Fourth Stage

General Surgery

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Lecture 8

Fluid balance

The fluid in the body is separated into different 'compartments:

1 - the intracellular compartment (within the cells)

2-the extracellular compartment, which is further subdivided into:

A- interstitial (between the cells).

B-intravascular (in the blood vessels) - and in each of these areas the concentration of salts, or electrolytes, differs. The body normally maintains excellent electrolyte balance, better than any doctor could hope to achieve by careful fluid and electrolyte infusions, and in this regard the kidneys play a vital role. However, as with any body system, diseases occur that prevent normal homeostasis.

In addition, during the perioperative period, patients are subjected to a number of exogenous influences, for example, fasting and intravenous fluid administration, which can outstrip the body's normal homeostatic capabilities.

Principles of electrolyte balance:

Some common principles apply when considering homeostasis of any electrolyte.

These are based on a number of factors:

• Distribution and barriers: it's important to know the normal concentration of an

electrolyte in any given fluid compartment.

• Output: it is necessary to know the amount of the electrolyte that is consumed each day through normal cellular and systemic functions, and also how much is lost normally by excretion.

• Intake: the amount of the electrolyte that needs to be acquired to maintain

concentrations of the electrolyte in the body should be balanced with the amounts actually taken in. Any inefficiency in uptake, either lack or excess from the method of administration, needs to be noted and corrected.

Normal homeostasis

Fluid compartments:

A patient's body water content depends on the constitution of that person's body.

This varies according to age, sex and percentage of body fat, and can range from 50 to 75% of body weight. For simplicity an account of an average 70 kg man is given.

A 70 kg man is 60% of the body weight is water equal about 42 L.

This is distributed between the two main compartments as shown in Table below

Intracellular fluid (ICF)	28 L
Extracellular fluid (ECF)	14 L
interstitial fluid	10.5 L
intravascular fluid	3.5 L

Barriers between compartments, osmolality and electrolyte concentrations Osmolality (measured in milliOsmoles; mOsm) is defined as the strength of a solution. It is derived from the number of active ions in that solution. Cations are positively charged ions and anions are negatively charged. In each body compartment, there is normally a balance between cations and anions.

The main extracellular cation is sodium (Na^+) and the main intracellular cation is potassium

(K^+). The osmolality of plasma is derived from the equation:

2 x sodium (Na) + urea + glucose

The normal range is 280-290 mOsm/L. This value allows the clinician to estimate whether the patient has a relative excess or lack of water in the body and can be measured easily clinically.

However, various factors can affect plasma osmolality, causing inaccuracies

That must be noted clinically. The presence of an exogenous, osmotically active molecule such as alcohol in the blood is a good example .The intracellular and extracellular fluid are separated by the cell membrane.

This acts as asemipermeable membrane, allowing free passage of water but not electrolytes. Because of the difference in concentration of electrolytes between the two compartments, water will move from the compartment with lower osmolality to that with higher osmolality, therefore diluting it. This is known as an osmolality

gradient To maintain the differences in ions between intracellular and extracellular fluids, sodium ions are constantly driven from the intracellular compartment by a pump mechanism, which actively drives them out in exchange for potassium ions. The enzyme involved in this active pumping mechanism is ATPase, and thus this process is known as the ATPase exchange pump. As a result, sodium is the major extracellular cation and potassium is the major intracellular cation.

Homeostatic mechanisms

Sodium regulation

The volume of extracellular fluid (ECF) relates directly to the total amount of sodium in the body, the vast majority of which is extracellular. The concentration of sodium is maintained between narrow limits by free transfer of water between the ECF and the intracellular fluid (ICF). Hence, a large amount of total sodium, held in the extracellular compartment, recruits water from the ICF, increasing the volume of the ECF and diluting the sodium such that it is maintained at a normal concentration.

Potassium regulation

Potassium excretion and secretion by the kidney is intimately associated with sodium reabsorption. Nearly all the potassium that is filtered in the glomerulus is reabsorbed in conjunction with sodium (cotransporter) in the proximal nephron. In the distal tubule the reabsorption of sodium causes an electrochemical gradient, resulting in secretion of potassium (and hydrogen ions). Therefore, the more sodium that is reabsorbed, under the action of aldosterone, the more potassium is excreted.

Water regulation

As described above the main determinate of water reabsorption is the osmotic drive associated with sodium reabsorption. There is capacity for fine-tuning of water reabsorption, independent of sodium, which occurs in the most distal part of the nephron, called the collecting duct.

The hormone antidiuretic hormone (ADH) is produced by the posterior part of the pituitary gland. Its release is influenced by numerous factors including plasma osmolality, stress, surgery and thirst. ADH increases the permeability of the collecting duct to water, increasing its reabsorption.

This results in water conservation by the body and is the basis of the ability to concentrate urine. The stress of surgery results in increased ADH release, causing a degree of water retention.

Abnormalities of body water

Dehydration

In the case of water or electrolyte deficiency the kidney is acted upon by numerous systems to prevent further excess loss while maintaining adequate waste product excretion. However, in extreme circumstances these compensatory mechanisms are outstripped, causing shrinkage of the body fluid compartments.

1- Insufficient intake

Failure to match fluid output with sufficient intake results in dehydration. This is a

common danger in surgical practice, with patients undergoing periods of starvation due to disease processes, preoperative preparation and postoperative recovery.

2- Excess loss

Common surgical procedures, diseases and complications cause an abnormally high fluid loss. The principles for management of these are the same. Treatment should be directed at the underlying cause, in an attempt to decrease future losses.

Supportive replacement therapy is determined by measuring the amount and type of fluid loss, with special note being made of its electrolyte concentration so that appropriate loss can be corrected

3- Hemorrhage

Bleeding can lead to a fluid deficit that requires replacement, the principles of which are considered in the section on shock.

4**- Diarrhea**, bowel obstruction and bowel preparation Gastrointestinal secretions are rich in solutes and the increased losses occurring in the above conditions can need aggressive replacement. When the bowel is obstructed, the fluids do not leave the body but accumulate in the gut lumen, outside the extracellular fluid compartment. This is known as a third-space loss.

5- Vomiting

Vomitus is also solute rich. In addition, it is highly acidic and the loss of hydrogen

ions has an important effect on acid-base balance in the body.

6- Fistulae

Gastrointestinal fistulae bypass the capability of fluid reabsorption further down the gastrointestinal tract.

Losses therefore, particularly from high fistulae and particularly to the skin, can be large and solute rich. patients, generalized oedema and acute heart failure can be easily precipitated.

7- Diuresis: drugs and renal disease Diuretic drugs used for the treatment of fluid overload & can be over-effective and result in dehydration by losses into the urine. Similarly, a number of renal diseases, including common disorders such as diabetic nephropathy, result in production of excess amounts of urine.

8- Insensible losses

Losses through the skin can be significant. A common example is pyrexia, whereby water evaporates from the surface using latent heat of evaporation.

Massive amounts of plasma are lost from the surface of burns, and one of the mainstays of burns management is fluid resuscitation.

9- Respiratory losses

The tachypnoea and pyrexia of respiratory complications of surgery can result in

appreciable fluid loss.

Table 5.3 Normal daily water losses (70-kg man)

Gastrointestinal (faeces)	100 mL
Respiration	500 mL
Insensible (latent evaporation from skin)	700 mL
Urine	1700 mL (variable, depending on fluid status)
Total	3000 mL

Fluid overload and oedema

1- Excess intake

By far the most common cause of fluid overload in surgical practice is excessive intravenous administration. This is more likely to occur in patients with pre-existing renal and cardiovascular disease, and such patients therefore require careful thought about their fluid regime and may need close monitoring modalities.

2- Decreased loss

Several medical conditions result in pathophysiological salt and water retention.

They are of relevance to surgical practice as these patients might require surgical intervention, where inappropriate fluid management can exacerbate their condition.

The altered cardiovascular dynamics of cardiac failure results in pathophysiological alterations in the renin-angiotensin-aldosterone axis, causing salt and water retention and further increases in venous pressure.

3- Renal disease

Diseases that reduce the glomerular filtration rate result in an impaired ability to excrete sodium. Complex interactions are seen in many renal diseases that alter tubular reabsorption of sodium and lead to retention of sodium and its accompanying water.

4- Liver disease

Patients with cirrhosis have raised portal venous pressure, causing similar changes to those seen in cardiac failure and hence salt and water retention.