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Body Fluids in Surgery

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Abstract

Water makes up about 60% of the total mass of the human body. Due to the constant movement in the body, water nourishes the organs through which it passes and renews the fluids in them. The amount of body fluid is regulated by the skin and kidneys. Sweating maintains the internal temperature at 37 oC, and the kidneys filter toxins and remove metabolic products from the blood through urine. The human body obtains water through food (almost all food contains water), breaking down nutrients that provide energy and fluid intake (water and beverages). No other nutrient is involved in so many different functions of the human body as water. With smaller losses, disturbances occur, and a loss of 15% of the total water content already causes death. It is interesting to mention that a man can live without food for weeks, even months, while without water he can live very short.

Key words: Fluid, Water, Surgery, Emergency, Patient

Introduction

In the 'average' person, water contributes 60% to the total body weight: 42 L for a 70 kg man [1]. Forty percent of the body weight is intracellular fluid, while the remaining 20% is extracellular. This extracellular fluid can be subdivided into intravascular (5%) and extravascular or interstitial (15%). Fluid may cross from compartment to compartment by osmosis, which depends on a solute gradient, and by filtration, which is the result of a hydrostatic pressure gradient.

The electrolyte composition of each compartment differs. Intracellular fluid has a low sodium and a high potassium concentration. In contrast, extracellular fluid (intravascular and interstitial) has a high sodium and low potassium concentration. Only 2% of the total body potassium is in the extracellular fluid. There is also a difference in protein concentration within the extracellular compartment, with the interstitial fluid having a very low concentration compared with the high protein content of the intravascular compartment.

Knowledge of fluid compartments and their composition becomes important when considering fluid replacement. In order to fill the intravascular compartment rapidly, a plasma substitute or blood is the fluid of choice. Such fluids, with high colloid osmotic potential, remain within the intravascular space, in contrast to a crystalloid solution such as compound sodium lactate (Hartmann's) solution, which will distribute over the entire extravascular compartment, which is four times as large as the intravascular compartment. Thus, of the original 1 L of Hartmann's solution, only 250 mL would remain in the intravascular compartment. Five percent dextrose, which is water with 50 g of dextrose added to render it isotonic, will redistribute across both intracellular and extracellular spaces.

In addition to water, body fluids also contain solid substances that dissolve, called solutes [2]. Some solutes are electrolytes and some are nonelectrolytes. Electrolytes are chemicals that can conduct electricity when dissolved in water. Examples of electrolytes are sodium, potassium, calcium, magnesium, acids, and bases. Nonelectrolytes do not conduct electricity; examples include glucose and urea.

Fluids and electrolytes move in the body by active and passive transport systems. Active transport depends on the presence of adequate cellular adenosine triphosphate (ATP) for energy. The most common examples of active transport are the sodium-potassium pumps. These pumps, located in the cell membranes, cause sodium to move out of the cells and potassium to move into the cells when needed.

In passive transport, no energy is expended specifically to move the substances. General body movements aid passive transport. The three passive transport systems are diffusion, filtration, and osmosis.

Water is very important to the body for cellular metabolism, blood volume, body temperature regulation, and solute transport. Although people can survive without food for several weeks, they can survive only a fe w days without water. Thirst is the major indicator that a healthy adult needs more water.

The heart pumps blood, a fluid consisting of red cells, white cells and plasma, around the body [3]. The red cells carry oxygen to the tissues and carbon dioxide from the tissues; the white cells are important in fighting disease and the plasma transports nutrients to the tissues and waste products from the tissues, which are metabolised in the liver or excreted by the kidneys. Blood remains fluid because of a fine balance between factors which cause the blood to clot and factors which cause clots to dissolve. When a small hole appears in the circulation, the body has the ability to repair this: first, by stopping the leak and, secondly, by repairing the hole. Leaks from the circulation are stopped by platelet plugs and the blood's ability to clot. When clotting does occur, the body has the ability to dissolve clots using an active fibrinolytic system. The body is better able to deal with clots from the venous side of the circulation than the arterial side.

Water Retaining fluid is of greater importance in the body chemistry of infants than that of adults because fluid constitutes a greater fraction of the infant's total weight [4]. In adults, body water accounts for approximately 60% of total weight. In infants, it accounts for as much as 75% to 80% of total weight; in children, it averages approximately 65% to 70%.

Fluid is distributed in three body compartments: (a) intracellular (within cells), 35% to 40% of body weight; (b) interstitial (surrounding cells and bloodstream), 20% of body weight; and (c) intravascular (blood plasma), 5% of body weight. The interstitial and the intravascular fluid together are often referred to as the extracellular fluid (ECF), totaling 25% of body weight. In infants, the extracellular portion is much greater, totaling up to 45% of total body weight. In young children, this amount is 30%; in adolescents, it is 25%.

Fluid is normally obtained by the body through oral ingestion of fluid and by the water formed in the metabolic breakdown of food. Primarily, fluid is lost from the body in urine and feces. Minor losses, insensible losses, occur from evaporation from skin and lungs and from saliva (of little importance except in children with tracheostomies or those requiring nasopharyngeal suction). Infants do not concentrate urine as well as adults because their kidneys are immature. As a result, they have a proportionally greater loss of fluid in their urine. In infants, the relatively greater surface area to body mass also causes a greater insensible loss. Fluid intake is altered when a child is nauseated and unable to ingest fluid or is vomiting and losing fluid ingested. When diarrhea occurs, or when a child becomes diaphoretic because of fever, the fluid output can be markedly increased. Dehydration occurs when there is an excessive loss of body water.

Accurate replacement of fluid deficits requires an understanding of the distribution volume of body fluids [5]. For a person weighing 70 kg, total body water (TBW) is about 42 L (60% of weight in kg). The total body water exists within discreet but dynamic fluid compartment. Two-thirds of the TBW (28 L) is intracellular water. The remaining third (14 liters) in the extracellular compartment is divided into the intravascular (5 L, one-third) and extravascular (9 L, two-thirds) compartments. Blood is composed of around 60% plasma (extracellular compartment) and 40% red and white blood cells and platelets (intracellular compartment). Plasma consists of inorganic ions (predominantly sodium chloride), simple molecules such as urea, and larger organic molecules (predominantly albumin and the globulins) dissolved in water. Interstitial fluid bathes the cells and allows metabolic substrates and wastes to be diffused between the capillaries and cells in the tissue. Excess free interstitial fluid enters the lymphatic channels and is ultimately returned to the plasma. The majority of the interstitial water exists within a proteoglycan matrix in a gel form. The transcellular fluids are extracellular and include the cerebrospinal fluid, aqueous humor, and pleural, pericardial, and synovial fluids.

The chemical composition of the intracellular fluid includes potassium and magnesium as the principal cations [6]. Phosphates and proteins are the principal anions. In the extracellular fluid, sodium is the principal cation and chloride and bicarbonate are the principal anions. Because plasma has a higher protein content (organic anions), its concentration of cations is higher and it has fewer inorganic anions than interstitial fluid. In any given solution, the number of milliequivalents of cations present is balanced by precisely the same number of milliequivalents of anions.

The differences in ionic composition between intracellular and extracellular fluid are maintained by the semipermeable cell membrane. Although the total osmotic pressure of a fluid is the sum of the partial pressures contributed by each of the solutes in that fluid, the effective osmotic pressure depends on those substances which fail to pass through the pores of the semipermeable membrane. The dissolved proteins in the plasma are primarily responsible for effective osmotic pressure between the plasma and the interstitial fluid compartments, also known as the oncotic pressure. While sodium, as the principal cation of the extracellular fluid, contributes a major portion of the osmotic pressure, it is the intravascular proteins that do not penetrate the cell membrane freely that constitute the oncotic pressure.

The water intake is approximately the sum of the weight, expressed in grammes, of fluid and of solid food ingested, because solid food when digested and metabolised yields three-fifths its own weight as water [7]. The water intake should be about 2500m1 daily, half of which is taken as drinks.

Water is excreted as exhaled air, 400m1, evaporation including sweat 500-1000m1, urine 1200m1, and faeces 200m1. Water lost by exhalation and evaporation is used for heat regulation and the quantity lost varies widely according to the circumstances. Insufficient fluid intake shows as a decrease in urine output. The absolute daily minimum of urine is the 600m1 required to carry the 50g of urinary solids excreted daily; below this toxic metabolites are returned to the blood. At this concentration the specific gravity is raised from 1.015 to 1.030. All patients who have difficulty in feeding because of acute trismus or mouth injuries should have a fluid balance chart. This shows on the credit side all fluid taken in 24 hours including metabolic water, and on the debit side the urine passed plus an estimate for water lost by evaporation which may be very high in febrile states. For all practical purposes the urine output is a measure of the water balance

Critical Illness

The term 'critical illness' describes the condition of a patient who has a likely, imminent or established requirement for organ support; in simple terms where death is possible without timely and appropriate intervention [8]. Some patients are at greater risk of developing critical illness than others. Also certain conditions bring a likelihood of severe physiological stress. It is unfortunately commonplace for the junior surgeon to be faced with a critically ill surgical patient, in various situations-from the peritonitic teenager admitted to A&E to the elderly post operative hip replacement on HDU. It is crucial that a systematic approach is taken to assessment and treatment.

While it is more challenging to manage the patient with multiple organ failure it is rarely rewarding; rescuing the elderly post-laparotomy patient from cardiac failure brought about by fast atrial fibrillation is far harder than anticipating the hypokalaemia (causing the cardiac irritability) associated with ileus: prediction and prevention is essential. Prediction can begin with pre-operative assessment (such as identifying chronic airways disease or poor nutritional state) but continues through knowledge of the common problems associated with the condition/operation (such as the risk of chest infection after laparotomy). Prevention encompasses specific steps such as adequate replacement of fluid and electrolytes, adequate analgesia, chest physiotherapy and thromboprophylaxis, but the role of regular review (e.g. ward rounds) cannot be overstated.

In critical illness and after complicated major surgery, the obligatory extracellular volume required to maintain adequate venous return to the heart rises due to the loss of salt water and protein into sites of tissue damage, obstructed bowel, serous body cavities and the relaxation of the peripheral vascular bed [9]. In some situations (e.g. sepsis), the amount of sequestered fluid may be prodigious due to an enormous capillary leak and sufficient to cause circulatory failure. This is the situation seen often in critically ill surgical patients. Consequently, it is reasonable to suspect hypovolaemia in most patients and act accordingly.

Epidural anaesthesia causes vasodilatation and this increased vascular space needs filling or controlling. This is particularly so if the patient has also been cold after surgery and vasodilates further as they warm up. In these patients, the commonest error is inadequate fluid resuscitation, whether in volume, fluid type or rate of delivery.

By way of contrast, major but uncomplicated surgery produces a different situation. Surgery itself causes activation of the anti-diuretic hormone (ADH) and angiotensin-aldosterone, thereby retaining fluids and causing reduced urine output for 24–48 hours. Thus, in a well patient with otherwise normal parameters, isolated, modest oliguria can be acceptable. With fast-track recovery programmes advocating early and liberal oral intake and less in the way of bowel preparation (which dehydrates the patient significantly), the elective patient is less likely to be volume depleted. These patients often need much less in the way of postoperative fluids; in these 'well' patients, excessive fluids cause more harm than good. Here, excessive provision of sodium and water is now recognised as the principal cause of avoidable problems. This is a very different set of circumstances to the critically ill patient who, not infrequently, needs intravenous fluids rapidly for life-saving resuscitation. Fluid resuscitation from shock using an appropriate colloid or crystalloid was dealt with in the chapters on assessment and shock.

Trauma Patient

Physical examination alone is unreliable for the diagnosis of intra-abdominal injuries in patients who have sustained blunt abdominal trauma [10]. Diagnostic imaging is therefore relied on to diagnose or rule out intra-abdominal injuries. The ideal screening examination for intra-abdominal injuries would have a high degree of sensitivity, which would allow for the safe exclusion of significant injuries while maintaining an acceptable specificity, effectively decreasing the number of patients requiring definitive imaging.

Early reports suggesting a high sensitivity for the identification of intraperitoneal free fluid generated great enthusiasm for the use of FAST as a screening modality in the work-up of blunt trauma patients. The majority of the studies reporting high sensitivities for FAST, however, are limited by major methodological issues: A definitive reference gold standard was not applied to all patients and in the majority of studies, long-term follow-up was not available. This may contribute to an underestimation of false negative results. More important, recent studies and systematic reviews have challenged the value of the FAST examination in the initial evaluation of blunt trauma patients, specifically because of its inability to rule out significant intra-abdominal injuries. Increasing concerns that FAST may miss clinically significant injuries have contributed to an increasing awareness about the limitations of this imaging modality as a screening method for blunt abdominal trauma.

Focused abdominal sonography for trauma (FAST) is a standardized ultrasound examination that aims to identify the presence of free fluid in the pericardium and peritoneal cavity. As an initial diagnostic adjunct, the ultrasound has several advantages: It is noninvasive, repeatable, accessible, portable, rapid, and cost-effective. However, ultrasound is highly operator dependent, and several patientrelated factors, such as subcutaneous emphysema, morbid obesity, severe chest wall injury, narrow subcostal area, and a large hemothorax, may limit adequate image acquisition.

Ultrasound works on the principle that the ultrasound emitted as a pulse from a transducer travels at constant velocity into tissue and is reflected by varying amounts from different tissue interfaces and travels back to the receiver at the same speed [11]. The transducer is a piezoelectric crystal that both transmits and receives the ultrasound. The time required for the pulse to travel to the interface and back can be used to determine the depth of that interface. An image of the slice of the body is obtained by directing a narrow beam of high-energy sound waves into the body and recording the manner in which the sound is reflected by different structures. Sound is transmitted well through any fluid but poorly or not at all through air or bone. Returning echoes are electronically converted into a video image on a monitor, the resulting picture being a wedge-shaped slice of the area of interest.

All seriously injured patients must have their pulse rate, blood pressure, respiratory rate, level of consciousness and tissue oxygenation monitored continuously [12]. Patients with an associated head injury must be monitored using the Glasgow Coma Scale. A urinary catheter and the measurement of central venous pressure provide additional valuable information for monitoring resuscitation when there are signs of hypovolaemia. An intra-arterial pressure line is also very useful for continuously monitoring the blood pressure,and allows easy sampling of arterial blood for blood gas and acid/base measurement.

Once blood loss is suspected, the patient must be given immediate fluid replacement through two wide-bore cannulae inserted into the veins of the cubital fossae. Fluid can be given faster through a central venous catheter if this has been inserted for monitoring purposes and is not contra-indicated by the presence of neck and chest injuries. One to two litres of crystalloid (normal saline) or colloid should be given aftersending a sample of the patient's blood for grouping and cross-matching. For patients with clear signs of shock, request at least 4 units of blood.

Patients who fail to respond to the rapid restoration of their blood volume in the absence of cardiac or major respiratory problems, e.g. tamponade or tension pneumothorax, probably have severe continuing blood loss. In these circumstances the blood transfusion should be started while making a rapid assessment of the potential sites of concealed blood loss. The most common are the pleural or abdominal cavities. Fractures of the pelvis can also cause catastrophic blood loss.

The assessment of intravascular volume and the adequacy of volume resuscitation are among the most difficult clinical challenges facing the trauma surgeon [13]. Crude clinical parameters such as systolic blood pressure, heart rate, and urine output are inaccurate for several reasons. First, hypoperfusion can coexist with normotension until severe derangements occur (compensated shock). Second, hypotension, tachycardia, cold extremities, decreased urine output, and poor capillary refill are only present in patients who have lost at least 30% of their blood volume (Class III hemorrhage). Third, both blood pressure and heart rate are affected by anxiety, pain, and medications. CVP, central venous oxygen saturation, and the changes in CVP in response to volume loading are also relatively poor indicators of intravascular volume. Furthermore, it is unclear whether improved values of cardiac index, oxygen consumption, and oxygen delivery are valid markers of reduced morbidity and mortality. Administration of fluid predictably increases cardiac output, blood pressure, and tissue perfusion in the hypovolemic patient. Hence, it might seem logical to start rapid fluid infusion as soon as possible at the scene. However, when evacuation time is less than 1 h (usually in urban scenarios), attempts to gain intravenous access and to administer large fluid volumes at the scene may delay arrival to the hospital, which has been shown to reduce outcome in severely injured patients (the "scoop and run" vs. "stay and play" debate). Moreover, as discussed above, increasing blood pressure in patients with uncontrolled hemorrhagic shock may enhance or resume bleeding.

Emergency

All ES patients require some form of resuscitation, whilst this may only be intravenous (IV) fluid to replace intravascular losses, supplemental oxygen or appropriate analgesia, others will require full resuscitation, including airway management, central access and fluids [14].

Resuscitation can occur anywhere in the hospital and is not limited to the emergency room or the intensive care unit. The traditional ABC approach is tried and tested and is an appropriate pathway for the ES patient. Patients with small bowel obstruction or pancreatitis, for example, will have significant fluid losses and will require aggressive early fluid resuscitation, guided by measurement of urine output and/or central venous pressure. In the unwell or unstable patient, resuscitation must proceed at the same time as the evaluation and life-threatening conditions treated as they are discovered. It is vital to get senior help when looking after seriously ill patients and early referral to critical care and/or an outreach team will be valuable. Septic and peritonitic patients can decompensate rapidly and early involvement of critical care before surgery will be particularly valuable. The patient may need transfer to critical care before surgery for ventilatory and/or cardiovascular support. The surviving sepsis guidelines should be followed in septic patients and the sepsis care bundles commenced, however, the fundamental requirement is surgical drainage of the driving infection.

Conclusion

Body fluids make up our internal environment in which all processes in the body take place. Water has the largest share in the composition of body fluids, and the whole organism. The average share of water in the body of an adult is about 60%. It is a major component of cellular and extracellular fluid. Extracellular fluid consists of plasma and fluid that fills the space between cells. The composition and volume of body fluids in the body should be approximately constant in order to maintain homeostasis. Homeostasis is the ability of an organism to keep its internal conditions stable independently of external influences. All organisms must regulate their internal environment in order to survive.

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