POTASSIUM DISTURBANCE IN CRITICALLY ILL PATIENTS

An Essay

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Master Degree in **the Intensive Care**

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اختلال البوتاسيوم في مرضي الحالات الحرجة

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Summary

Potassium is the major intracellular cation. The normal plasma K^+ concentration is 3.5–5.0 mmol/L, whereas that inside cells is about 150 mmol/L. Therefore, the amount of K^+ in the ECF (30–70 mmol) constitutes <2% of the total body K^+ content (2500–4500 mmol). The ratio of ICF to ECF K^+ concentration (normally 38:1) is the principal result of the resting membrane potential and is crucial for normal neuromuscular function.

Potassium is essential for a number of critical body functions including enzymatic reactions that regulate protein synthesis, glycogen synthesis, cell growth, and cell division. In excitable cells, such as cardiac myocytes, the relationship of intracellular to extracellular potassium concentrations is critical in establishing the resting membrane potential. The serum potassium itself has effects on conductance of potassium through specific K^+ channels, effects that also are critical to cardiac conduction velocity. A very dramatic consequence of potassium abnormalities is complete skeletal muscle paralysis, which can occur with either a severe increase or a severe decrease in serum levels of potassium. Potassium is also an important local mediator of vascular tone in muscle beds.

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Ahmed Abdou Elsaid Elsayed

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
ACEIs	Angiotensin converting enzyme inhibitors
ACTH	Adreno cortico trophic hormone
ADH	Antidiuretic hormone
ARB	Angiotensin receptor blocker
ARF	Acute renal failure
ATP	Adenosine triphosphate
AVP	Argenin Vasopressin hormone
cAMP	Cyclic Adenosine Monophosphate
CCD	Cortical collecting duct
CD	Collecting duct
CL^-	Chloride ion
CLC-KB	Chloride channel- kidney B
CNT	Connecting tubule
COX	Cyclooxygenase
CVVH	Continuous veno- venous hemofilteration
DCT	Distal collecting tubule
EC	Extracellular
ECF	Extracellular fluid
ECG	Electroencephalogram
ENaC	Epithelial sodium channel
ESRD	End stage renal disease
GFR	Glomerular filtration rate
GIT	Gastrointestinal tract
H^+	Hydrogen ion
HD	Hemodialysis
HypoPP	Hypokalemic periodic paralysis
IC	Intracellular
ICF	Intracellular fluid
ICU	Intensive care unit
K^+	Potassium ion
KCL	Potassium chloride

LIST OF ABBREVIATIONS (Cont…)

Abbreviation	Meaning
mEq/L	Milli equivalent per litre
Mg	Milli gram
mM	Milli mole
Mosm	Milli osmole
MR	Mineralocorticoid receptor
Na^+	Sodium ion
$NaHCO_3$	Sodium bicarbonate
NH_4CL	Ammonium Chloride
NKCC2	Sodium-Potassium-Chloride Cotransporter
NSAIDs	Non steroidal anti-inflammatory drugs
OSMP	Plasma osmolarity
OSMU	Urine osmolarity
PD	Peritoneal dialysis
PG	Prostaglandin
PHA	Pseudohypoaldosteronism
PT	Proximal tubule
PTK	Protein tyrosin kinase
RAAS	Renin Angiotensinogen Aldosterone System
ROMK	Renal outer medullary potassium channel
RRT	Renal replacement therapy
RTA	Renal tubular acidosis
TALLH	Thick ascending limb of loop of Henle
TTKG	Transtubular K^+ Concentration Gradient
VR	Vasopressin receptor

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Introduction

Potassium is the most abundant intracellular (IC) cation, and plays a vital role in many body functions, including a vital role in regulating neuromuscular excitability. Potassium balance is largely determined by dietary intake and kidney function. The kidneys are the main source of potassium loss, with 80% to 90% of potassium losses occurring via urine. A primary function of potassium familiar to most critical care nurses is its role in regulating the electrical action potential across cell membranes (cardiac, skeletal, and smooth muscle) ***(Porth, 2011).***

Sodium/potassium-adenosine triphosphate (ATP) pump helps to maintain a higher IC potassium concentration (140 to 150 mEq/L) compared with a lower extracellular (EC) concentration of 3.5 to 5 mEq/L ***(Corwin, 2008).***

Critically ill patients often experience alterations in one or many of the factors that affect the activity of this pump, such as insulin, glucagon, catecholamines, aldosterone, pH, serum osmolality, and IC potassium levels ***(Alicia et al., 2011).***

Hypokalemia is defined as a serum potassium concentration below 3.5 meq/L and considered severe if below 2.5 meq/L or if a patient is symptomatic. Hypokalemia can develop in ICU patients as a result of intracellularshifts of potassium, increased losses of potassium, or, less commonly, decreased ingestion or administration of potassium. Serum potassium levels do not correlate well with intracellular potassium levels. Potassium supplementation and dosing are largely empirical and guided by serum potassium levels. It has been estimated that for every 0.3meq/L decrease in serum potassium concentration, the total body potassium deficit is approximately 100meq ***(Michael, 2005).***

Hyperkalaemia is defined as serum potassium greater than 5.5 m mol/l. True hyperkalaemia should however be distinguished from pseudohyperkalamia a rise in serum potassium secondary to release of intracellular potassium during phlebotomy or storage of blood sample. Hyperkalaemia could be due to transcellular shift, increase in intake or decrease in output. Transcellular shift is often due to metabolic acidosis; however, a sudden rise in osmolality, especially in association with insulin deficiency, could result in significant hyperkalaemia. B-blockers alone are rarely associated with significant hyperkalaemia, however, they could play a contributory part. In the presence of ECG ghanges, hyperkalaemia should be considered as an emergency and treatment should begain immediately ***(Ethier et al., 2005).***

Aim of The Work

The aim of the work is to review and discuss disturbances in potassium homeostasis; causes, their effects, management and correction of these disturbances.

Chapter 1

Potassium Homeostasis

Total body potassium (TBK):

Potassium is the major intracellular cation. The normal plasma K^+ concentration is 3.5–5.0 mmol/L, whereas that inside cells is about 150 mmol/L. Therefore, the amount of K^+ in the ECF (30–70 mmol) constitutes <2% of the total body K^+ content (2500–4500 mmol). The ratio of ICF to ECF K^+ concentration (normally 38:1) ***(Harrison, 2008).***

Total body stores of potassium are related to body size and muscle mass **(fig. 1).** Approximately 65% to 75% of potassium is in muscle.Thus, potassium content declines with age, mainly as a result of a decrease in muscle mass ***(Mandel, 1997)***, ***(Gennari, 1998), (Porth, 2006).***

Daily minimum requirements of potassium:

It ranges between 1600-2000 mg/day or 40-50 mEq/day (40mg = 1mEq). Potassium intake varies widely according to the type of diet consumed, age and race. Thus 15-20 years old may consume up to 3500 mg of potassium daily ***(Mandal, 1997).***

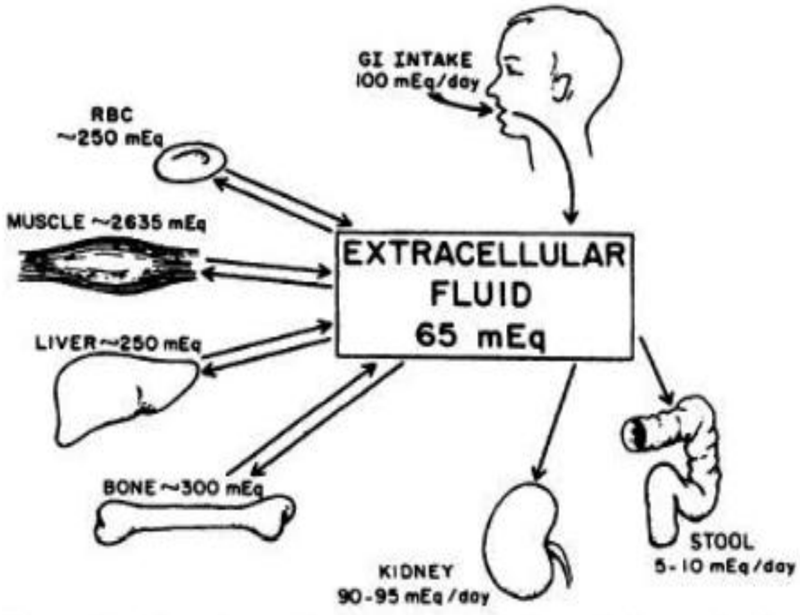

Figure (1): Internal and external potassium balance in humans, *Quoted from* ***(DeFronzo and Bia, 1985)***

Routes of elimination:

Renal excretion is the major route of elimination of dietary and other sources of excess K^+. The filtered load of K^+ (GFR x plasma K^+ concentration = 180 L/d x 4 mmol/L = 720 mmol/d) is ten- to twenty fold greater than the ECF K^+ content. The glomeruli would filter 900meq. of potassium each twenty four hour period, this is far in excess of 70 to 100meq., the average daily exretion for an adult.This would indicate then that reabsorption of potassium by the renal tubular cell takes place, possibly in association with phosphorylaton during tubular reabsorption of glucose ***(Harrison, 2008).***

Less than 10% of potassium ingested is lost in stool, which could increase, in severe degree of renal failure. Sweat has a mean potassium concentration of 9mEq/L, so the net loss of potassium by this route is less than 5mEq/day ***(Rastergar and Soleimani, 2001).***

Beneficial effects of potassium:

1) Cardiovascular system:

Epidemiological and clinical studies show that a high-potassium diet lowers blood pressure in individuals with both raised blood pressure and average population blood pressure. Also, increasing potassium intake reduces cardiovascular disease mortality. This is mainly attributable to the blood pressure-lowering effect and may also be partially because of the direct effects of potassium on the cardiovascular system. A high-potassium diet may also prevent or at least slow the progression of renal disease. An increased potassium intake lowers urinary calcium excretion and plays an important role in the management of hypercalciuria and kidney stones and is likely to decrease the risk of osteoporosis. It was found also that a 10 mEq increase in daily potassium intake was associated with 40% reduction in deaths from stroke independent of other known cardiovascular risk factors including blood pressure ***(Khaw and Barren, 2002), (He and MacGregor, 2008).***