Fluid	9L.	12
Plasma	3L.	4

However, the water is not present in its pure form, but rather has many substances dissolved within it. The chemical compositions of the two main compartments are markedly different.

Concentrations of Main Ions Within Body Fluids Expressed in mEq/L.

Cations

	Plasma	ISF	ICW
Na^+	140	144	10
K^+	4	4	150
Ca^{++}	5	5	
Mg^{++}	2	2	38
	151		198

Anions

	Plasma	ISF	ICW
Cl^-	103	117	3
HCO_3^-	27	30	10
Pr^-	16		65
$HPO_4^=$	2	2.3	100
$SO_4^=$	1	1.1	20
Undeter.	2	2.3	
	151		198

ECW

Interstitial composition is predictable from the plasma as all constituents except the plasma proteins are freely diffusable between the plasma and the interstitial water. The concentration of solutes within the ISF may be derived by applying Donnan factors to their plasma concentration.

ICW

Difference in ionic concentrations between extra- and intra-cellular fluids cannot be explained solely by Donnan laws of equilibrium nor physicochemical laws but reflect the metabolic activity of cells which provides energy for the biological pump which keeps Na^+ out and K^+ within the cell.

Osmotic Relationships

Cell membranes are freely permeable to H_2O but not to all other substances. So body water is distributed in the various compartments in osmotic equilibrium. The osmolarity of a solution is proportional to the concentration of osmotically active particles it contains. Total ECW osmolarity = 285 mOsm/L. (Na=260 mOsm/L.). This is equal to the total ICW osmolarity.

One may wonder why the chemical and osmolar concentrations of a solution are not proportionately the same. This is due to the fact that all substances do not have equal degrees of osmotic activity. Some constituents are freely diffusable and do not constitute an effective osmotic force, e.g. urea; others are osmotically inactive because they are bound to protein, e.g. Mg^{++}. In fact the bulk of osmotically active solute in the ECW is Na^+ and in the ICW is K^+.

From laws governing osmotic equilibrium certain important relationships can be derived.

(1)

$$Na^+_s = \frac{Na^+_{EC} + K^+_{IC}}{TBW} = \text{Body Osmolarity}$$

i.e., the concentration of serum Na^+ is determined by the concentration of total osmotically active cation in the total body water, therefore an alternation in the serum Na^+ will reflect changes in body osmolarity.

(2)

$$ECW = \frac{Na^+_{EC}\ (TBW)}{Ca^{++}}$$

The extracellular water is directly related to body Na^+ and is influenced by the ratio of Na^+ to total osmotically active cation and TBW.

Regulation

Physiologically body osmolarity is regarded by thirst and the antidiuretic hormone. These mechanics are responsive to changes in serum Na^+ concentration. The response is directed toward controlling H_2O ingestion and excretion. Control of ECW involves thirst, aldosterone, ADH and variable changes in the GFR, with changes in the extracellular volume occuring through loss or retention of isotonic quantities of Na^+ and H_2O.

Therapy

It is useful to remember the way nature corrects disorders of body osmolarity and ECW and to apply the same principles in the therapy of fluid and electrolyte disturbances. In treating disorders of the ECW the basis for therapy would be the appropriate administration or restriction of saline, (including use of diuretics). Disorders of body osmolarity require appropriate adjustment of water intake.

Diagnosis

As in any medical problem a careful history is important. Physical examination in the case of ECW disorders may reveal signs of edema and circulatory overload when the volume is increased, or in the case of decreased ECW, signs of plasma hypovolemia. With a distrubance of body osmolarity the signs are closely related to the rate at which the condition develops and when present, indicate cerebral dysfunction that may range from confusion to coma. Laboratory investigations useful in diagnosing ECW disorders are hematocrit determination, serum proteins, and urinary Cl^- (which are usually greater than 20mEq/L. with a decreased ECW). The chief laboratory aid to diagnosis of an alteration of body osmolarity is the serum Na^+ concentration.

CLASSIFICATION OF DISORDERS OF ECW & BODY OSMOLARITY

1. *Decrease In Extracellular Water—*
   Loss of isosmotic fluids, e.g., loss from GI tract.
   Treatment—saline administration.

2. *Increase In Extracellular Water—*
   Isotonic retention, e.g.,
   (i) congestive heart failure, nephrosis or cirrhosis.
   (ii) due to excess administration of isotonic saline in oliguric states.
   Treatment—salt restriction diuretic therapy.

3. *Decrease In Body Osmolarity—*
   (1) H_2O and Na^+ loss treated with H_2O.
   Treatment—fluid restriction or if necessary hypertonic saline.
   (2) chronic illness with malnutrition (inability to keep K^+ within cell).
   (3) inappropriate secretion of ADH: this may occur in bronchogenic carcinoma, metastatic tumors, head injuries.

4. *Increase In Body Osmolarity—*
   (1) cardiac patient with extrarenal loss, e.g., pneumonia, tracheostomy.
   (2) excess use of hypertonic saline in patients with severe renal disease.
   Treatment—(a) salt restriction or if indicated, (b) H_2O administration.

5. *Decrease In Extracellular Water. Decrease In Body Osmolarity—*
   Here there is loss of saline as well as additional Na^+, K^+ loss,
   (1) adrenal insufficiency.
   (2) GI tract and large sweat losses partially replaced with H_2O.
   (3) renal Na^+ wasting.
   Treatment—(a) isotonic saline or as indicated, (b) hypertonic saline.

6. *Increase In Extracellular Water. Increase In Body Osmolarity—*
This condition can be induced by administration of hypertonic saline to oliguric patients.

Treatment—restriction of Na^+ and H_2O.

7. *Increase In Extracellular Water. Decrease In Body Osmolarity—*
This is a condition in which edema is accompanied by hyponatremia.
(1) chronic—occurs in congestive heart failure, nephrosis, cirrhosis.
(2) acute — (i) may occur in edematous patients on a low sodium diet.
(ii) occurs in cirrhotics following paracentesis.
(iii) occurs with administration of excess H_2O to oligurics.
Treatment—(a) H_2O restriction or as indicated, (b) hypertonic saline.

8. *Decrease In Extracellular Water. Increase In Body Osmolarity—*
Here the disturbance in the ECW is minimal.
(1) H_2O loss without salt loss, e.g., coma, diabetes insipidus.
Treatment—H_2O administration, usually as glucose solution.
(2) water loss in excess of salt loss.
(i) sweat losses.
(ii) GI losses and insensible losses.
Treatment—isotonic saline is usually sufficient.

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