SALT AND WATER

Salt and Water Learning Objectives

At the completion of this module the student should be able to:

- List the various body fluid compartments and their respective volumes.
- Relate the factors that influence distribution of fluid between these compartments.
- Define osmolarity.
- Estimate osmolarity based on serum sodium, glucose, and urea nitrogen concentrations.
- Define free water.
- Calculate free water deficit in a hypernatremic patient.
- Define total body volumes and effective circulating volume.
- List the physical and laboratory findings that are used in the assessment of total body volume and effective circulating volume.
- Distinguish between osmo-regulation and volume regulation.
- Describe the role of water and sodium balance in osmo-regulation and volume regulation.
- Describe the role of ADH/Vasopressin in osmo-regulation and volume regulation.
- Interpret serum osmolarity, sodium concentration and urine osmolarity and utilize these values in assessing a patient with hyponatremia.
- Define SIADH.
- List causes of SIADH.

Case 1:

A 40-year-old man, as so often happens to those in the full bloom of youth, decides to get into better physical condition. In late spring he begins a program of exercises and jogging. After several weeks, summer comes to Chicago. Realizing that he has but a short period of time to trim down his 90 kg physique, he puts on his sweat suit and runs to Lake Forest; sweating profusely along the way. On admission to Lake Forest Hospital he is barely sweating, has a rapid pulse and rapid respiration. His blood pressure is 90/60 mmHg and his temperature is 102°F (ambient temp = 100°F). In short, the man is suffering heat prostration. If we assume that he has been acclimatized and therefore has a low sweat sodium concentration, then he has suffered a pure water deficit. His serum electrolytes were:

sodium - 168 mEq/L, chloride - 140 mEq/L, bicarbonate = 16 mM/L, potassium - 5.8 mEq/L
BUN = 28 mgm/dl, creatinine - 1.5mgm/dl, glucose - 90mg/dl

1. What is the patient's total body water at the beginning of his run?

2. Using the serum electrolytes on admission and the original total body water, how much water did he lose during his run? (assume no sodium loss)

3. What percent of his total body water was lost?

4. What is the patient's serum osmolarity on admission?

5. What is the patient's cellular osmolarity on admission?

6. What is his weight at the time of admission?

7. What was the volume of his extracellular and intracellular compartments?
   a. Originally
   b. On admission.

Case 2:

One day after a power outage, Burger World offers a half price sale. John decides to take advantage of this bargain and eats four "Big Worlds." The following day he develops severe abdominal cramps and watery diarrhea. John calls his doctor (who unfortunately missed half of his renal rotation) and is told to drink plenty of water to prevent "dehydration" and to drink orange juice to replace his potassium losses. John does that for two days, but his diarrhea persists and he gets progressively weaker. Finally, after he develops a headache and some confusion, his wife takes him to the hospital.

Physical Examination: supine: BP 90/60, pulse 120. Standing: BP 60/40, pulse 140. Lungs: clear. Heart: rapid heart sounds. Abdomen: hyperactive bowel sounds, mild diffuse tenderness. Extremities: no edema.

Labs: Sodium 105 mEq/L, potassium 3.5mEq/L, chloride 83 mEq/L. Bicarbonate 10 mEq/L, BUN 42 mg/dl, creatinine 1.2 mg/dl, glucose 90 mg/dl.

Urinalysis: specific gravity 1.020, pH 5, no protein, no heme
Urine Sodium 10 mEq/L; Urine osmolarity 800 mosm/L

1. Estimate John's serum osmolarity?
    a. Is his serum osmolarity normal?
    b. Does John have a free water excess or deficit?

2. What is meant by effective circulating volume?
    a. What is John's effective circulating volume? How do you know?
    b. What does John's urine sodium tell you about his effective circulating volume?

3. Since getting sick, has John's intracellular volume increased, decreased, or stayed the same?

4. Since getting sick, has John's extracellular volume increased, decreased, or stayed the same?

5. Is John's urine osmolarity appropriate considering his serum osmolarity?

6. Why is John producing a concentrated urine?

7. Does John have SIADH?

8. John is given normal saline in the hospital. What will happen to the following?
    a. Urine sodium
    b. Urine osmolarity
    c. Serum sodium

9. What should John have been drinking?

Case 3:

Bob is a 60-year-old man who has had two heart attacks in the past. He was being treated with Digoxin and Lasix for heart failure. He read in the newspaper that 60% of a patient's weight is made up of water and that everyone should drink at least 8-cups of water a day. He also heard about some herbs that are good for the heart. Being unhappy with his medical progress, he stops the Digoxin and Lasix and gives the herb/water combination a try. One week later he notices that his legs are getting swollen and that he has been having difficulty breathing while lying flat and while walking. He also has been feeling out of sorts. Having second thoughts about his new treatment, he returns to his doctor.

Physical Examination: supine: BP 100/60, pulse 120. Standing: BP 100/60, pulse 120 positive jugular venous distention. Lungs: bilateral rales halfway up. Heart: S3 gallop. Abdomen: benign. Extremities: 3+ edema to knee.

Labs: Sodium 115 mEq/L, potassium 3.5mEq/L, chloride 79 mEq/L, bicarbonate 24 mEq/L, BUN 56 mg/dl, creatinine 1.5mg/dl, glucose 90 mg/dl.

Urinalysis: specific gravity 1.020, pH 5, no protein, no heme,
Urine sodium 10mEq/L; Urine osmolarity 600 mosm/L

1. Estimate Bob's serum osmolarity?
    a. Is his serum osmolarity normal?
    b. Does Bob have a free water excess or deficit?

2. Is Bob's total body volume increased, decreased, or normal?

3. What is Bob's effective circulating volume?
    a. Why is Bob's effective circulating volume abnormal?
    b. What does Bob's urine sodium tell you about his effective circulating volume?

4. Since getting sick, has Bob's intracellular volume increased, decreased, or stayed the same?

5. Since getting sick, has Bob's extracellular volume increased, decreased, or stayed the same?

6. Is Bob's urine osmolarity appropriate considering his serum osmolarity?

7. Why is Bob producing a concentrated urine?

8. Does Bob have SIADH?

9. Bob like John is given normal saline in the hospital. What will happen to the following?
    a. Urine sodium
    b. Urine osmolarity
    c. Serum sodium
    d. Bob's shortness of breath

10. What would be appropriate therapy for Bob?

Case 4:

Bill was a 52-year-old farmer who, apart from sporadic cough and expectoration, had been well until the start of the present illness. From February through March of 1976 his cough and expectoration increased associated with dyspnea, fatiguability and weight loss. For more than thirty years the patient had smoked approximately twenty cigarettes per day.

On admission the main complaints were fatigue, weight loss, anorexia, dyspnea, cough, and hemorrhagic sputum.

Physical examination revealed the following: height 173cm, weight 61kg, BP 135/80 mmHg, pulse:80 and skin tugor normal. A few enlarged lymph nodes were felt in the neck, and the breath sounds were decreased over the upper part of the right side of the thorax. There was no edema. The remainder of the physical exam was not remarkable.

Chest x-ray: infiltrate in the right apical region.

Labs: Sodium 118 mEq/L, chloride 82 mEq/L, potassium 4.6 mEq/L, bicarbonate 24 mEq/L, glucose 90 mg/dl, creatinine 0.7 mg/dl, and BUN 10 mg/dl.

Urinalysis: no protein, glucose or blood; microscopic exam negative.

Urine cultures: no growth.

Urine sodium: 60 mEq/L. Urine osmolarity: 700 mosm/L.

1. Estimate Bill's serum osmolarity?
    a. Is his serum osmolarity normal?
    b. Does Bill have a free water excess or deficit?

2. Is Bill's total body volume increased, decreased, or normal?

3. What is Bill's effective circulating volume?
    a. What does Bill's urine sodium tell you about his effective circulating volume?

4. Since getting sick, has Bill's intracellular volume increased, decreased, or stayed the same?

5. Since getting sick, has Bills's extracellular volume increased, decreased, or stayed the same?

6. Is Bill's urine osmolarity appropriate considering his serum osmolarity?

7. Why is Bill producing a concentrated urine?

8. Does Bill have SIADH?

9. What are the causes of SIADH?
    a. What endocrine abnormalities need to be ruled out?

10. What happens if you give ADH and water to a normal person?

11. What happens if you give ADH but water restrict a normal person?

12. Bill like Bob and John is give normal saline in the hospital. What will happen to the following?
    a. Urine sodium
    b. Urine osmolarity
    c. Serum sodium

13. What would be appropriate therapy for Bill?

Case 5:

A 67-year-old man is admitted to the emergency room comatose. His breathing rate is slightly elevated. The other vital signs are normal. The admitting physician thinks that he looks "dry." BP is 85/40 and pulse is 140. Neurological examination reveals some flaccidity of his right extremities and a stroke is suspected. The man is making copious quantities of urine, which contain large amounts of glucose. The urine test for ketone bodies is negative. Serum chemistries are as follows:

Sodium	130 mEq/L
potassium	3.8 mEq/L
chloride	98 mEq/L
bicarbonate	20 mEq/L
Urea N	70 mgm/dl
creatinine	2.5 mgm/dl
glucose	1600 mgm/dl
acetone	negative
osmolarity	385 mOsm/L

1. Estimate the patient's serum osmolarity?
    a. Is his serum osmolarity normal?
    b. Does he have a free water excess or deficit?
    c. Can the patient have SIADH?
    d. Why is this patient's serum sodium concentration low?

2. Is the patient's total body volume increased, decreased, or normal?

3. What is the patient's effective circulating volume?

4. Is the patient's intracellular volume increased, decreased, or normal?

5. Is the patient's extracellular volume increased, decreased, or normal?

6. How did this patient develop his salt and water abnormalities?

7. If the patient received insulin and did not receive any salt and water, what would be the effect upon his body fluid compartments?
    a. What would happen to his serum sodium concentration?

8. What would be the appropriate intravenous fluids to administer to this patient?

Case 6:

A 30-year-old man suffers severe head trauma and is admitted to the hospital comatose. He is receiving intravenous dextrose in water. Several hours after admission he is noted to be passing copious quantities of amber colored fluid from his urethral catheter. An alert medical student immediately recognized this fluid to be urine and carries out a urinalysis. The urine specific gravity is noted to be 1.005, the remainder of the urinalysis is normal. The patient continues to produce at least 250 ml urine per hour.

Serum electrolytes reveal the following: blood urea nitrogen 28 mg/dl, creatinine 1.5 mg/dl, sodium 157 mEq/L, potassium 4.6 mEq/L, chloride 120 mEq/L, bicarbonate 27 mEq/L, glucose 90 mg/dl.

A serum osmolarity is done and is 335 mosm/L, the urine osmolarity is 100 mosm/L

1. Does the patient have a free water deficit or excess?
    a. Assuming he weighs 70kg, calculate it.

2. Is the patient's urine osmolarity appropriate for his serum osmolarity?

3. What is meant by the term diabetes insipidus and how is this different from diabetes mellitus?

4. What do you expect this patient's ADH level to be?
    a. What disease would he have if his ADH level is low?
    b. What disease would he have if his ADH level is high?
    c. How would you verify this, short of directly measuring an ADH level?
    d. How would the result of the above test influence therapy?