Potassium Disorders

Normal Potassium Balance

100 mEq K+

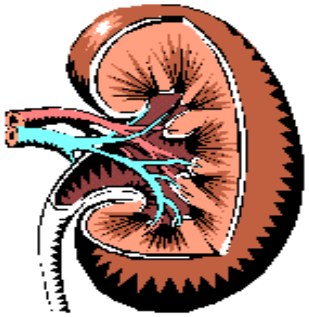
RBC
~250

Extracellular fluid
65 mEq

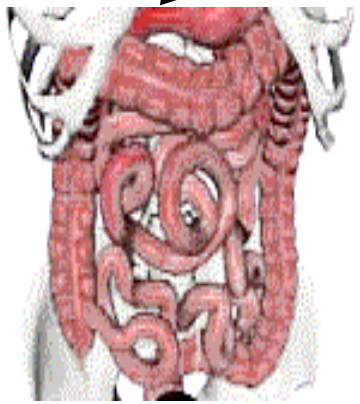
Muscle
~2500

Liver
~250

Bone
~500



90-95
mEq



5-10 mEq

Extra-renal K^+ Homeostasis: Shift/Redistribution

- **4 major factors: -**
  - Hormones
  - Acid base status
  - Plasma tonicity
  - Plasma $[K^+]$

B

Acute	
Factor	Effect on potassium
Insulin	Enhanced cell uptake
β-Catecholamines	Enhanced cell uptake
α-Catecholamines	Impaired cell uptake
Acidosis	Impaired cell uptake
Alkalosis	Enhanced cell uptake
External potassium balance	Loose correlation
Cell damage	Impaired cell uptake
Hyperosmolality	Enhanced cell efflux

Chronic	
Factor	Effect on ATP pump density
Thyroid	Enhanced
Adrenal steroids	Enhanced
Exercise (training)	Enhanced
Growth	Enhanced
Diabetes	Impaired
Potassium deficiency	Impaired
Chronic renal failure	Impaired

Mineralocorticoids (Aldosterone):-

- Produced by Zonae Glomerulosa of the Adrenal cortex :-
- Release stimulated by:-
  - Activation of Renin/Angiotensin system:-
    - Volume sensors, JGA etc.
  - Direct effect of K^+ on adrenal.
- Effects of Aldosterone:-
  - Exchange of Na^+ for K^+ or H^+ with net loss of K^+ and gain of sodium.

Mineralocorticoids (Aldosterone):-

- **Sites of action:**
  - Distal renal tubule
  - Colon
  - Sweat Glands
- **In renal failure, the colon is an important site for K^+ regulation**
- **Cortisol has mineralocorticoid activity**

Acid/Base

- **Metabolic Acidosis ↑ [K+]: -**
  - Inhibition of renal tubular K^+ secretion
  - Shift of K^+ from ICF to ECF

- **Metabolic Alkalosis ↓ [K^+]**

ECF [K^+] depends upon:

Intake

Redistribution: ECF and ICF

- –Hormones
- –Acid base status
- –Plasma tonicity
- –Plasma [K^+]

Output

Kidney

Sweat glands

Gut (colon)

Renal Handling of K^+

600 mmol/day

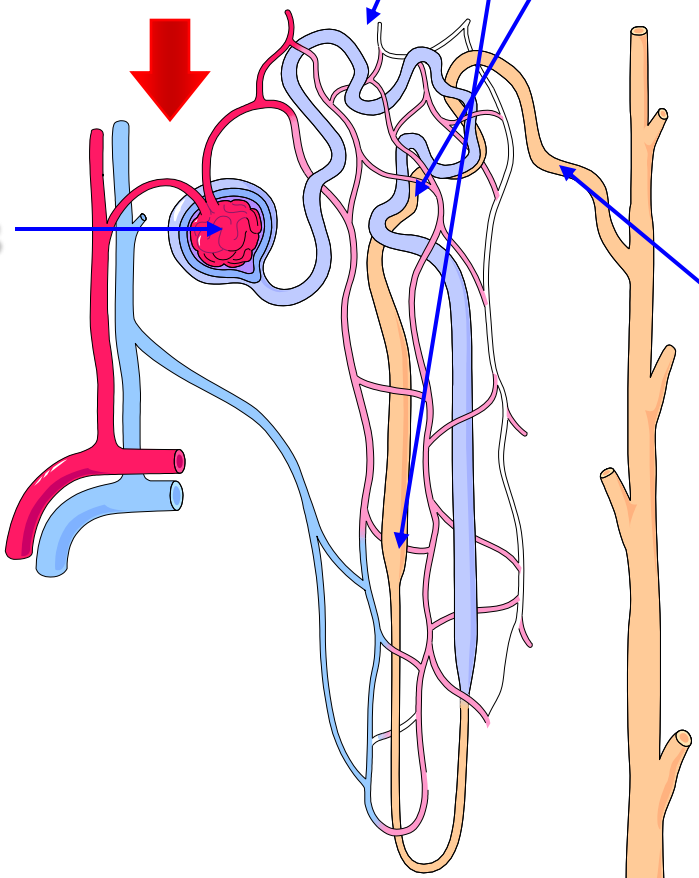
K^+ Filtered

Proximal Tubule (60-70%)

Ascending Loop of Henle (20-30%)

Distal tubule: 10% remaining

100% K^+ Reabsorbed



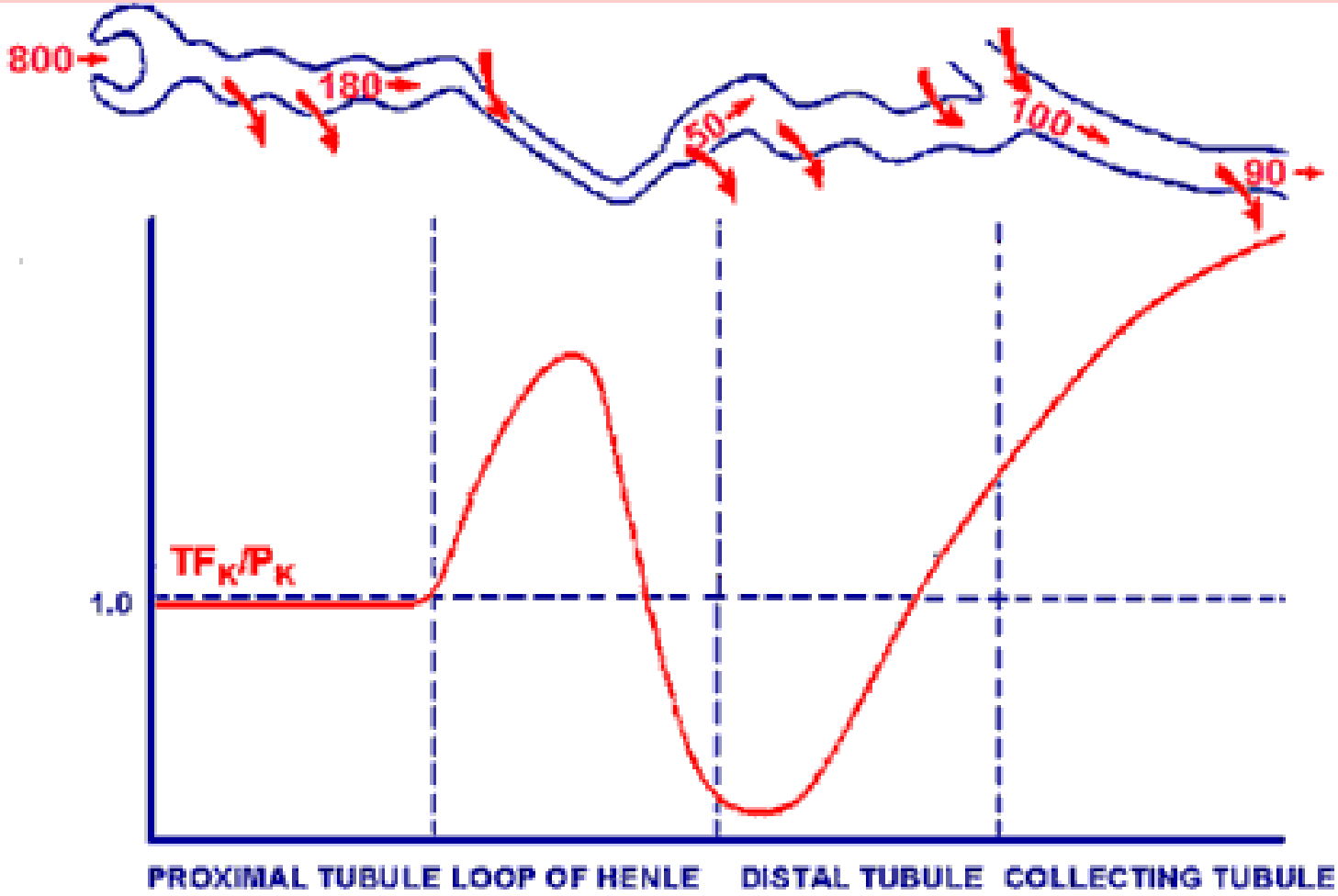
Glomerulus

Renal artery

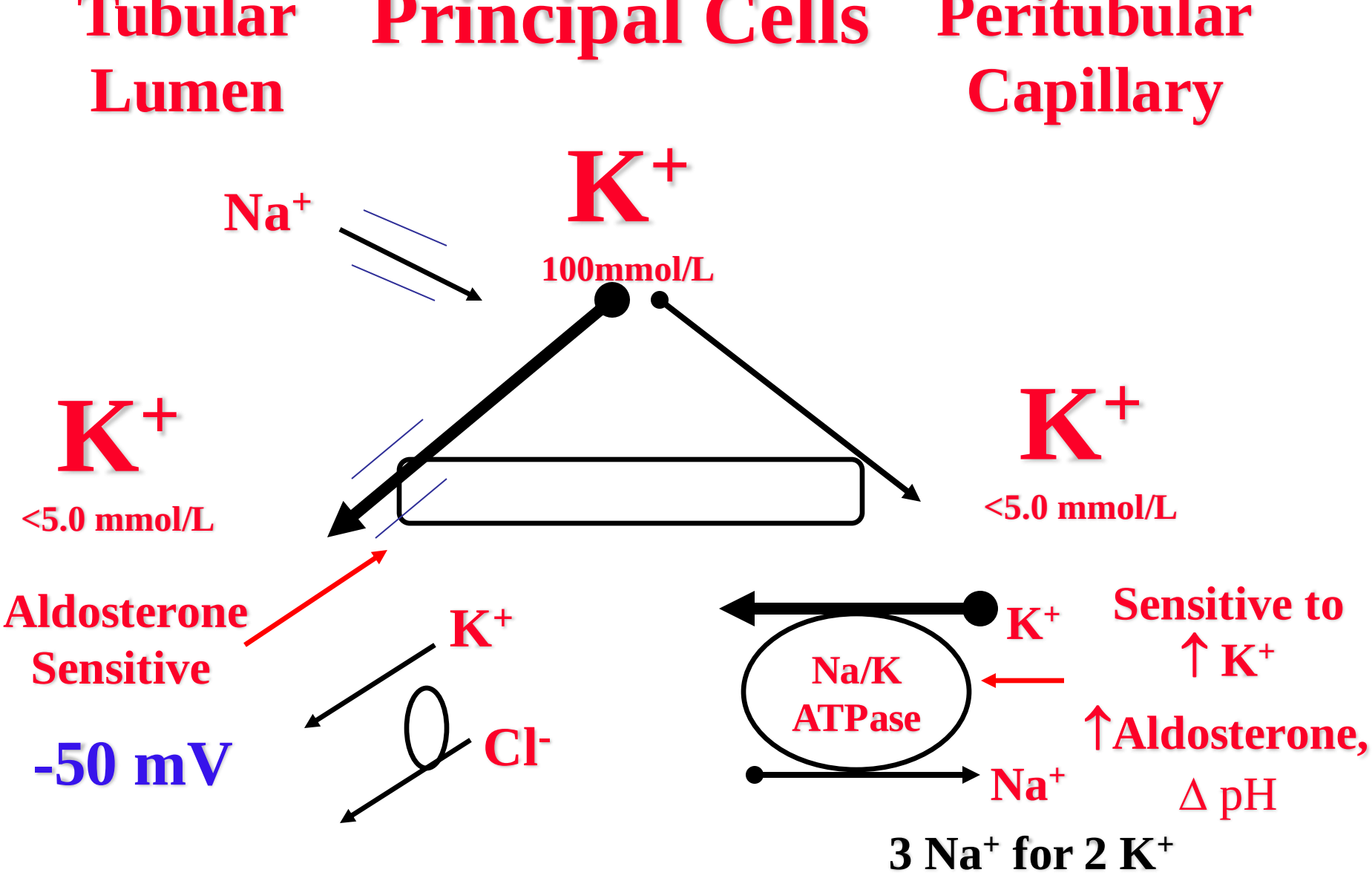
Distal Tubule = Fine tuning. Aldosterone K^+/H^+ for Na^+

100 mmol/day K^+ excreted (10-20%)

TUBULAR TRANSPORT OF POTASSIUM



- 60-65% of filtered K is reabsorbed in the proximal tubule without a change in concentration. An additional 25% is reabsorbed in the loop of Henle and distal tubule. A countercurrent gradient is established.
- K is secreted by the late distal tubule and collecting tubule. Secretion accounts for almost all of the K that is excreted.

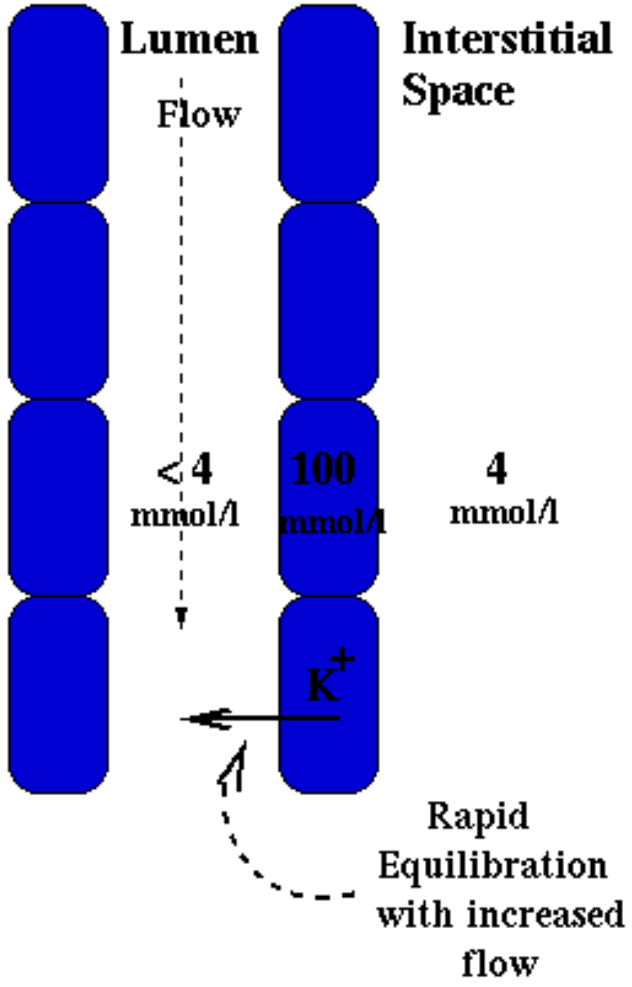

Tubular Lumen
Principal Cells
Peritubular Capillary
Na+
K+
100mmol/L
K+
<5.0 mmol/L
K+
<5.0 mmol/L
Aldosterone Sensitive
-50 mV
K+
Cl-
Na/K ATPase
K+
Na+
Sensitive to ↑ K+
↑Aldosterone, Δ pH
3 Na+ for 2 K+

Factors favouring K+ secretion

- **Increased Na^+ reabsorption**
  - Exchange
- **Increased intra-cellular K^+**
  - Concentration gradient
- **Decreased H^+ secretion.**
  - Aldosterone
  - Electrochemical gradient.

Increased fluid delivery to lumen causes increased K+ excretion: -

- Wash out.
  - diuretics
  - poorly absorbed anions
  - osmotic diuresis

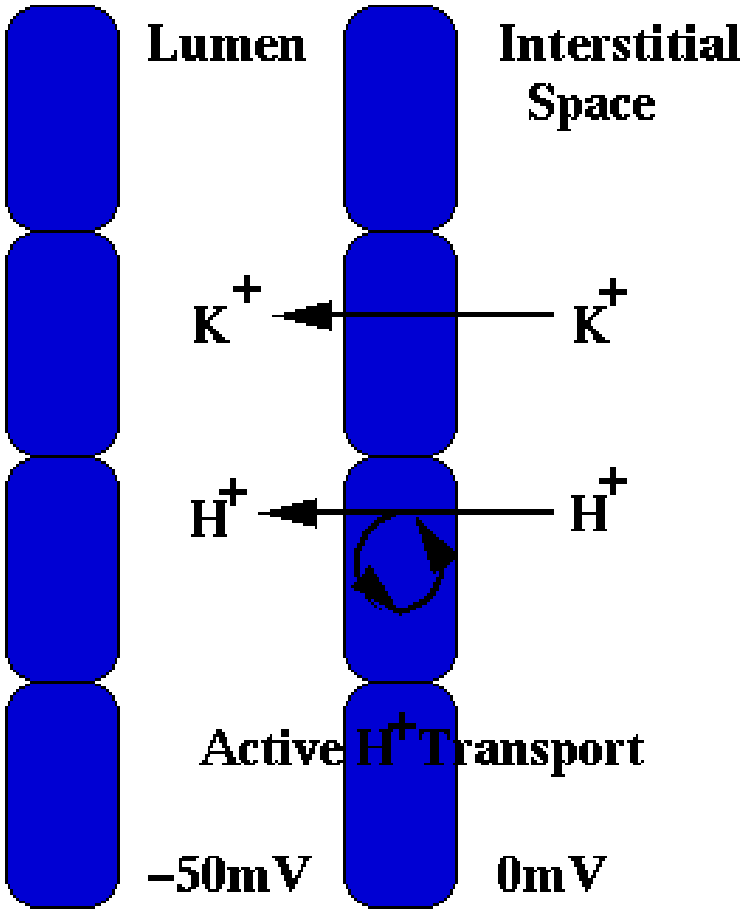


Electrochemical Gradient: -

- Distal tubule actively secretes H^+
- K^+ and H^+ are neutralising the same electrical gradient

Acidosis Causing

Hyper-kalaemia



Etiology of Hyperkalemia

- Increased intake
- Movement from cells into extracellular fluid
- Decreased urinary excretion
- Combinations of above

Movement from cells into ECF

- Pseudohyperkalemia
  - Movement of K+ out of cells during or after blood drawing
    - Hemolysis
    - Fist clenching (local exercise effect)
    - Marked leukocytosis
- Metabolic acidosis – non organic acids
- Insulin deficiency
- Hyperosmolality
- Beta blockade

Movement from cells into extracellular fluid

- Tissue catabolism
  - Trauma
  - Cytotoxic agents (TLS)
  - Severe hypothermia
- Severe exercise
- Digitalis overdose
- Hyperkalemic periodic paralysis
- Post cardiac surgery
- Succinylcholine

Hypoaldosteronism

- Decreased activity of renin-angiotensin system
  - Hyporeninemic hypoaldosteronism (T4 RTA)
  - NSAIDS, ACE-I, CSA
- Primary decrease in adrenal synthesis
  - Adrenal insufficiency, CAH, heparin
- Aldosterone resistance
  - K+sparing diuretics, trimethoprim, CSA
  - pseudohypoaldosteronism

Hyperkalaemia

Factitious

- Improper collection
- Haematological disorders

Increased input

- Oral
- IV therapy

Altered distribution

- Acidemia
- insulin deficiency
- Crush Injury or haemolysis

Reduced excretion

- Renal Failure
- Mineralocorticoid deficiency (Addison's)
- Tubular defects

Drugs

- Potassium sparing diuretics (spiranolactone)
- Inappropriate use of K supplements with above

Hyperkalaemia

Most usual causes

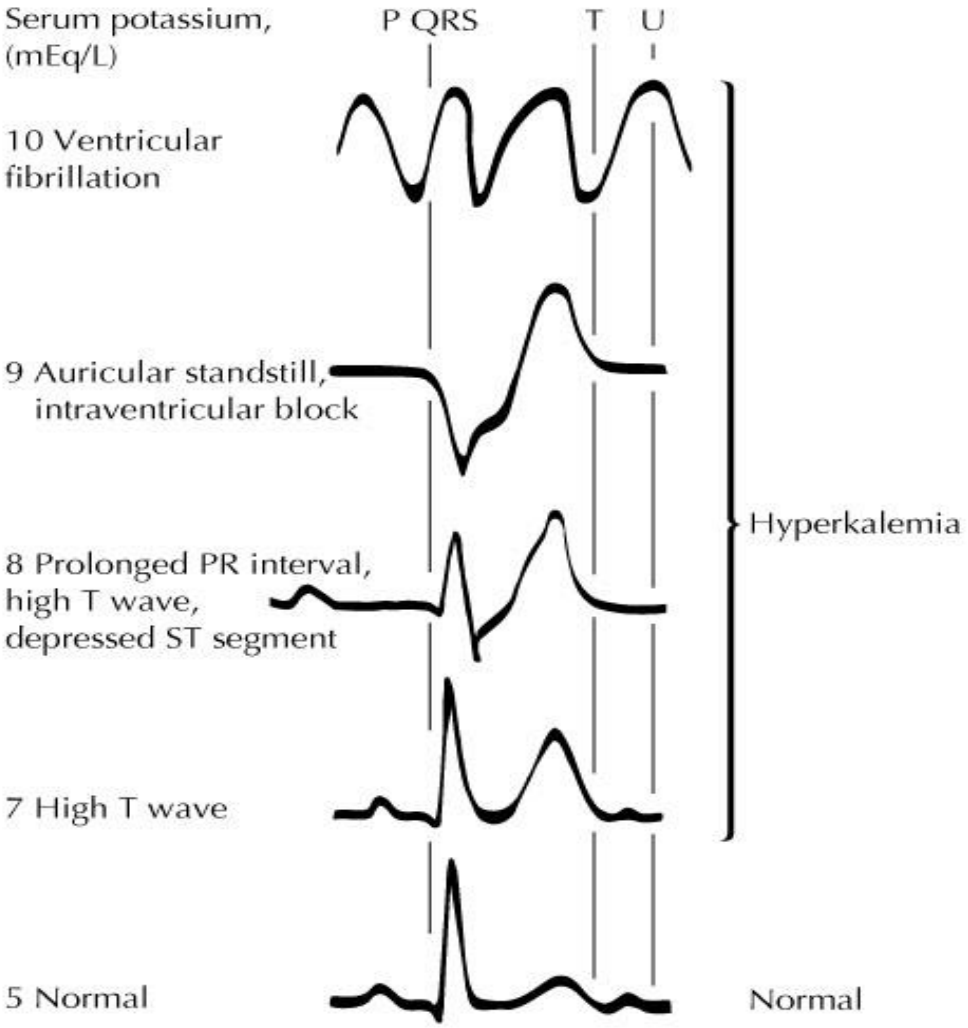
- Decreased renal function
- Redistribution secondary to acidosis

Consequences of Hyperkalaemia

- Neuromuscular - Weakness, parasthesia, paralysis
- Gastrointestinal - Nausea, vomiting, pain, ileus
- Cardiovascular - Conduction defects, arrhythmias, Cardiac arrest

S&S of Hyperkalemia

- Muscle weakness – decr magnitude of resting MP
- Cardiac toxicity Enhanced by :
  - Hypocalcemia
  - Acidemia
  - Hypomagnesemia
  - Rapid onset



Treatment of Acute Hyperkalemia

1) Assess urgency
2) Stabilize myocardium: Ca-Gluconate
3) Redistribute K+ from ECF to ICF:

   Insulin/D50, Albuterol (high dose), $NaHCO_3$.
4) Remove K+ from body: kayexalate,diuretics, and dialysis

Treatment of chronic hyperkalemia

- Limit intake!
  - 2 g/day
  - OTC that contain K+
- Avoid drugs that induce (NSAIDs!)
- Increase K excretion
  - Diuretics, avoid constipation, +/- kayexalate

Etiology of Hypokalemia

1) Decreased net intake
2) Increased entry into cells
3) Increased GI losses
4) Increased urinary losses
5) Increased sweat losses
6) Other losses (dialysis)

Decreased net intake

- Normal 100 mEq/d (40-120)
- Renal excretion as low as 5–20 mEq/d
- Thus, decreased intake rare cause, but increases susceptibility to hypokalemia
- Clay ingestion can bind dietary K+ in the gut reducing absorption.

Increased Entry into Cells

- Elevated extracellular pH
  - H+ released from cellular buffers
- Increased availability of insulin
- Elevated beta-adrenergic activity

Increased Entry into Cells

- Periodic paralysis:
  - Familial, autosomal dominant, onset up to 30 yo, severe.
  - Acquired with thyrotoxicosis (Asian men)
  - Episodes precipitated by:
    - Rest post-exercise
    - Carbohydrate meal
    - Stress, cold
    - Administration of insulin or epinephrine
  - Sudden movement of K+ into cells, acute decrease in [K+]
  - Plasma [K+] is normal between attacks

Increased GI losses

- Vomiting
- Diarrhea
- Intestinal fistulas
- Tube drainage
- Loss of colonic secretions
  - Villous adenoma
  - Laxative abuse

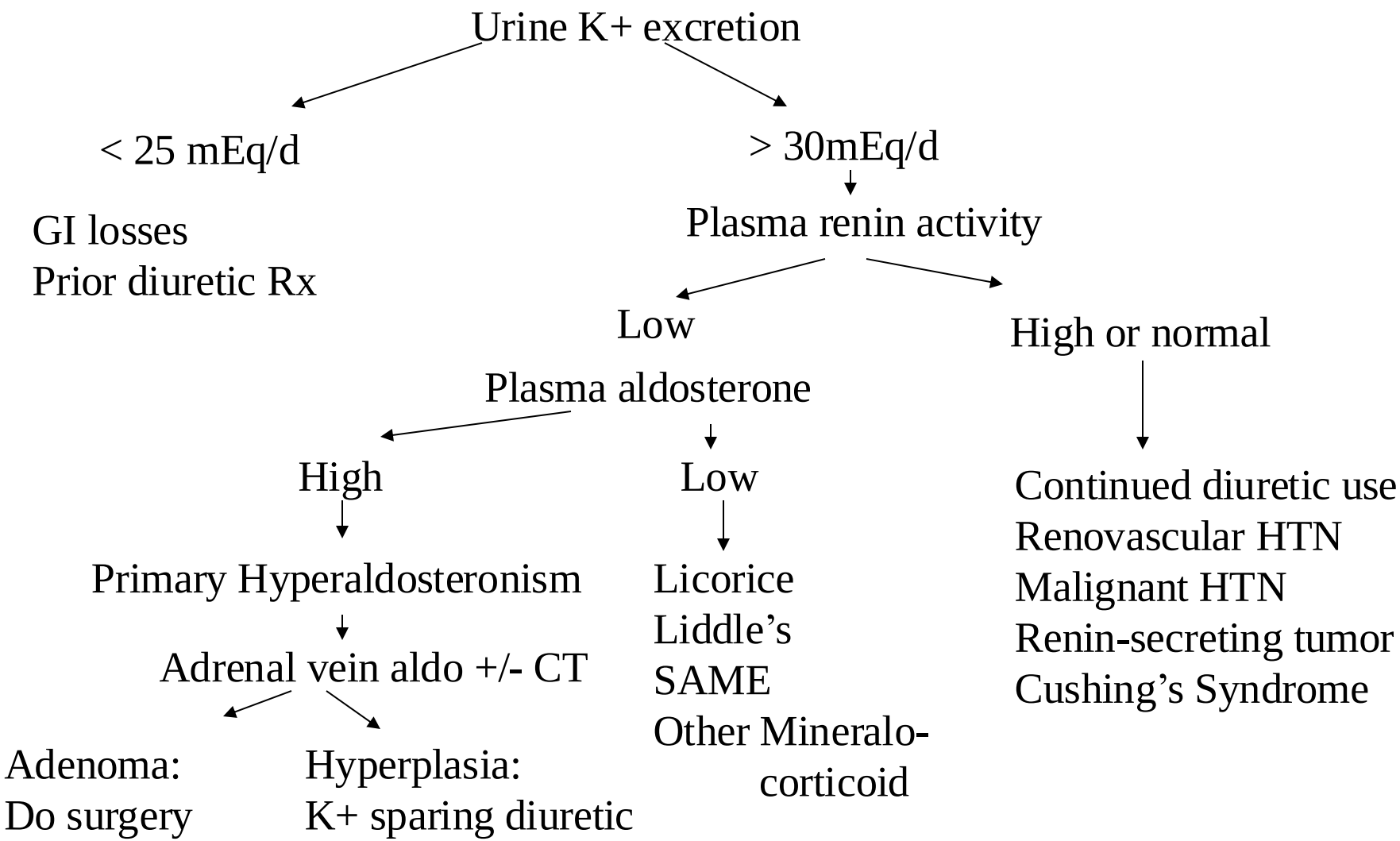
Increased urinary losses

- Diuretics
  - Increased flow to K+ secretory sites
  - Enhanced secretion of aldosterone
- Bartter's or Gitelman's Syndrome
- Mineralocorticoid excess.
- Reabsorption of Na+ in presence of nonreabsorbable anion.
- RTAs.

Consequences of Hypokalaemia

- **Skeletal muscle** - Weakness, paralysis
- **Gastrointestinal** - Paralytic Ileus
- **Kidney** - Impaired concentrating ability, Tubular defects
- **Cardiac** - Conduction defects, arrhythmias, Digoxin toxicity

Hypokalemia and Hypertension



Role of cortisol

- Cortisol binds to mineralocorticoid receptor with equal avidity to aldosterone
- Conversion to cortisone by 11β-hydroxysteroid dehydrogenase prevents mineralocorticoid activity
- Cortisol acts as mineralocorticoid with:
  - Excess cortisol production: Cushing's
  - Impairment of 11β- : real licorice, syndrome of AME

Work-up of hypokalemia

- H&P
  - Diarrhea
  - Vomiting
  - Diuretics
  - Periodic paralysis
  - Offending drugs
- Acid-base balance
- Urine potassium
  - >25-30 meq/ indicates renal losses
  - < 15 meq/L on spot usually rules out urine losses

TABLE 4. FOODS WITH HIGH POTASSIUM CONTENT.

- Highest content (>1000 mg [25 mmol]/100 g)
  - Dried figs
  - Molasses
  - Seaweed
- Very high content (>500 mg [12.5 mmol]/100 g)
  - Dried fruits (dates, prunes)
  - Nuts
  - Avocados
  - Bran cereals
  - Wheat germ
  - Lima beans
- High content (>250 mg [6.2 mmol]/100 g)
  - Vegetables
    - Spinach
    - Tomatoes
    - Broccoli
    - Winter squash
    - Beets
    - Carrots
    - Cauliflower
    - Potatoes
  - Fruits
    - Bananas
    - Cantaloupe
    - Kiwis
    - Oranges
    - Mangos
  - Meats
    - Ground beef
    - Steak
    - Pork
    - Veal
    - Lamb

Hypokalaemia: Treatment

Not urgent UNLESS complications

- Oral is preferable to IV therapy
- Deficits:
  - K = 3 mmol/L ~ 300 mmol
  - K = 2 mmol/L ~ 600 mmol

Oral treatment

- Normal intake + 60 mmol/day
- Slow K …. 8 mmol.

I.V. treatment

- 10 mmol/hr Maximum!

55 yo lady with DM >10 years associated with DM nephropathy and retinopathy, HTN >10 years, CKD III with baseline Cr around 1.8-2.0 presented for regular clinic visit. Na 138, K 5.7, HCO3 18, Cl 112, Cr 1.8. Urine pH 5.0. ABGs showed 7.32/34/18.

What is the most likely diagnosis?

a. Diarrhea induced metabolic acidosis.
b. Methanol overdose.
c. Ethylene Glycol overdose
d. RTA 4
e. Distal RTA

70 yo man presented to the ER c/o fever, chills and SOB for one week. CXR showed bilateral pneumonia. BP is 100/60 (baseline around 140s-150s/80s-90s). Lab showed Cr of 5.0. K 7.0. EKG showed hyper-acute T waves.

What is the best next step?

A. IV calcium gluconate.
B. PO kayexalate.
C. IV furosemide
D. Emergent HD catheter and dialysis.
E. Call the nephrology team and tell them to come and take care of their patient since you are busy and have other patients to see in the ER.

58 year old lady presented to the ER with weakness. Na 136. K 3.1. Cl 110. CO_2 15. ABGs showed pH 7.28. $PaCO_2$ 30. HCO_3 16. Urine: Na 10 meq/l, K 8 meq/l, Cl- 40 meq/l.

What is the most likely diagnosis?

a. DKA
b. Lactic acidosis
c. Severe vomiting
d. Severe diarrhea
e. RTA

24 year old lady presented to the ER with weakness. BP 85/45. BMI 35. Na 138. K 2.8. CO2 34. Mg 1.2. ABGs 7.49/45/34. She has been trying hardly to lose weight but denies laxatives or diuretics use.

What is the best next step to reach a most likely diagnosis?

a. Given low serum Mg along with other lab values she most likely has Gitelman syndrome.
b. Given low serum Mg along with other lab values she most likely has Bartter syndrome.
c. She is most likely abusing laxatives. Ask more questions about laxatives abuse.
d. Send a blood and urine sample for diuretics screen.
e. She most likely had anorexia nervosa.