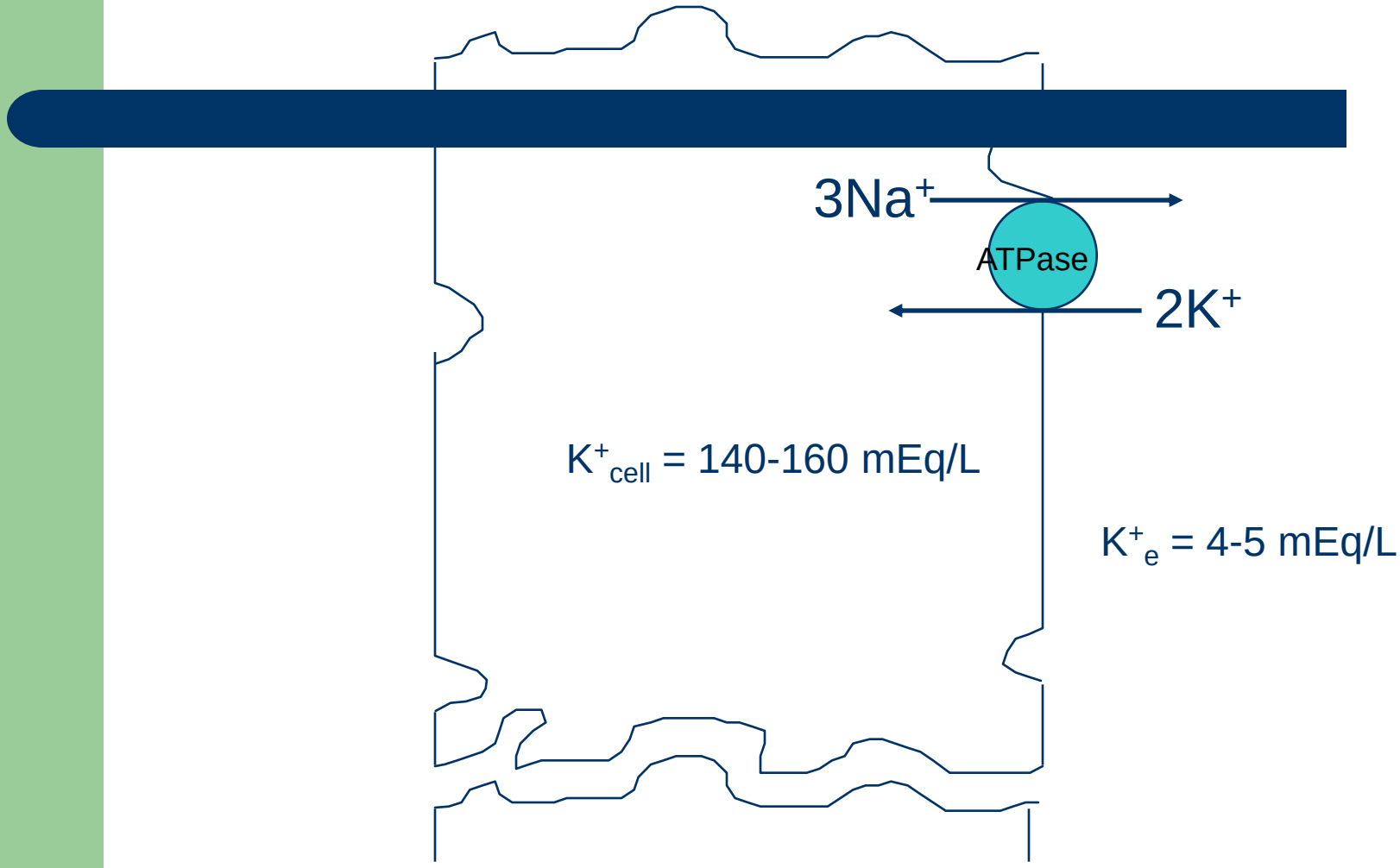
Potassium Disorders

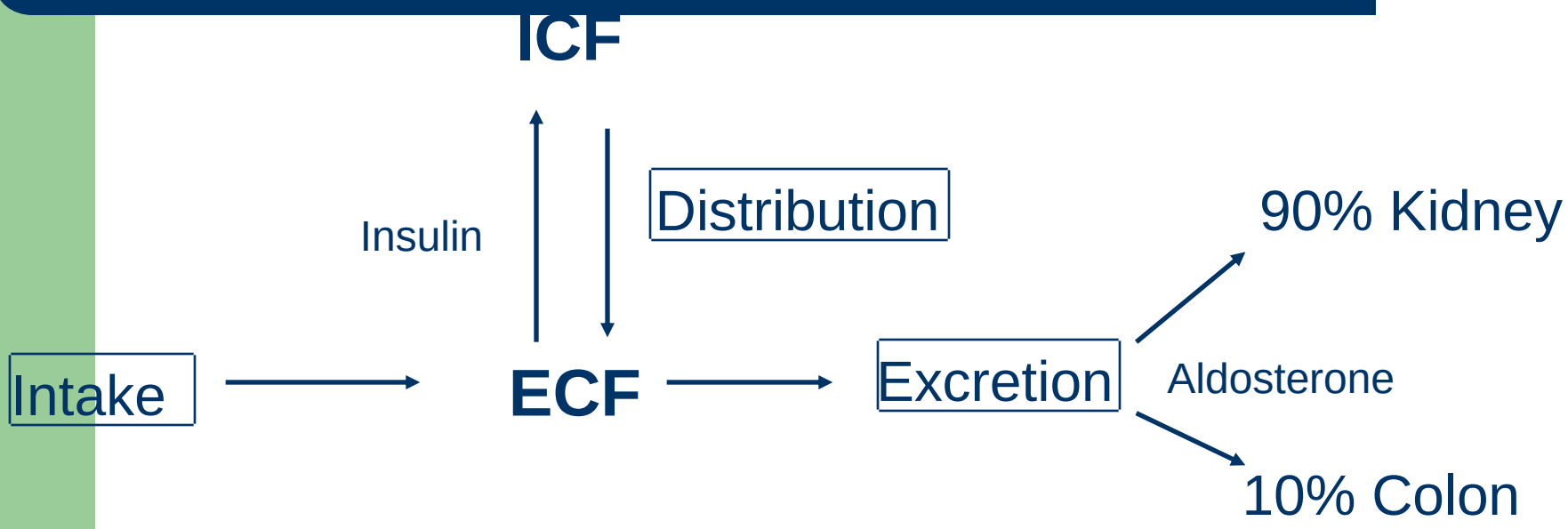
Dr.BOSHRA HASANZAMANI
www.mums.ac.ir/rsc-ktc

- plasma K^+ concentration between 3.5 and 5.0 m*M*
- potassium is excreted, approximately 90% in the urine and 10% in the stool

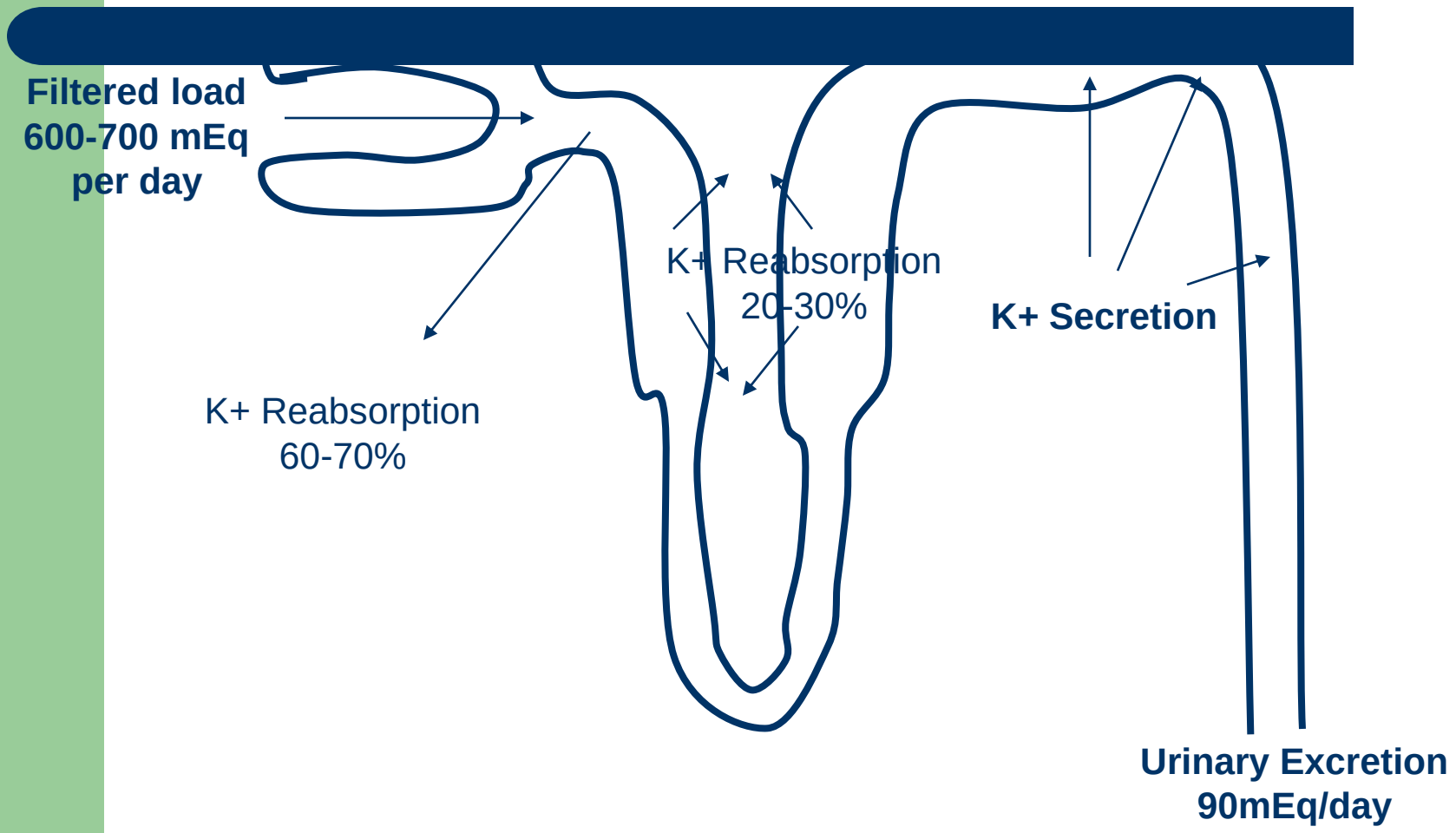
Transcellular K+ Distribution



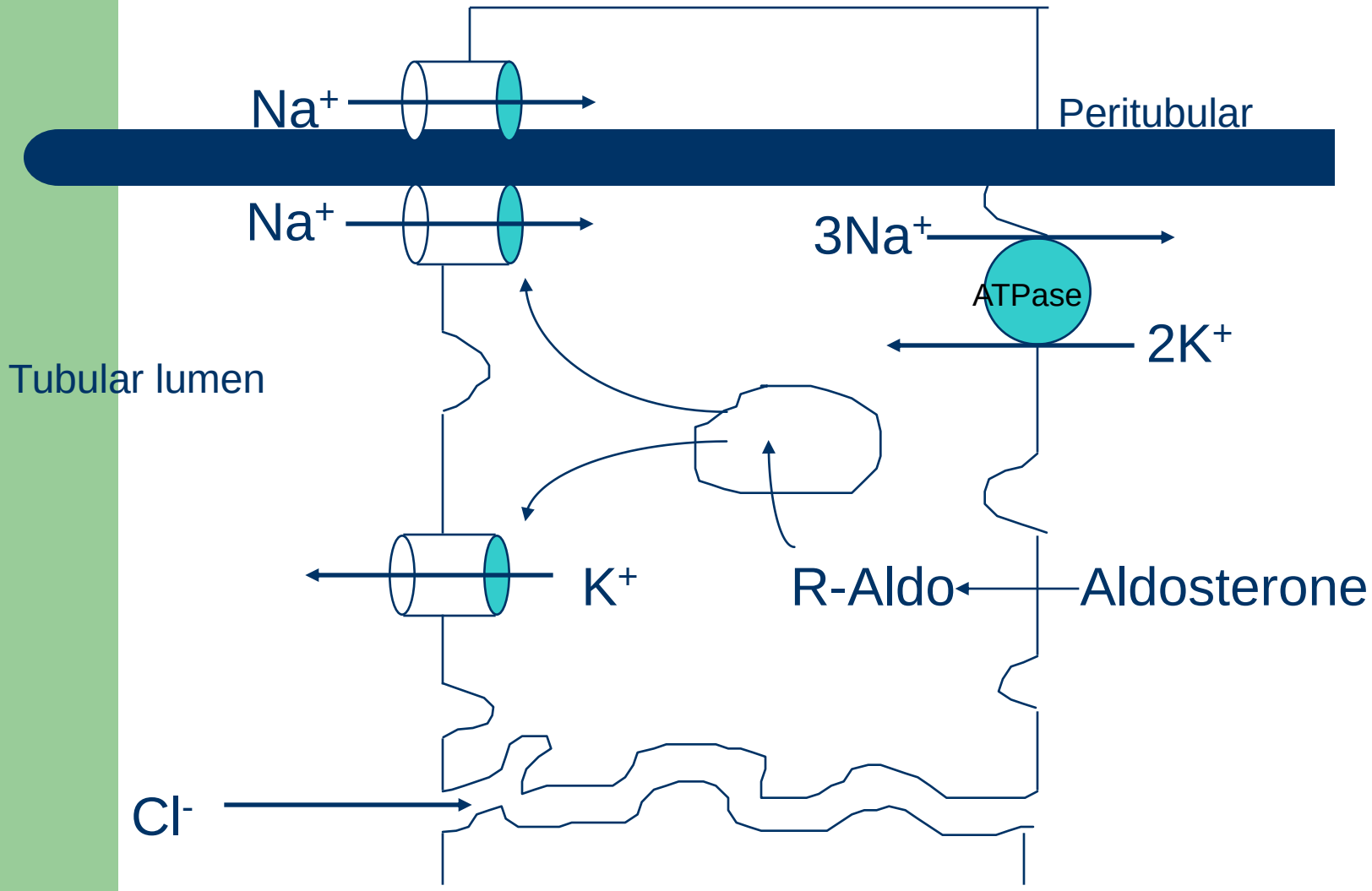
Components of Potassium Homeostasis



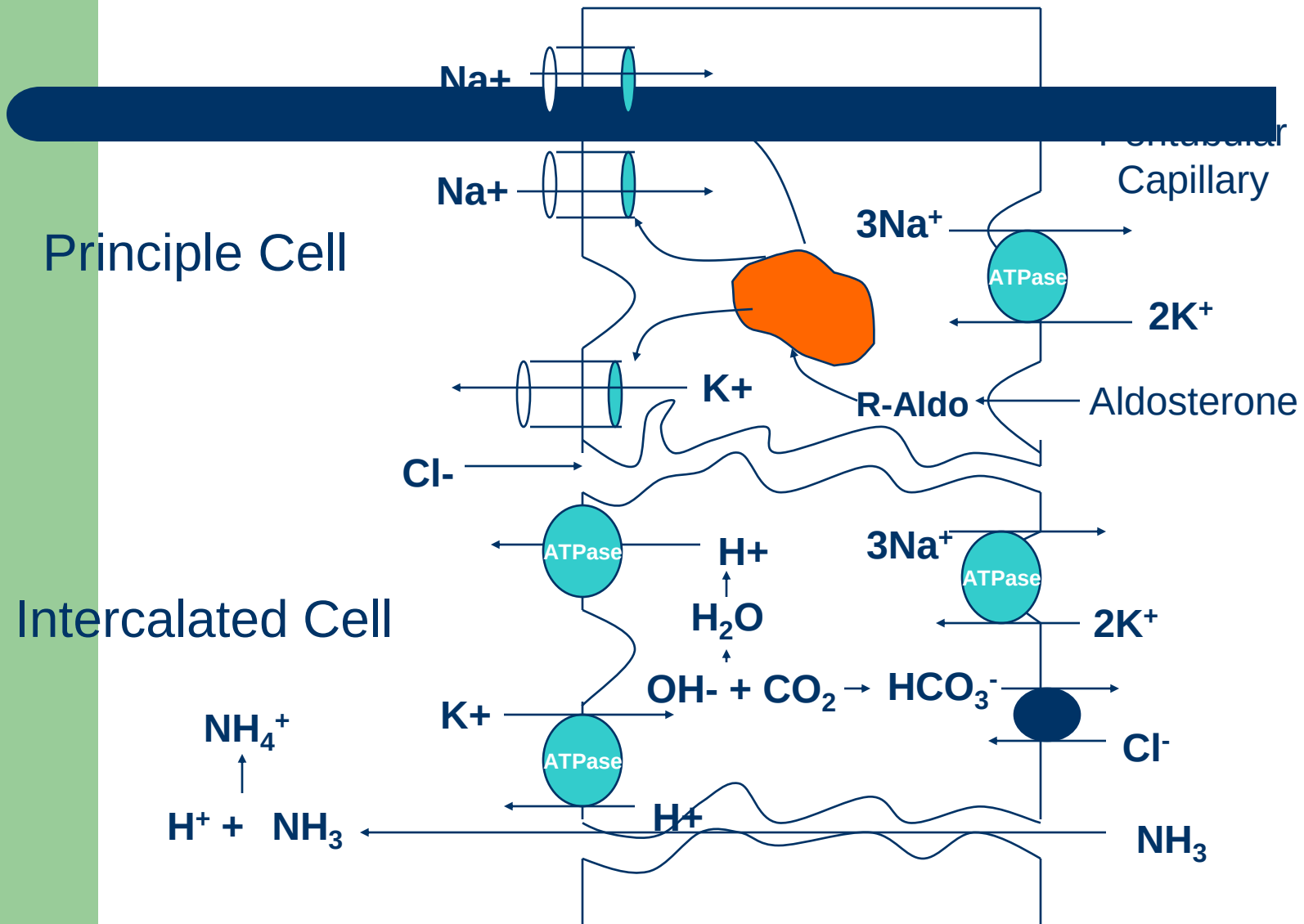
Renal Tubular Potassium Handling



Cortical Collecting Duct - Principle Cells



Cortical Collecting Duct



- principal cells of the connecting tubule (CNT) and cortical collecting duct (CD) that play a dominant role in renal K^+ secretion
- alpha-intercalated cells of the outer medullary CD function in renal tubular reabsorption of filtered K^+ in K^+-deficient states.

HYPOKALEMIA

- defined as a plasma K^+ concentration <3.6 Mm
- occurs in up to 20% of hospitalized patients

Causes of Hypokalemia

- I. Decreased intake
- II. Redistribution into cells
- III. Increased loss

Decreased intake

- A. Starvation
- B. Clay ingestion

Redistribution into cells

- A. Acid-base
  1. Metabolic alkalosis
- B. Hormonal
  1. Insulin
  2. Increased ß $_2$-adrenergic sympathetic activity: post-myocardial infarction, head injury
  3. ß$_2$-Adrenergic agonists: bronchodilators, tocolytic
  4. α -Adrenergic antagonists
  5. Thyrotoxic periodic paralysis
  6. Downstream stimulation of Na^+/K^+-ATPase: theophylline, caffeine

Redistribution into cells

- C. Anabolic state

  1. Vitamin B12 or folic acid administration (red blood cell production)

  2. Granulocyte-macrophage colony-stimulating factor (white blood cell production)

  3. Total parenteral nutrition

Redistribution into cells

- D. Other
  1. Pseudohypokalemia
  2. Hypothermia
  3. Familial hypokalemic periodic paralysis
  4. Barium toxicity: systemic inhibition of "leak

Increased loss

- A. Nonrenal

1. Gastrointestinal loss (diarrhea)
2. Integumentary loss (sweat)

- B. Renal

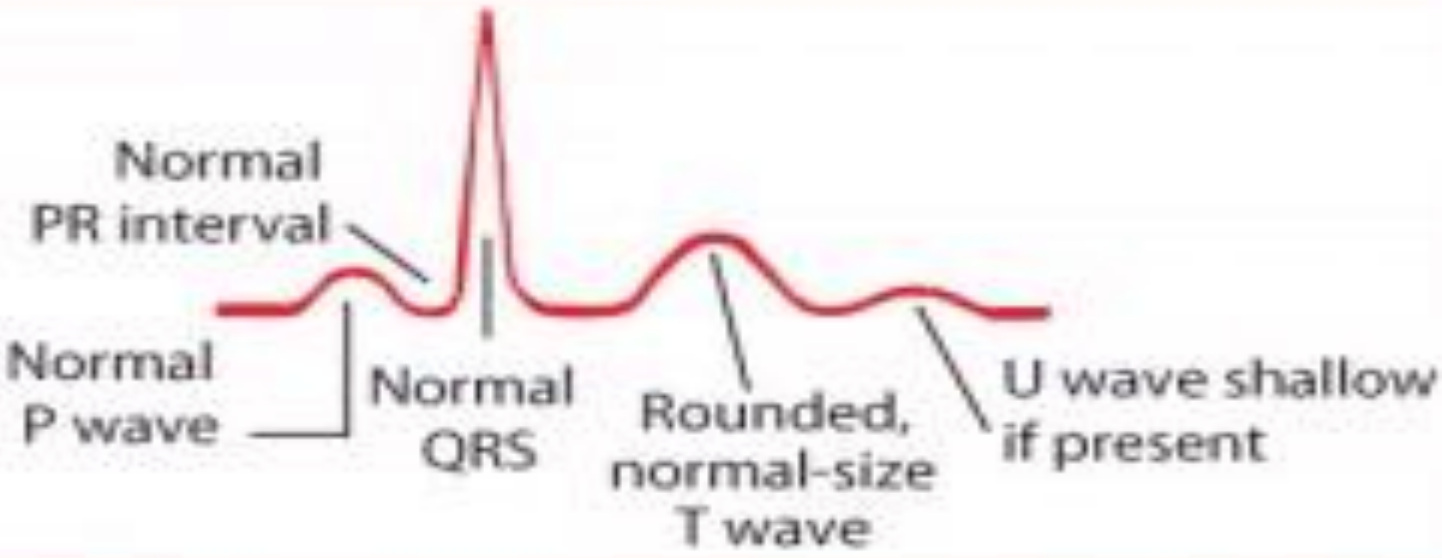
1. Increased distal flow and distal Na^+ delivery
2. Increased secretion of potassium
3. Magnesium deficiency

Clinical Features

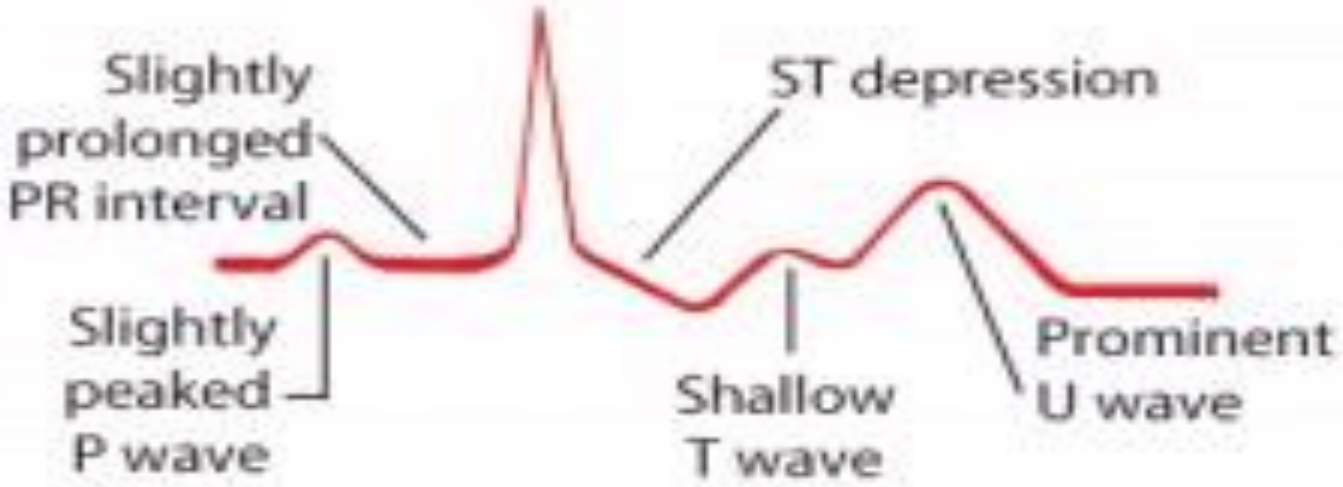
- prominent effects on cardiac, skeletal, and intestinal muscle cells
- risk factor for both ventricular and atrial arrhythmias
- Electrocardiographic changes in hypokalemia include :

  - broad flat T waves, ST depression, and QT prolongation
- these are most marked when serum K^+ is <2.7 mmol/L

Normokalemia



Hypokalemia



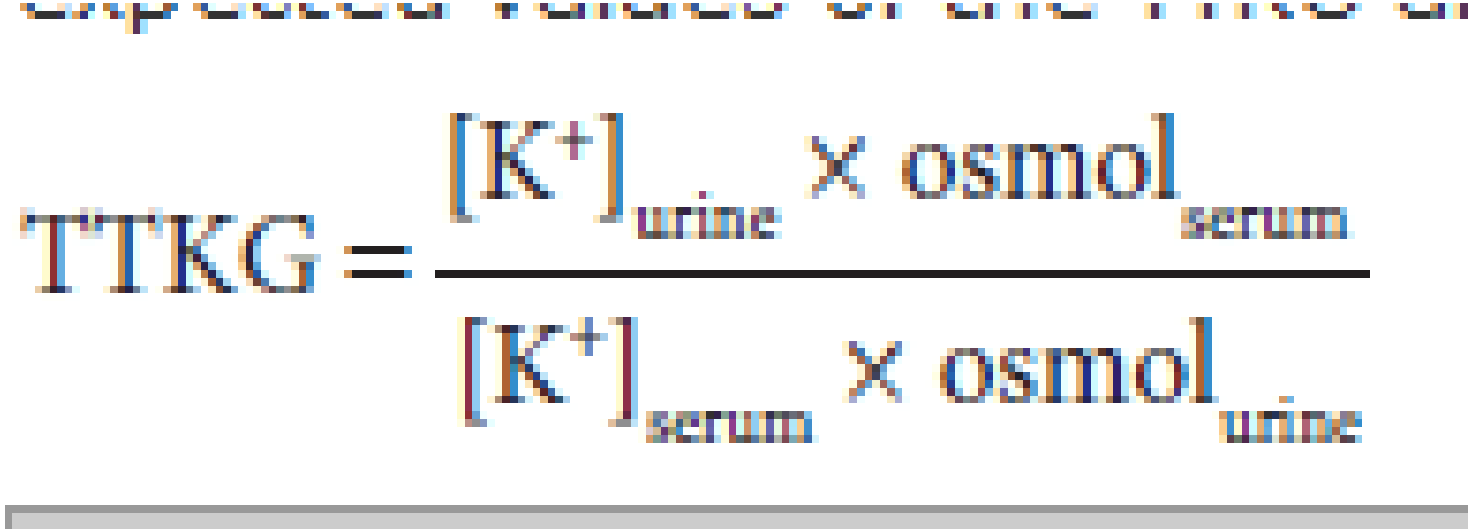
- skeletal muscle :
  - weakness and even paralysis
  - skeletal myopathy and predisposes to rhabdomyolysis
- on intestinal smooth muscle may cause intestinal ileus.

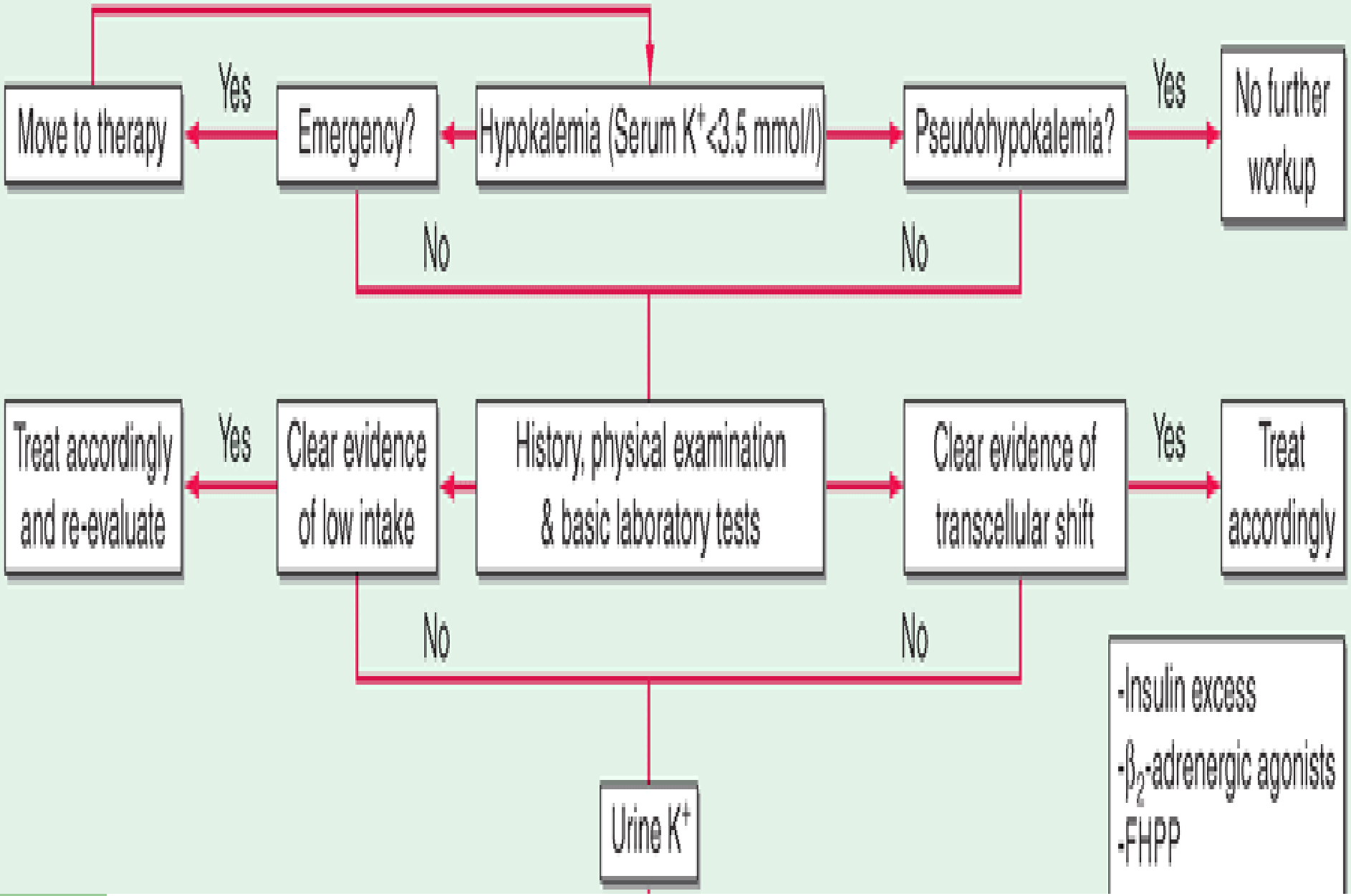
functional effects of hypokalemia on the kidney

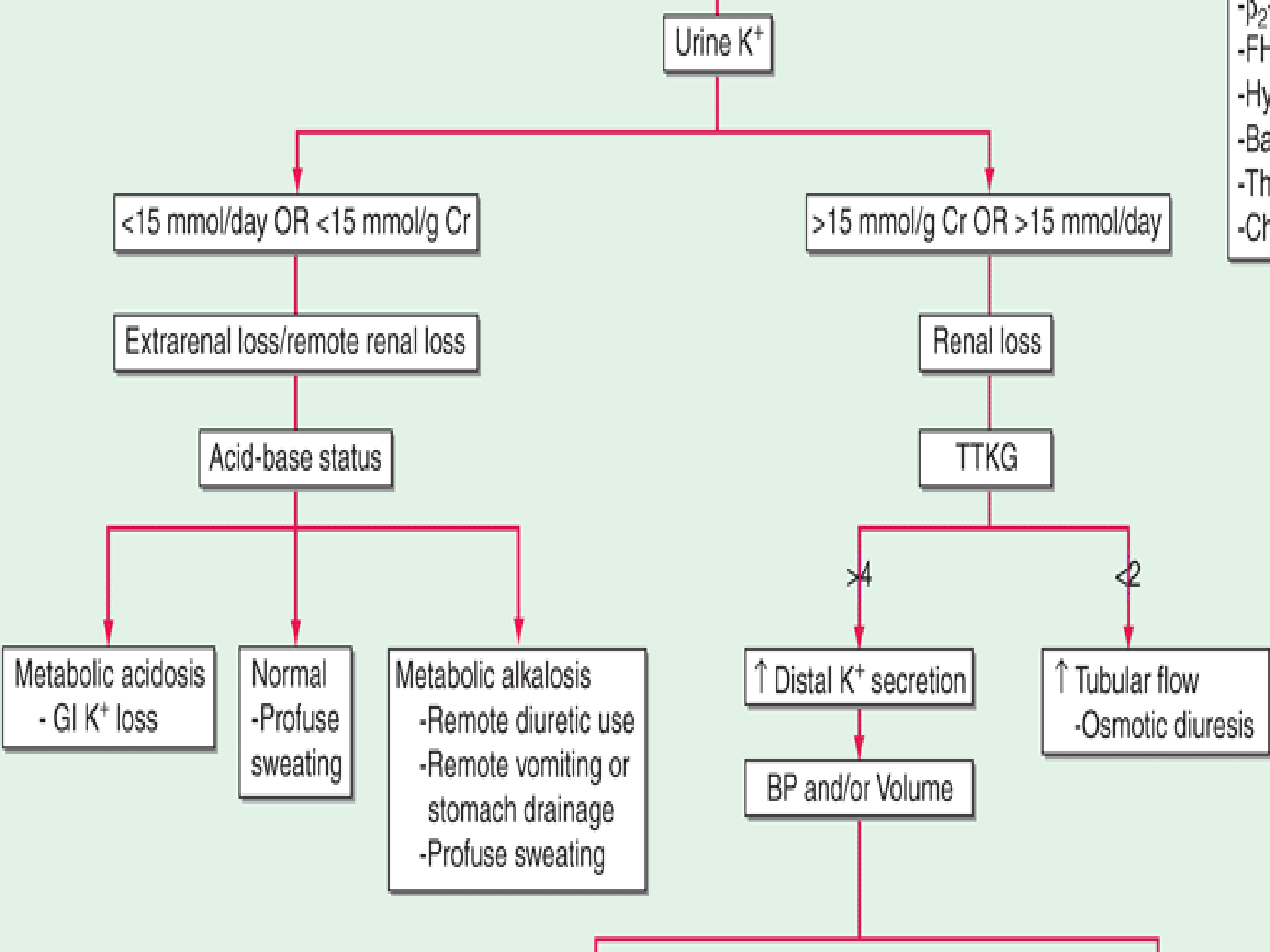
- Na^{+}-Cl^{-} and HCO_3^{-} retention
- polyuria
- Phosphaturia
- hypocitraturia
- activation of renal ammoniagenesis

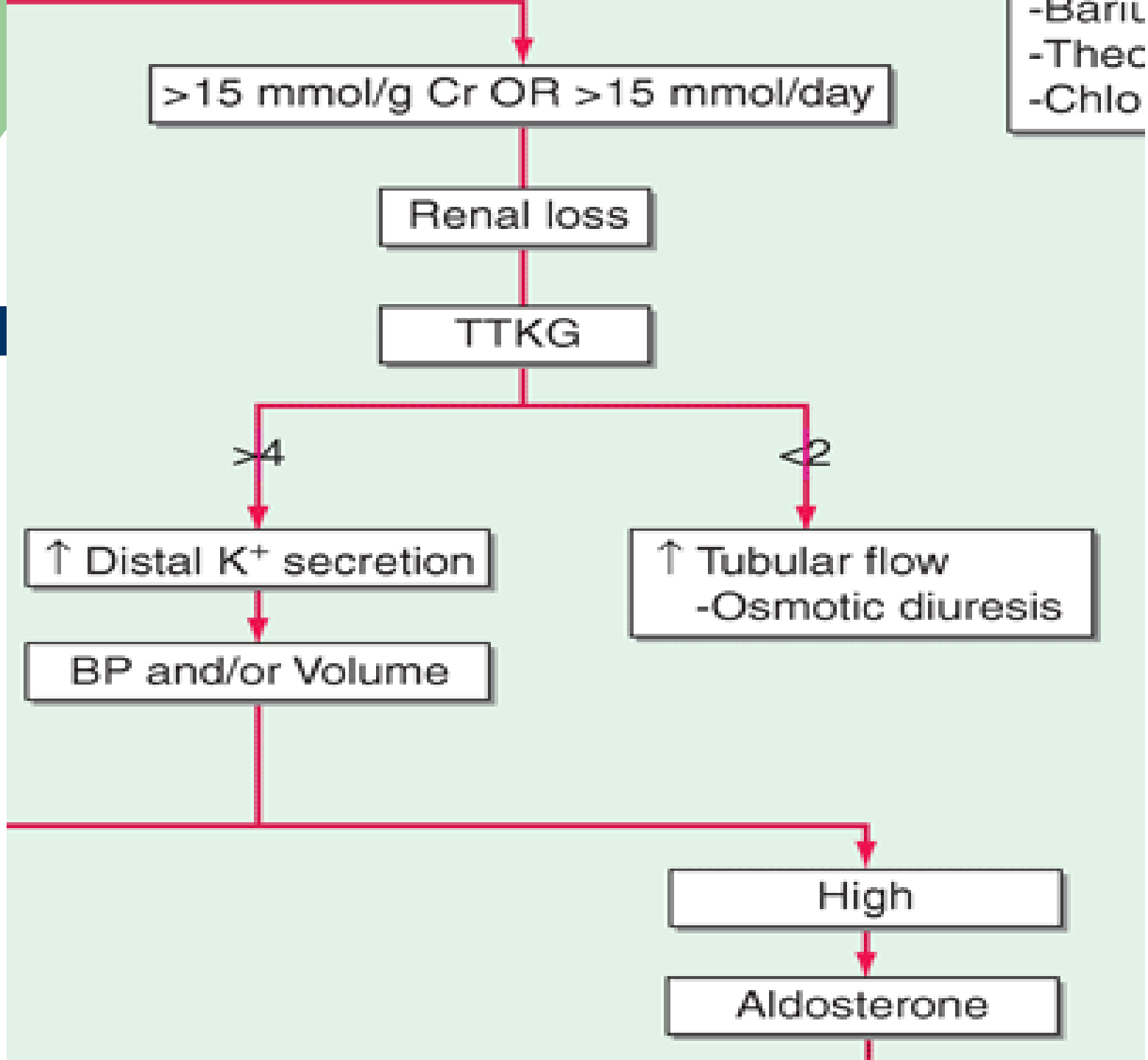
Structural changes in the kidney due to hypokalemia

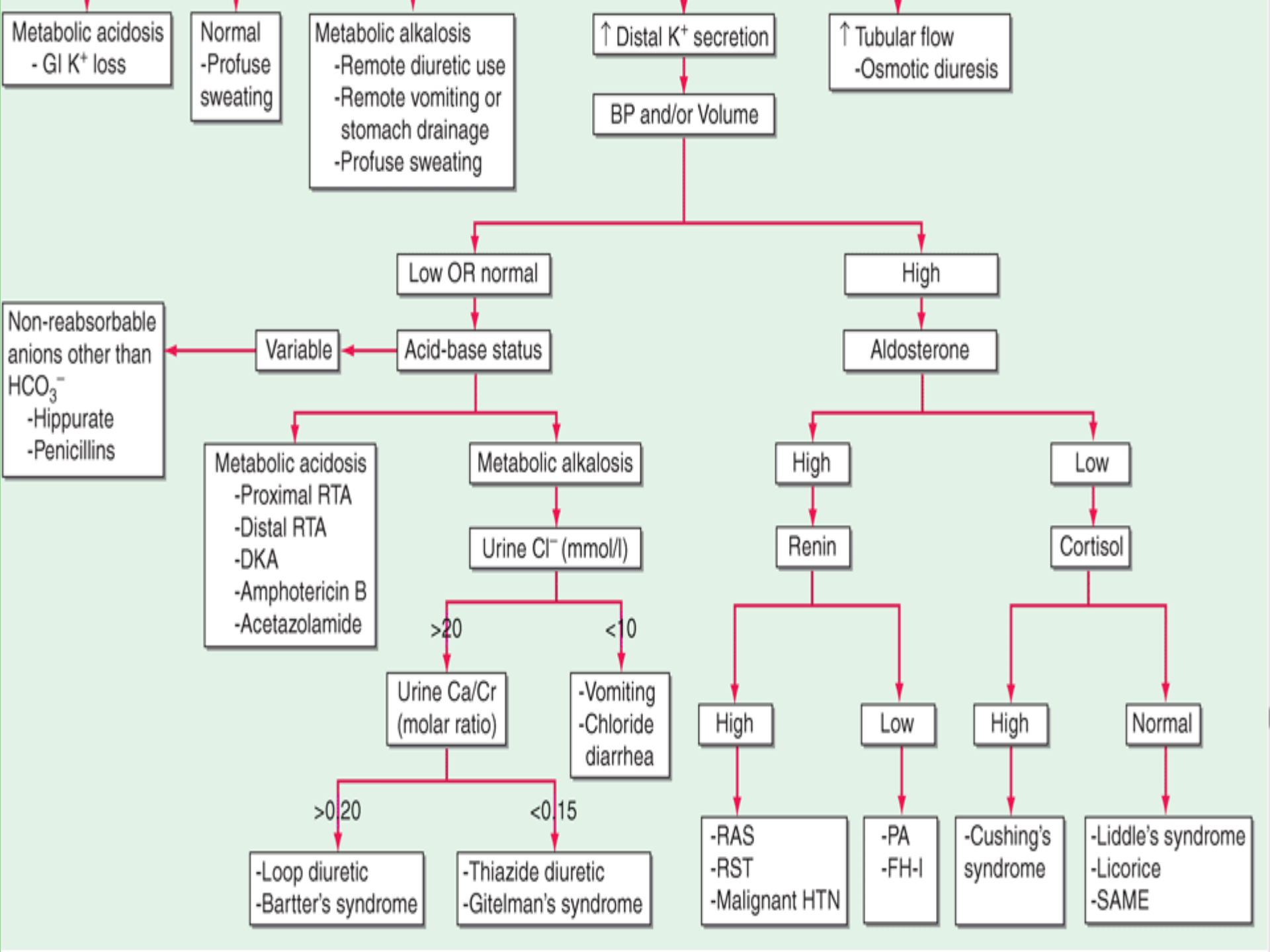
- vacuolizing injury to proximal tubular cells
- interstitial nephritis
- renal cysts
- predisposes to acute kidney injury and ESRD


TTKG = [K+]urine x osmolserum / [K+]serum x osmolurine


Hypokalemia (Serum K+<3.5 mmol/l)
Pseudohypokalemia?
Yes
No further workup
No
Emergency?
Yes
Move to therapy
History, physical examination & basic laboratory tests
Clear evidence of transcellular shift
Yes
Treat accordingly
No
Clear evidence of low intake
Yes
Treat accordingly and re-evaluate
No
Urine K+
-Insulin excess
-β2-adrenergic agonists
-FHPP


Urine K+
<15 mmol/day OR <15 mmol/g Cr
>15 mmol/g Cr OR >15 mmol/day
Extrarenal loss/remote renal loss
Renal loss
Acid-base status
TTKG
>4
<2
Metabolic acidosis
- GI K+ loss
Normal
-Profuse sweating
Metabolic alkalosis
-Remote diuretic use
-Remote vomiting or stomach drainage
-Profuse sweating
↑ Distal K+ secretion
↑ Tubular flow
-Osmotic diuresis
BP and/or Volume


-Barit
-Thec
-Chlo
>15 mmol/g Cr OR >15 mmol/day
Renal loss
TTKG
>4
<2
↑ Distal K+ secretion
↑ Tubular flow
-Osmotic diuresis
BP and/or Volume
High
Aldosterone


Metabolic acidosis
- GI K^+ loss
Normal
-Profuse sweating
Metabolic alkalosis
-Remote diuretic use
-Remote vomiting or stomach drainage
-Profuse sweating
↑ Distal K^+ secretion
↑ Tubular flow
-Osmotic diuresis
BP and/or Volume
Low OR normal
High
Non-reabsorbable anions other than HCO_3^-
-Hippurate
-Penicillins
Variable
Acid-base status
Aldosterone
Metabolic acidosis
-Proximal RTA
-Distal RTA
-DKA
-Amphotericin B
-Acetazolamide
Metabolic alkalosis
Urine Cl^- (mmol/l)
High
Low
Renin
Cortisol
>20
<10
Urine Ca/Cr (molar ratio)
-Vomiting
-Chloride diarrhea
High
Low
High
Normal
>0.20
<0.15
-Loop diuretic
-Bartter's syndrome
-Thiazide diuretic
-Gitelman's syndrome
-RAS
-RST
-Malignant HTN
-PA
-FH-I
-Cushing's syndrome
-Liddle's syndrome
-Licorice
-SAME

Hyperkalemia

- plasma potassium level of 5.5 Mm
- decrease in renal K^+ excretion is the most common underlying cause in up to 10% of hospitalized patients

Causes of Hyperkalemia

- I. "Pseudo" hyperkalemia
- II. Intra- to extracellular shift
- III. Inadequate excretion

Pseudo" hyperkalemia

- A. Cellular efflux: thrombocytosis, erythrocytosis, leukocytosis, in vitro hemolysis
- B. Hereditary defects in red cell membrane transport

Intra- to extracellular shift

- A. Acidosis
- B. Hyperosmolality; radiocontrast, hypertonic dextrose, mannitol
- C. ß-adrenergic antagonists
- D. Hyperkalemic periodic paralysis

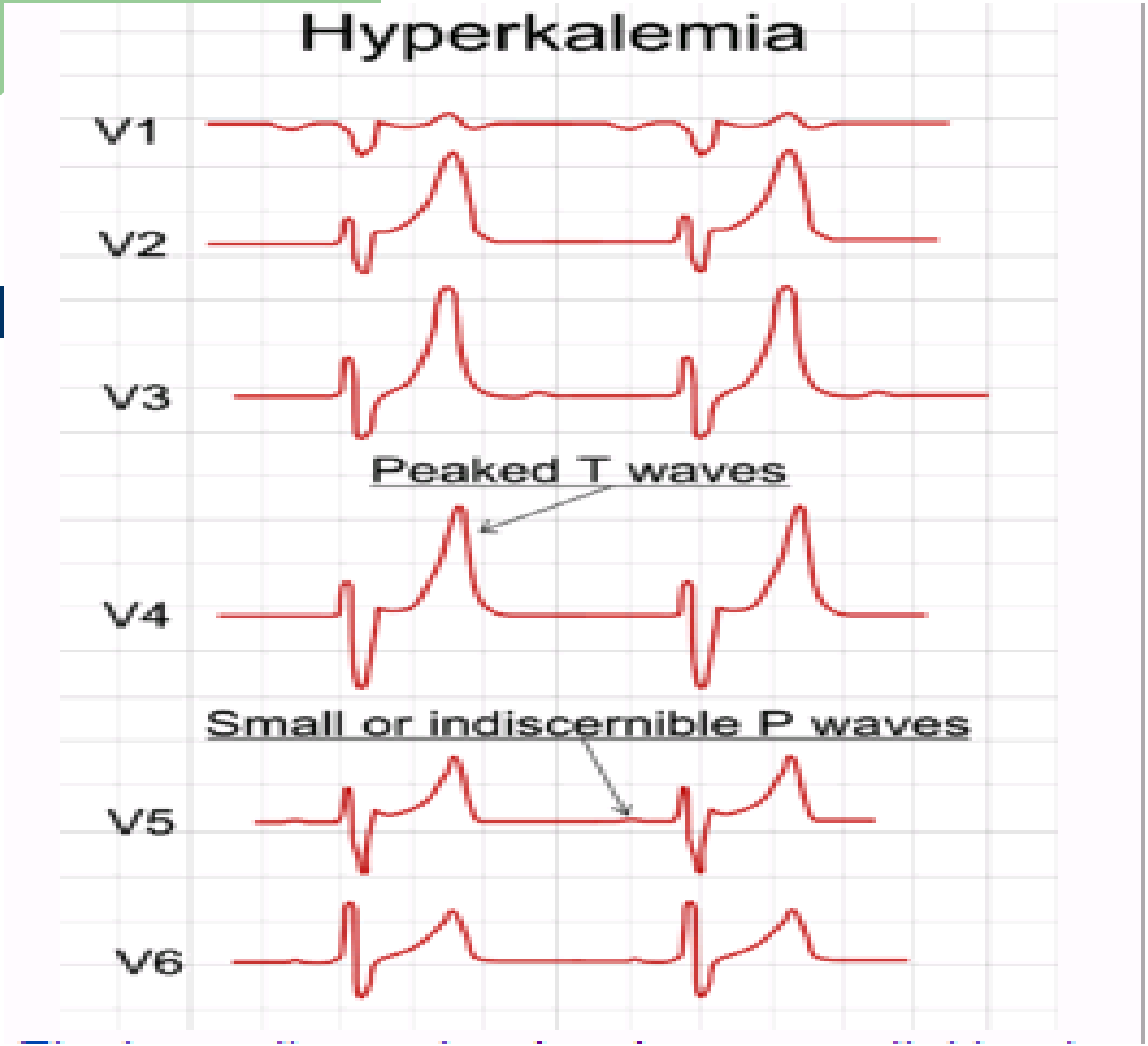
Inadequate excretion

- A. Inhibition of the renin-angiotensin-aldosterone axis
- B. Decreased distal delivery
- C. Hyporeninemic hypoaldosteronism
- D. Renal resistance to mineralocorticoid
- E. Advanced renal insufficiency
- F. Primary adrenal insufficiency

Clinical Features

- Cardiac arrhythmias
- changes in T-wave morphology
- prolongation of the PR and QRS intervals
- loss of the P wave
- widening of the QRS complex
- development of a sine-wave

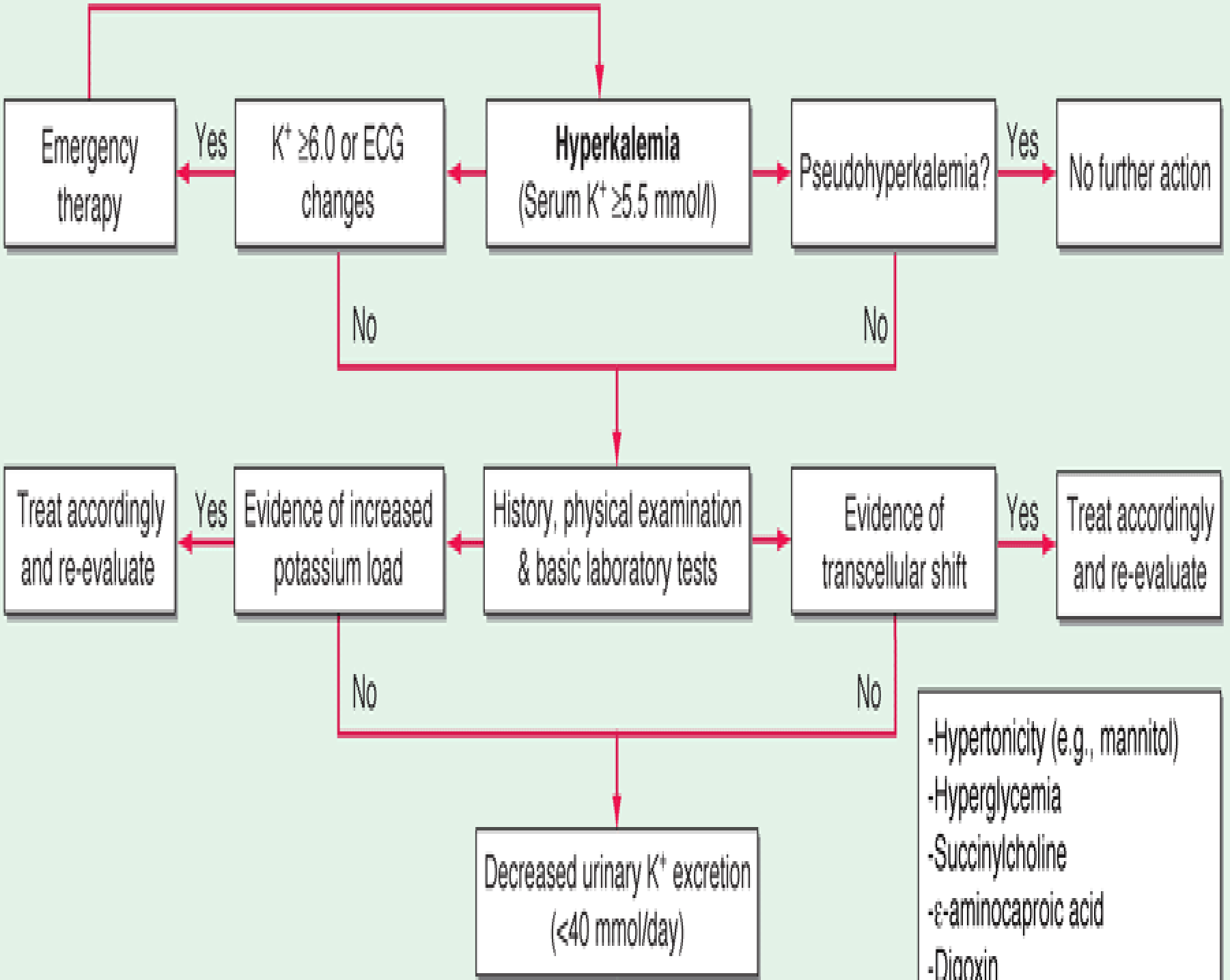
- tall peaked T waves (5.5–6.5 m*M*)
- loss of P waves (6.5–7.5 m*M*)
- widened QRS complex (7–8 m*M*)
- sine wave pattern (8 m*M*)

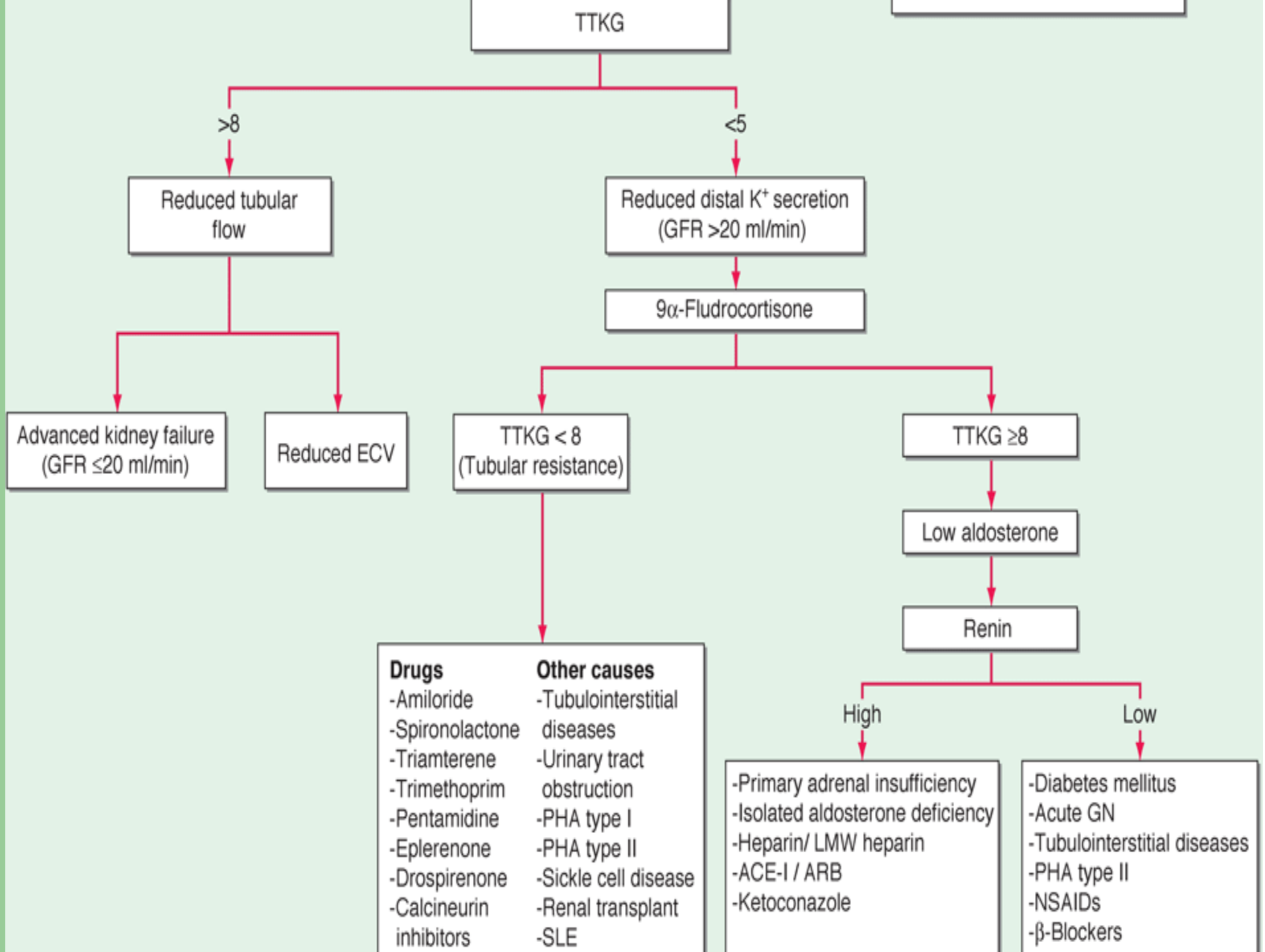

Hyperkalemia
V1
V2
V3
Peaked T waves
V4
Small or indiscernible P waves
V5
V6

Clinical Features

- ascending paralysis
- hyperkalemia per se can contribute to metabolic acidosis

DIAGNOSTIC APPROACH


Hyperkalemia
(Serum K+ ≥5.5 mmol/l)
Pseudohyperkalemia?
Yes
No further action
No
K+ ≥6.0 or ECG changes
Yes
Emergency therapy
History, physical examination & basic laboratory tests
Evidence of transcellular shift
Yes
Treat accordingly and re-evaluate
No
Evidence of increased potassium load
Yes
Treat accordingly and re-evaluate
No
Decreased urinary K+ excretion
(<40 mmol/day)
-Hypertonicity (e.g., mannitol)
-Hyperglycemia
-Succinylcholine
-ε-aminocaproic acid
-Digoxin


TTKG
>8
<5
Reduced tubular flow
Reduced distal K+ secretion (GFR >20 ml/min)
9α-Fludrocortisone
Advanced kidney failure (GFR ≤20 ml/min)
Reduced ECV
TTKG < 8 (Tubular resistance)
TTKG ≥8
Low aldosterone
Renin
High
Low
Drugs
-Amiloride
-Spironolactone
-Triamterene
-Trimethoprim
-Pentamidine
-Eplerenone
-Drospirenone
-Calcineurin inhibitors
Other causes
-Tubulointerstitial diseases
-Urinary tract obstruction
-PHA type I
-PHA type II
-Sickle cell disease
-Renal transplant
-SLE
-Primary adrenal insufficiency
-Isolated aldosterone deficiency
-Heparin/ LMW heparin
-ACE-I / ARB
-Ketoconazole
-Diabetes mellitus
-Acute GN
-Tubulointerstitial diseases
-PHA type II
-NSAIDs
-β-Blockers