WATER AND ION BALANCE AND IMBALANCE

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Summary

As an “open system”, the human body can freely intake fluids and salts. Despite this free intake of fluids the vital processes in our body demand a dynamically constant composition of the fluids and electrolytes in the “milieu interior”. Therefore, the body has developed complex and precise regulating mechanisms to control the fluid and electrolyte balance. Water and ion imbalances are of great importance in most clinical conditions. These imbalances may be caused by a variety of renal problems as in diabetes mellitus or it may happen due to other non-renal causes as, for instance, after an excessive vomiting. The former is an example of primary disturbance of the water and electrolyte balance, while the latter is a secondary form of such imbalances. Other examples of secondary water and electrolyte imbalances can be seen in fever, burn or other skin injuries and massive surgeries, just to name a few. These secondary imbalances often can lead to life threatening conditions. Therefore, not only the underlying conditions should be treated, but also any possible water and electrolyte imbalances must be diagnosed and targeted.

Most cases of water and electrolyte imbalances can be diagnosed by simple examinations such as measuring the body weight or plasma electrolyte concentrations, checking the skin turgor or the dryness of tongue and mucosal membranes. When an ion imbalance occurs in the body fluids, the measurement of the concentration of that ion in plasma can only show the ratio of that ion relative to water. This cannot be an indication of the excess or lack of that ion in the body fluids. For instance, in the case of water retention, the concentration of sodium in plasma is decreased (hyponatremia), while the total body sodium content is not changed.

1. Introduction

Water is essential to all living organisms. Even in terrestrial organisms like humans the greatest mass of the body—and even individual cells—is water. Water is the most essential component of all tissues except probably in the adipose tissue, which stores hydrophobic triglycerides. Most metabolic reactions take place in water solutions. Therefore there are several regulatory mechanisms, which contribute to the maintenance of the water balance in cells and whole organisms. Several ion pumps regulate the ion and water intake in each cell. In the organism there are again several mechanisms, which contribute to the water balance. Thirst stimulates us to drink, but we can also drink at will. Water is lost through the skin, urine and feces. The first two routes are dominant in normal situations while the latter may dominate during diarrhea. Diarrhea can be a very serious disease especially in children and elderly. The daily exchange of the water pool is great in young babies. As water evaporation—breaking the hydrogen bonds between the water molecules—needs much energy, sweating is the most efficient method to regulate the heat balance (see *Thermoregulation*). The more water is lost in sweating, the more intensive is thirst and the less water is excreted in urine.

Life started in cells surrounded by seawater (*see Autotrophic, Heterotrophic and Other Nutritional Patterns*), and most of the physiological reactions still require ions. Water and ion balances work together hand by hand in cells and at the organism level. We cannot excrete distilled water from the kidneys, although both concentration and dilution of urine are possible within certain limits. Neither can we stop excreting urine since the minimum obligatory urine volume in humans cannot be less than some 500 ml per day. Lesser urine volumes indicate renal dysfunction. Such low volume urine is usually highly concentrated. In the same way, the excretion of a diluted urine, for example with a density of 1.010 in the morning can be the sign of a renal malfunction.

Sweating is a normal human responses to the increase of body temperature. Again in addition to the loss of water we are losing ions. With excessive sweating, the volume of urine excretion decreases.

The replenishment of ions takes place both by drinking and eating, as most foods contain water and ions. The regulation of food intake and thirst are linked together at the hypothalamic level in the general housekeeping center of our brains. The hypothalamus produces antidiuretic hormone (ADH) which is secreted in the neurohypophysis into the blood circulation to regulate the urine volume. If the ADH excretion is disturbed, the urine volume increases. In this disturbance, diabetes insipidus, the person is unable to

concentrate the urine, and the excreted urine volume can reach up to 15-25 liters per day if left untreated.

In the more common form of diabetes (diabetes mellitus) the urine volume increases due to the presence of glucose in the urine. The capacity of the kidney tubules to reabsorb glucose is less than the glucose amount present in the primary urine of diabetic patients. Thus glucose remains in the urine and increases its osmolarity, which consequently prevents the reabsorption of water. As a result, a greater volume of urine is produced. Such patients are generally thirsty.

The kidneys can also be the reason for water imbalance, for instance when they are not responsive to the antidiuretic hormone. A much more common condition is, however, is when the kidney tubules have been destroyed to the extent that the concentrating ability of kidneys is disturbed. Luckily the reserve capacity of the kidneys is remarkable and it takes quite some time before kidney disease has progressed to that level.

In this chapter, some balance aspects are discussed in more detail.

2. Water Balance

The homeostatic balance of body fluids is dependent on water and electrolyte intake and loss. The total water entering our body is the sum of (1) that contained in the food we eat, (2) that derived from the oxidation of ingested food, or so-called metabolic water, and (3) that which we drink. The amount we drink can vary greatly, but certain minimum amounts are required every day. This minimum amount very much depends on the external conditions such as humidity, temperature and physical activity. On the other hand, we lose water via (1) insensible water loss through skin pores and respiration, (2) water lost in the feces, and (3) water lost in the urine. The thirst center in the hypothalamus ensures that this minimum daily intake of water reaches our body by drinking.

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