FLUID BALANCE IN PEDIATERIC SURGERY

THESIS

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INTRODUCTION

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Water is the most abundant single constituent of the body , representing more than half of the body weight. It is very important for the viability of body organs, it is the medium in which all metabolic reactions occur, and all the nutrients and solutes of the body are dissolved or suspended in it. Body water content is remarkably constant in healthy individuals despite its rapid turnover rate.

Traditionally , the total body fluid has been divided into two major compartments according to their location relative to the cell membrane. Intracellular fluid (ICF) represents all the water with its solutes present inside the cells. It is in this medium that all the essential chemical reactions of the body occur . It approximates 40% of the body weight .

The extra cellular fluid (ECF) represents all the fluid surrounding the cell. Normally the ECF can be assumed to equal 20% of body weight and is further divided into two major compartments by the vascular membrane, plasma volume (5% of body weight) and interstitial fluid (ISF) which forms 15% of body weight .

Another small compartment which is usually considered as specialized fraction of extra cellular fluid is the transcellular water compartment which consists of the fluid present in body cavities such as, secretions of gastrointestinal tract, urine, cerebro-spinal fluid and intra-occular fluid. The volume of transcellular compartment is variable depending on absorption and secretory activities of the intestine, during the fasting state it represents about 1-2% of body weight (Fleischman ,1982).

As regard composition of body fluids, electrolyte concentrations differ markedly in the various compartments. The most striking differences are the relatively low content of protein anions in ISF compared to ICF and plasma, and the fact that Na^+ and Cl^- are largely extracellular, where as most of K^+ is intracellular . The differences in composition of the various body fluid compartments are due , in large part , to nature of the barriers separating them . The membranes of cells separate interstitial fluid and intracellular fluid and the capillary wall separtes interstitial fluid from plasma. The forces preducing movement of water and other molecules across these barriers are diffusion, solvent drag, filtration, osmosis, active transport by Na^+-K^+ pump mechanism and the processes of exocytosis and endocytosis (Ganong ,1981).

The volume of ECF is kept remarkably constant despite large variations in salt and water intake . Homeostasis is achieved through mechanisms that act to maintain the osmolality of ECF . The reason for such vigorous defence of osmolaity is not immediately clear, but may be related to the optimum performance of intracellular reactions involving protein and electron transfer (Bevan , 1978). The physiological mechanisms that control the osmolality of extracellular fluid also affect intracellular volume . A number of physicochemical and biological mechanisms act to maintain the cellular content of osmotically active solutes (Macknight and Leaf ,1977). So if ECF osmolality decreases water must enter the cells. Conversely , if ECF osmolality increases due to an increase in solutes that penetrate cell membranes poorly , cellular volume will decrease. The major determinant of ECF osmolality is sodium so it is the quantity of sodium in the ECF that determines the volume of this compartment (Shorecki, and Brenner, 1981).

PHYSIOLOGY OF WATER AND ACID-BASE BALANCE

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Water metabolism :

Obviously , daily water replacement exist because there are daily water losses. Losses of water are secondary to heat production. In normal humans, body temperature is approximately 37°c. The balance between heat production and heat loss is a function of both mass and surface area . An implication of this relationship is the fact that for each unit of mass, the human infant will have to produce much more heat than the adult to balance the losses, because the infant's surface area to mass ratio is about three times that of the adult (Fleischman ,1982) .

Water gains :

Water gains in the body are either exogenous or endogenous . Exogenous water gain consists of water obtained by ingestion , intravenous infusion, or catabolism of food . A normal adult person drinks approximately 1500 to 2000 ml of water per day . The free form water ingested food amounts to 250 ml. Another 250 to 300 ml of water is liberated by the oxidation of food . The average daily intake of fluid for a child is about 700 ml and for an infant 300 to 400 ml .

As a general rule, approximately 10 ml of water is produced with the liberation of 100 cal from oxidation of either fats, carbohydrates or proteins , (fat supplies about 9 cal/gram, protein and carbohydrate 4.1 cal/gram) . Endogenous water is obtained as a result of cellular shrinkage , destruction of cells and oxidation of fats, carbohydrates and proteins in tissue cells. In other wards, endogenous water due to gain of free form water released by shrinkage or destruction of cells, amounts to 750 ml/kg of lean muscle (Schafer et al.,1977). Water of cellular oxidation is produced by oxidation of fats, carbohydrates and proteins within the tissue cells and yields 150 ml/kg of lean muscle . Each kg of muscle that is catabolized produces 900 ml (750 ml + 150 ml) or roughly one liter of water. Similarly , the oxidation of 1 kg of fat liberates 1080 ml of water. During total starvation approximately 2000 ml of endogenous water is produced daily by the catabolism of 1 kg of muscle and 1 kg of fat . During ordinary surgical convalescence or the so called period of "resting-starvation" 500gm of protein and 500 gm of fat are catabolized daily to yield 990 ml of endogenous water (375 ml+ 75 ml + 540 ml). Consequently , during the postoperative period, when patient is not eating , approximately 1 liter of endogenous water will be released each day. This volume of endogenous water is excreted by the normal functioning kidney as "excess water" in urine .

Water losses :

There are 2 types of water losses, obligatory losses and abnormal water losses which is sometimes termed additive because they are added onto losses of water by obligatory routes.

Obligatory losses: are daily water losses from the body which may be divided into three categories insensible water loss, urine production, and losses in stool. All these losses are ongoing at a state of rest. The sum of the three obligatory routes of water loss equals 100 ml/100 cal expended, or 1 ml/cal expended. Changes in environmental temperature and humidity , body temperature , ventilation volume per minute and muscular activity , all increase obligatory water losses and inturn are largely dependent on energy expenditure.

The following table may approximate the daily water losses in infants and children (in ml).

	Urine	Stool	Insensible	Total
Infant under 10 kg	200-500	25-40	75-300	300-840
Child under 40 kg	500-800	90-100	300-600	890-1500

(Adapted by Brook ,1962)

Abnormal water losses :

In addition to obligatory water losses there are abnormal water losses induced by diseases or unusual environmental condition. These losses are not necessarily related to caloric expenditure .Hyperventilation as induced by disease such as pneumonia or by drug action such as that of toxic levels of salicylate may cause as much as 45 ml/100 cal of water to be lost. The amount of water vapour lost is affected by humidity of the environment in which the patient is placed. Low humidity increases and high humidity decreases water loss .

The gastro-intestinal tract is the site of absorption of ingested water and under certain pathological conditions, a place where abnormal water losses may occur. Certain intestinal disorders may induce a secretory diarrhea in which the loss of water may be enormous. Vomiting is a symptom that can also lead to considerable water loss. For hospitalized patients, drainage tube in the stomach or intestine may remove very considerable volumes of water and electrolytes .

Regulation of water balance :

To maintain a constant state , the amount of body water derived from intake and from oxidation of carbohydrates, fats and proteins must equal losses from kidneys, lungs, skin and gastrointestinal tract. Precise control of the amount of water in the body is dependant upon a finely regulated feed back system involving the hypothalamus, posterior pituitary and collecting ducts of the nephrons.

Thirst: under conditions of health, water losses, normal and sometimes abnormal, are affected by intake of water. The process is governed by thirst mechanism. Thirst in-turn is controlled by the central nervous system centres that are present in the hypothalamus. Elevation of extracellular fluid osmolality such as that seen with infusion of a hypertonic saline solution will stimulate certain osmoreceptors in the hypothalamus which in-turn initiate thirst sensation and drinking. An increase of one to two percent in osmolal concentration causes thirst, and a decrease to normal or below normal stops thirst sensation. However, hemorrhage can cause increased drinking and sensation of thirst even though there's no change in osmolality of plasma. This results from reduction in the extracellular volume. The effect of ECF volume depletion on thirst is partly mediated via the renin-angiotensin system. Renin secretion is increased in cases of hypovolaemia. Remin acts on angiotensinogen which is synthesized in the liver to form angiotension I. The converting enzyme transforms angiotensin I to angiotensin II. Most of the conversion occurs during passage of blood through the lungs, but