Disorders of Potassium Homeostasis

P Baburaj[a], Harikrishnan B L[a]

a. Department of Medicine, Jubilee Mission Medical College and Research Institute, Thrissur, Kerala*

ABSTRACT

Published on 28th June 2012

Potassium is the predominant intracellular cation. Details of potassium regulation in the body are discussed. Disorders of Potassium homeostasis is the common electrolyte imbalance encountered. In this article, the physiology of homeostasis, hypokalemia and hyperkalemia are discussed.

Keywords: Intracellular cation, Hyperkalemia, Hypokalemia

*See End Note for complete author details

INTRODUCTION

Potassium is the predominant intracellularcation. Disorders of Potassium homeostasis is the common electrolyte imbalance encountered. In this article, the physiology of homeostasis, hypokalemia and hyperkalemia are discussed.

PHYSIOLOGY

Distribution

Total body Potassium (K) :3500meq Intracellular K: 150-160meq Extracellular K: 3.5-5meq
Daily intake of K: 80-100meq
Normal urinary excretion: 85% of dietary K
Normal Foecal excretion:15%of dietary K

- -K+ is a major determinant of volume of cell and osmolality of body fluids
- Extracellular Potassium greatly influences the neuromuscular function.

The Ratio of Intracellular and extracellular determine the membrane potential of excitable tissue. i.e Excitability is decreased in Hyperkalemia and increased in Hypokalemia.

REGULATION OF K BALANCE

1) Internal Mechanism

(a) Na-K ATP ase Pump actively transports K into the cell. (b) Insulin promotes entry of K into the cell. (c) Beta-Adrenergic agents-Catecholamine enhance cellular K uptake. (d) Aldosterone also helps in cellular uptake of K. (e) Blood pH and Hco3 by way of acidosis and alkalosis produce shift of K in &out of cell, acidosis will produce K efflux-and alkalosis will induce K influx. (f) ECF osmolality promotes passive K leakage from ICF to ECF.

2) External Mechanism

K balance is regulated mainly in kidney and gut.

(a) Renal Handling of K:

Most filtered K is reabsorbed quantitatively by proximal nephron 85% of dietary K is excreted by the distal segment of nephron. Renal response of hyperkalemia is quick, about half of acute load of K will appear in urine in 12hrs, at the same time response to hypokalemia very slow, Excretion of K does not fall to minimal level for 7-10 days.

Renal excretion of K is regulated by

1. Distal Tubular delivery of Na. 2. Cellular K concentration. 3. Plasma ph. 4.Aldoserone 5. Impermeant anions. 6.Tubular flow rate.

(b) 10-15% of dietary K is excreted through stool, Colon can be an important routé of K Excretion in Renal Failure.

Hypokalemia (Less than 3.5meq/L) –

1meq/L reduction in S.K level implies the net loss of 100-200 meq of K from the body. Symptoms will start appearing when the S.K level is less than 2.5meq/L.

Corresponding Author:
Dr. P Baburaj, Department of Medicine, Jubilee Mission Medical College and Research Institute, Thrissur, Kerala-680 005.
Phone: 9895080519, 0487 - 2335236. Email: drpbaburaj@yahoo.co.in

Causes

1. Reduced Intake-<40meq/L
2. G. I . Loss - Vomiting, Diarrhea, Villous adenoma, Fistulas, Ileus, Intestinal Obstruction.
3. Excess renal loss:
   a. Extra renal factors:
   - Diuretics/forced alkaline diuresis Conn's Syndrome
   - Cushing Syndrome
   - Bartter Syndrome
   - Liddle Syndrome
   - Gitelman Syndrome
   - Drugs- Carbenecillin, Amphotericin-B, Liquorise, Acetazolamide Corticosteroid
   - Renin Secreting Tumours.

   b. Renal Disease
   - Recovery phase of ATN
   - Relief of Obstructive uropathy
   - Renal tubular acidosis
4. ECF to ICF shift.
   a. Hypokalemic Periodic Paralysis
   b. Insulin therapy/Insulinoma
   c. Alkalosis
   d. Increased Beta Adrenergic activity
5. Miscelaneous:
   a. Hypomagnesemia
   b. Hypothermia

Relationship of Plasma K to total body Potassium

In most circumstances intracellular and extracellular K change are in the same direction. Hence alteration of S.K is a good index of total K change. However the presence of ECF depletion, Metabolic acidosis or insulin deficiency or Hypoaldosteronism, can develop clinically significant K depletion without change in plasma K. Similarly metabolic alkalosis, insulin therapy and Beta adrenergic receptors may induce hypokalemia despite normal body K.

CLINICAL FEATURES

Depends on severity and rate of development of hypokalemia. Main symptoms are due to skeletal muscles, heart & Alimentary system involvement. When S.K less than 2.5meq/L symptoms will manifest.

Neuroparalysis usually develops when Potassium concentration is less than 2meq/L.

1. Muscular weakness, hyporeflexia and paralysis of limb and respiratory muscles, Rhabdomyolysis.
2. Smooth muscle of GIT- Paralytic Ileus
3. Myocardial excitability is increased due to hyperpolarisation, producing arrhythmia-PAT with block, enhancing digitoxicity.
4. In the kidney it will produce nephrogenic diabetes insipidus due to ADH insensitivity, Vacoular Nephropathy-Hypokalemic Nephropathy.
5. Metabolic Alkalosis and Hypophosphatemia
6. Parasthesia and confusion.

DIAGNOSIS

Is on the basis of history and clinical features of primary disease, Low K of less than 3.5meq/L, urinary K less than 20-25meq/L,(extra renal loss of K) ECG shows flat T wave, Sagging of ST segment, prominence of U wave, Prolongation of QT interval. Evaluation of acid-base status, Endocrine workup, S.cortisol, S.Aldosterone, Plasma renin activity.

Clues for the diagnosis of hypokalemia

- Fluid loss with Urinary K <20meq/L: extra renal loss of K like diarrhoeal disease, ileus, villous adenoma
- HT N, Hyporeflexic Paralysis-Conn's syndrome Hypokalemia& U.K more than 20mq/day
- Recurrent hyporeflexic weakness<20 yrs of male Hypokalemic Periodic paralysis
- Moon facies, Truncal obesity, HT NHypercortisolism, Cushing's Syndrome
- Hyperchloremic Metaboic acidosis Alkaline urine, Nephrocalcinosis-RTA
- Polyuric phase of ATN
- Non oliguric renal failure in Leptospirosis-Hypokalemic ARF
- Hypokalemia, Hypomagnesemia, Hypercalciuria In creased Natriuresis, Hypocalcemia- BARTTER's Syndrome
- Hypokalemia, Hypomagnesemia with increased Natriuresis And hypocalciuria-Gitelman Syndrome
- Systemic HTN, Hypokalemia: Liddle syndrome (Pseudohyperaldosteronism)

TREATMENT OF HYPOKALEMIA

1. Prevention of Hypokalemia:

a. Diuretic therapy in patients with odema/HTN KCL 40-60 meq as elixir/cap/day

b. On corticosteroid Therapy-as above

c. Patients maintained in i/v fluids -KCL 60-80 meq/day

2. Correction of Hypokalemia

Total deficit=half of body weight in Kg x (5- S.K)

For i/v therapy the rate of infusion of KCL should not exceed 20meq/hr; not more than 200meq/ 24hrs. Conc:of K in i/v fluid should be not more than 60-80 meq/L. S.K level monitoring is essential during therapy. Oral therapy K. gluconate or citrate is preferred to avoid GI ulceration by KCL. Usual indication for i/v therapy are

- Diarrhea with hypokalemia
- Hypokalemic paralysis,
- Diabetic ketoacidosis,
- Forced alkaline diuresis.

3. Treatment of the cause of hypokalemia.

Hyperkalemia: (S.K more than 5meq/L)

-Less common and more dangerous than hyokalemia

Pathogenesis: Three important factors:

1. Tissue damage with release of K
2. Impaired renal excretion
3. Rapid administration of K by mouth or i/v

Aetiology:

1. Increased dietary intake
2. Shift of K from tissue.
   a. Tissue damage: Haemolysis, Rhabdomyolysis, crush injury, internal bleeding, snake bite
   b. Acidosis
   c. Hyperosmolality of ECF
   d. Insulin Deficiency
   e. Beta adrenergic antagonist
   f. Hyperkalemic Periodic Paralysis
3. Impaired Renal Excretion.
   a. Acute renal failure
   b. Chronic renal failure-ESRD
   c. Decreased tubular excretion as in SLE, Amyloidosis, Gordon's Syndrome, Transplanted kidney.
   d. Drugs- K sparing diuretics, ACE inhibitors
4. Abnormalities of Renin Angiotensin aldosterone system-
   a. Addisons disease
   b. CAH
   c. hyporenineaemic hypoaldosteronism - Diabetic
   d. Primary Hypoaldosteronism
5. Pseudohyperkalemia- in thrombocytosis and leucocytosis, due to release of potassium in vitro while clotting of blood.
6. Artifactual Hyperkalemia-Haemolysed sample, tight tourniquet.

CLINICAL FEATURES

Most important manifestation of Hyperkalemia is related to the alteration of cardiac excitability. Earliest change in ECG is peaked T wave When S.K is more than 6.5meq/L followed by prolongation of PR interval, absence of P wave, Widening of QRS complex and finally sine wave, terminally VF &cardiac arrest when S.K exceeds 8-10meq/L Hyperkalemia also produces flaccid muscular paralysis including respiratory muscles, Cranial nerves are Spared. Paraesthesia of hand and feet are common.

DIAGNOSIS

Diagnosis is confirmed by estimation of S.K and the characteristic ECG changes which is the best index of Hyperkalemia.

Management of Hyperkalemia:

Treatment of Hyperkalemia involves: 1)to reverse the cardiac side effects, 2) to improve intracellular uptake, 3) to remove excess potassium from the body. 4) Elimination of aetiological factors

- Drugs like-ACEI, Ksparing diuretic, ß blocker
- Acidosis
- Hyperosmolality

According to AHA 2005 guidelines, management should be guided in the serum .K level .In mild hyperkalemia (5-6 me q / L), furosemide and sod.polystyrene sulfonate can be used. For moderate (6-7meq/l) an in-

tracellular shift of potassium to be achieved using Insulin-glucose drip, salbutamol and sodium bicarbonate. In severe cases (>7meq/l with toxic changes), the cardiac toxicity needs to be controlled the earliest to prevent the advent of fatal arrhythmia. Calcium gluconate can be used as slow IV to achieve membrane stabilization. In addition to calcium, all the above modalities to be given to achieve lower serum K+ levels. In refractory cases, haemodialysis may be used as a last resort of treatment

a. Membrane effect: Calcium Gluconate 5-10ml of 10% solution over 2-5mins. Onset: Immediate; Duration: 30 mints

b. Intracellular shift of K:

   1. Insulin-Glucose drip -10units regular insulin i/v with 50 ml of 50% glucose or 100ml of 25% glucose.

      Onset of action:15-30mints,duration:2-6hrs

   2. Salbutamol -2-4ml of 5mg/ml salbutamol nebulised over 15mts.

      -Onset: 15-30mts,duration :2-3hrs

   3. Sodium Bicarbonate-50meq i/v over 5 mints

      -Onset:15-30mts,duration: 1-2hrs

c. Removal of excess S.K

   1. Furosemide-40-80mg i.v with saline if coexistent volume depletion
      -Onset :15-60minutes,duration: 4hrs

   2. Sodium Polystyrene sulfonate
      15-30gm in 50-100mL of 20% sorbitol either orally or as retention enema
      -Onset:1-2hrs, duration :4-6 hrs

   3. Haemodialysis-Onset :15-30mts

Long term Maintenance therapy:

- Restriction of K intake to <2-3g/dy
- Discontinuation of drugs interfering with K homeostasis
- Enhanced K excretion: furosemide, thiazide
- Fludrocortisone:(in Hypoaldosteronism)
- Long- term sodium polystyrene sulfonate therapy

Proper knowledge of the pathophysiology of disorders of Potassium homeostasis, proper history and physical examination and needed investigation will make one to have the correct diagnosis; thus the proper treatment.

END NOTE

Author Information

1. Dr. P Baburaj, Department of Medicine, Jubilee Mission Medical College and Research Institute, Thrissur, Kerala-680 005.
   Email: drpbaburaj@yahoo.co.in
   Phone: 9895080519, 0487 - 2335236

2. Dr. Harikrishnan B L, Department of Medicine, Jubilee Mission Medical College and Research Institute, Thrissur, Kerala-680 005.

Conflict of Interest: None declared

Cite this article as: P Baburaj, Harikrishnan B L. Disorders of Potassium Homeostasis. Kerala Medical Journal. 2012 Jun 28;5(2):53-56

REFERENCES

1. Sumeth S Hoskote, Ameth K Ghosh, JAPI 2008 Vol 56 685-692
1. Ethier JH, Kamel KS, Magner PO, Lemann J, Halperin ML. The transtubular potassium concentration in patients with hypokalemia and hyperkalemia. Am J Kidney Dis. 1990 Apr;15(4):309–15.
1. Gennari FJ. Hypokalemia. N Engl J Med. 1998 Aug 13;339(7):451–8.
1. Paice BJ, Paterson KR, Onyanga-Omara F, Donnelly T, Gray JM, Lawson DH. Record linkage study of hypokalaemia in hospitalized patients. Postgrad Med J. 1986 Mar;62(725):187–91.
1. Garg G Singer, Barry M Brenner. Harrison's Principles of Internal Medicine 17th Edition 280-285.
1. J.G.G Ledingham, Oxford Textbook of Medicine 3rd edition 3127-3135
1. Wilson, Foster, Larsen, Williams Textbook of Endocrinology 9th edition 595-597, 597-598