Encephalopathies Caused by Electrolyte Disorders in Intensive Care Unit

An essay
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بسم الله الرحمن الرحيم

يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ

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*First, thanks are all due to **Allah** for Blessing this work until it has reached its end, as a part of his generous help throughout our life.*

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Abdellatif Abdellhafiz Abdellatif Ali

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List of Abbreviations

ACEIS	:	Angiotensin converting enzyme inhibitors
ADH	:	Antidiuretic hormone
ANP	:	Atrial Natriuretic Peptide
AVP	:	Arginine Vasopressin
BNP	:	Brain Natriuretic Peptide
BNP	:	Brain natrueritic peptide
BUN	:	Blood urea & nitrogen
CBW	:	Current body water
CHF	:	Congestive heart failure
CKD	:	Chronic kidney disease
CNS	:	Central Nervous System
COPD	:	Chronic obstructive pulmonary disease
CSW	:	Cerebral Salt Wasting
CT	:	Computed tomography
D5W	:	Dextrose 5% water
DI	:	Diabetes insipidus
DI	:	Diabetes inspidus
EABV	:	Effective arterial blood volume
ECF	:	Extracellular fluid
ECV	:	Extracellular Volume
ETb	:	Endothelin receptors
Fhhnc	:	Familial hypomagnesaemia with hypercalciuria and nephrocalcinosis
GFR	:	Glomerular Filtration Rate
HHS	:	Hyperosmolar hyperglycemic syndrome

List of Abbreviations (Cont.)

ICF	:	Intracellular fluid
ICF	:	Intra-Cellular Fluid
ICU	:	Intensive Care Unit
IDDM	:	Insulin dependent diabetes mellitus
IDH	:	Ischemic heart disease
IDH	:	Isolated dominant hypomagnesemia
IRH	:	Isolated recessive hypomagnesemia
Mmol	:	Millimoles
Mosm	:	Milliosmole
MV	:	Mechanical ventilation
NDI	:	Nephrogenic diabetes inspidus
NDI	:	Nephrogenic diabetes insipidus
NG	:	Nasogastric
NIDDM	:	Non insulin dependent diabetes mellitus
NSAIDS	:	Nonsteriodal anti inflammatory drugs
P osm	:	Plasma osmolarity
PTH	:	Parathyroid hormone
PTHrP	:	Parathyroid hormone related protein
SIADH	:	Syndrome of inappropriate antidiuretic hormone secretion
TBW	:	Total body water
V2R	:	Vasopressin receptor
VRAs	:	Vasopressin receptor antagonists

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Introduction

Electrolytes are involved in many metabolic and homeostatic functions, including enzymatic and biochemical reactions, the maintenance of cell membrane structure and function, neurotransmission, nerve signal conduction, hormone function, muscle contraction, cardiovascular function, bone composition, fluid and acid base regulation. In addition to serum electrolyte concentrations, signs and symptoms of specific electrolyte disorders should be monitored in patients with electrolyte abnormalities. The severity of symptoms related to electrolyte disorders generally correlates with the severity of the disorder and the rate at which the disorder developed ***(Rose and Post, 2001).***

Hyperosmolality usually produces a generalized encephalopathy without localizing or lateralizing features, but an underlying focal lesion (e.g., stroke, multiple sclerosis, neoplasm) could become symptomatic under the metabolic stress of a hyperosmolar state. The prognosis of the hyperosmolality itself is good, but the long-term outlook depends upon the cause ***(Martin et al., 2011).***

Dysnatremias (hypo and hypernatremia) are common in patients admitted to the intensive care unit (ICU) with a prevalence approaching 20–30% in some studies. Recent

data reveals that both hypo- and hypernatremia present on admission to or developing in the ICU are independent risk factors for poor prognosis. The origin of hypernatremia in the ICU is often iatrogenic and due to inadequate free water replacement of ongoing water losses. The pathogenesis of hyponatremia in the ICU is more complicated but often is related to the combination of dysregulated arginine vasopressin production and concomitant inappropriate hypotonic fluid administration. Both the dysnatremia itself and the treatment of the electrolyte disturbance can be associated with morbidity and mortality making careful monitoring for and treatment of sodium disorders an imperative in the critically ill patient. Thus, a cornerstone of proper therapy is serial measurements of serum and urine electrolytes. The appropriate use of hypertonic (3%) saline in the treatment of hyponatremic encephalopathy has also shown to be very effective and the use of this therapy is reviewed here.

Recent data demonstrates that proper correction of hyponatremia is associated with improved short and long term outcomes ***(Ronco et al., 2010).***

About the Electrolytes under study

Sodium

Disorders of sodium and water balances are common in critically ill patients ***(Levin, 1998).***

Regulation of salt and water balance:

The body contains 45-75% by weight of water; the range reflects the differences in body composition between the different demographic groups, male and female, young and old. Adipose tissue contains up to 10% water; lean tissue contains 70-75% water. In young adult males, body water is about 60% of body weight and in young adult females, who have a higher percentage of body weight as fat, about 50%. With age, the proportion of body weight made up of water decreases because lean tissue mass declines and tends to be replaced with adipose tissue. In the newborn, the figure is nearer 80-85% owing to a relative expansion of the extracellular fluid (ECF) volume ***(Iain, 2009).***

Two main fluid spaces exist, the intracellular fluid (ICF) and the extracellular fluid (ECF). The latter is further separated into the intravascular space (plasma volume), the interstitial space (which includes lymph) and transcellular fluid, which is formed by the transport activity of cells: pleural, pericardial, peritoneal, cerebrospinal and gastrointestinal fluids. Table (1) summarizes the water content of the body and the distribution of fluid between the

main body spaces: the proportion of body water to total body weight is affected by age, gender and fat content ***(Michael, 2008).***

Table (1): Body fluid distribution in relation to age and sex

	Infant age 1 year	Male age 40 years	Female age 40 years
Weight (kg)	7	70	60
total body water (L)	4.9	42	30
ICF volume (L)	3.1	28	18
ECF volume (L)	1.7	14	12
Intravascular (L)	0.35	2.8	2.4

(Michael, 2008).

Table (2): Representative molar concentration of electrolytes within the body fluid spaces. Other predominant intracellular counter anions are sulphates and proteinates

Electrolyte	ECF (mmol/kg)	ICF (mmol/kg)
Sodium	***152***	***10***
Potassium	***4.3***	***160***
Calcium	***2.7***	***1.0***
Magnesium	***1.1***	***13***
Chloride	***109***	***10***
Bicarbonate	***29***	***10***
Phosphate	***1.5***	***50***

(Michael, 2008).

Osmolality:

Water balance is measured by changes in osmolality. Osmolality is the number of osmotically active particles (osmoles) per liter of solution. (Osmolarity is expressed per kilogram). Hypo-osmolality indicates an excess of water relative to osmoles; hyperosmolality indicates water deficiency. The serum osmolality [in milliosmols per liter (mosm/L)] can be calculated by the following formula:

Serum osmolality =

$$\mathbf{2\,(Na^{+} + K^{+}) + (glucose/18) + (BUN/2.8)}$$

Where mosm is milliosmol, Na is sodium, and K is potassium; glucose and urea are given in mg/dL. The molecular weight of glucose is 180; urea, 28. Conversion from mg/dL to mosm/L yields 18 and 2.8 **(Richard, 2003).**

The osmotic substances, according to the way they spread among the body's fluid compartments, are divided in:

- **Passive**, diffusible substances: inactive osmoles represented by the urea (physiological present) and methanol, ethanol, they do not stimulate any osmotic transmembranary gradient, and therefore a water movement among the two compartments.

- **Active**, requiring energy in order to spread/ diffuse: are represented by sodium, glucose usually found in ECF or unknown to the body (mannitol, glycerol); they determine an osmotic gradient and hence a water movement towards the more concentrated compartment from the more diluted compartment; they are responsible for the plasma tonicity **(Eva et al., 2010).**

In most clinical laboratories, plasma osmolarity is not routinely measured. However, because sodium and its associated anions account for about 94 percent of the solute in the extracellular compartment, plasma osmolarity (Posm) can be roughly approximated as:

Posm = 2.1 × Plasma sodium concentration.

So with a plasma sodium concentration of 140 mEq/L, the plasma Osmolarity would be estimated from the formula above to be about 298 mOsm/L **(Guyton and Hall, 2006).**

Tonicity:

Refers to the osmotic force (ability to move water across a semipermeable membrane) exerted by osmotically active particles. Hypotonic solutions will lose water to, and hypertonic solutions will gain water from an isotonic solution. Not all osmoles are equivalent in tonicity. Urea, for

example, readily crosses cell membranes and exerts no tonic force. Glucose will induce water movement from most cells. The major extracellular osmole, sodium, is responsible for the variation in serum tonicity in most cases and, as such, is largely responsible for the volume of extracellular fluid (ECV) **(Richard, 2003).**

Because sodium concentration is a major determinant of serum osmolality, it is largely for the normal regulation and distribution of total body water. In essence, total body water is controlled by renal manipulation of sodium with resulting water adjustment to maintain tonicity. Sodium and water balances are regulated primarily by serum osmolality but also by intravascular volume and pressure. An increase in extracellular fluid osmolality is detected by osmoreceptors in the hypothalamus that stimulates synthesis of Arginine vasopressin or antidiuretic hormone (ADH).

ADH is then transported to, and released from the posterior lobe of the pituitary gland. This result in reabsorption of water in the distal tubule and collecting duct in the kidney. ADH is also released in reasponse to decrease in arterial pressre and intravascular volume that are detected by low pressure baroreceptors in the right atrium and great veins and high pressure baroreceptors in the carotid sinus. Hypovolaemia and hypotension also result in increased