AUA 2026 MAY 15-18 Washington, DC

24-hr Urine Interpretation

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Section of Nephrology
WVU Medicine

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Disclosures

- None

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Why Do We Care?

- "By age 70, 19.1% of men and 9.4% of women report ever having a kidney stone"
- Obesity and Diabetes are strong risk factors
- Stone recurrence 50% in 5-10 years and 75% in 20 years
- 31% increased risk for myocardial infarction
- Increased risk of hypertension and CKD

Kidney Stone Pathophysiology, Evaluation and Management: Core Curriculum 2023 AJKD Vol 82 | Iss 5 | November 2023

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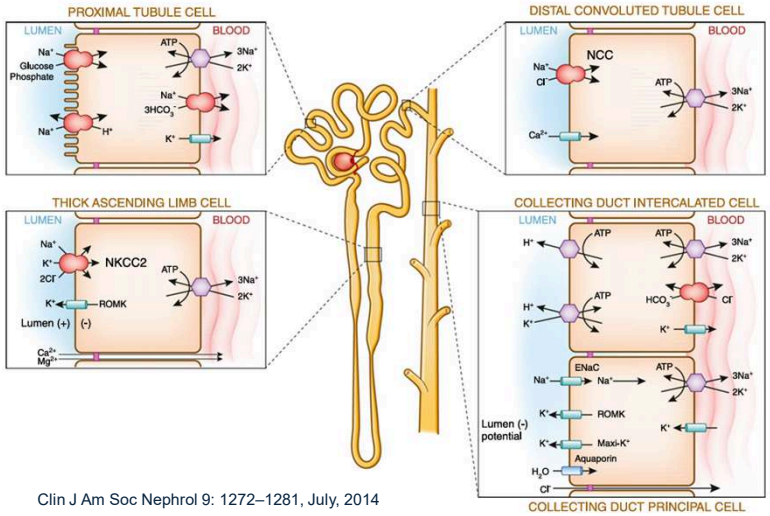
Nephron Anatomy

- Filtered Daily:
- ≈ 552,000mg Na^+
- ≈ 10g Ca^{2+}



Clin J Am Soc Nephrol 9: 1272–1281, July, 2014

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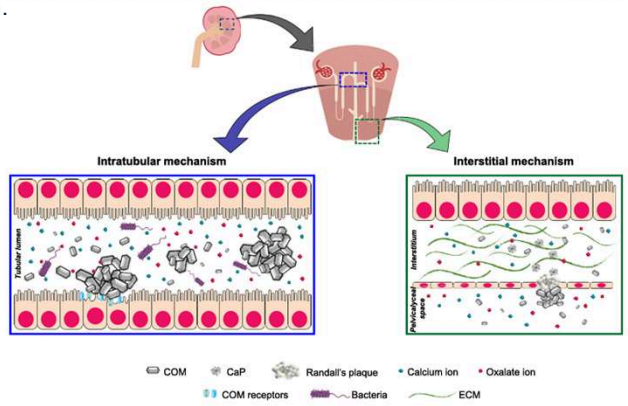
Kidney Stone Prevention. Advances in Nutrition 14 (2023)555–569



Randall plaque formation

FIGURE 2. Mechanisms of CaOx stone formation. The first mechanism takes place within tubular lumens involving supersaturation of crystalline salts, crystallization, growth, self-aggregation, and adherence on tubular epithelial cells. Bacteria (both urease-producing and non–urease-producing groups) also play roles in this intratubular mechanism. The second mechanism initially takes place at renal interstitium by forming the so-called Randall plaque, which is a result of interstitial hydroxyapatite CaP crystal deposition and tissue inflammation. Some of the Randall plaques at and adjacent to the papillary tip can erode into the pelvicalyceal system, where CaOx is commonly supersaturated and crystallized. CaOx crystals subsequently deposit on the eroded Randall plaque, which then serves as the stone nidus, and the stone starts to form. CaOx, calcium oxalate; CaP, calcium phosphate; COM, calcium oxalate monohydrate; ECM, extracellular matrix.

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Collection Methods

- Two 24-hour collections
  - Prefer one at work and one on a weekend
- Urine creatinine
  - Major influences of creatinine production: muscle mass and protein intake
  - Male: 20-25mg/kg
  - Female: 15-20mg/kg—seen in patient below

Date	Weight	Cr 24 Creatinine, Urine	Cr24/kg Creatinine/Kg Body Weight	Ca24/kg Calcium/Kg Body Weight	Ca24/Cr24 Calcium/Creatinine Ratio
12/30/2025	122.5	1727	14.1	2.5	178
08/19/2025	122.9	1957	15.9	1.9*	117
08/18/2025	122.9	2153✓	17.5	3.2*	184
06/03/2021	118.4	1751	14.8	2.8*	190
Ref. Interval		Not Applic.	8.7-20.3	<4	51-262
Units	kg	mg/24 hr	mg/24 hr/kg	mg/24 hr/kg	mg/g creat

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Date	Vol 24 Urine Volume (Preserved)	SS CaOx Calcium Oxalate Saturation	Ca 24 Calcium, Urine	Ox 24 Oxalate, Urine	Cit 24 Citrate, Urine	SS CaP Calcium Phosphate Saturation	pH pH, 24 hr, Urine	SS UA Uric Acid Saturation	UA 24 Uric Acid, Urine
12/30/2025	3410	3.83	**307**	**41**	1439	**1.39**	6.336	0.34	**1118**
08/19/2025	2960	4.86	229✓	**37**	772	0.05	**4.838**	**1.35**	468
08/18/2025	**1730**	**8.98**	**396**✓	**33**	722	0.25	**4.819**	**2.02**	410✓
06/03/2021	**1990**	**7.77**	**333**	**34**	979	0.27	**5.216**	**2.99**	**936**
Ref. Interval	500-4000	6.00-10.00	<200	20-40	>550	0.50-2.00	5.800-6.200	<1.00	<750
Units	mL/24 hr		mg/24 hr	mg/24 hr	mg/24 hr				mg/24 hr

✓ Verified by Repeat Analysis

30% CaOx
70% Uric Acid

Dietary Factors

Date	Na 24 Sodium, Urine	K 24 Potassium, Urine	Mg 24 Magnesium, Urine	P 24 Phosphorus, Urine	NH4 24 Ammonium, Urine	Cl 24 Chloride, Urine	Sul 24 Sulfate, Urine	UUN 24 Urea Nitrogen, Urine	PCR Protein Catabolic Rate
12/30/2025	**314**	57	162✓	**1717**	18	**261**	37	12.31	0.8
08/19/2025	99	74	73	**1019**	45	124	**52**	**14.63***	0.9
08/18/2025	154	80	81	**1708**	51	148	**86**	**17.33***	1.1
06/03/2021	**216**	62	**72**	**978**	41	**226**	**59**	**14.19***	0.9
Ref. Interval	50-150	20-100	30-120	600-1200	15-60	70-250	20-80	6.00-14	0.8-1.4
Units	mmol/24 hr	mmol/24 hr	mg/24 hr	mg/24 hr	mmol/24 hr	mmol/24 hr	meq/24 hr	g/24 hr	g/kg/24 hr

Date	Weight	Cr 24 Creatinine, Urine	Cr24/kg Creatinine/Kg Body Weight	Ca24/kg Calcium/Kg Body Weight	Ca24/Cr24 Calcium/Creatinine Ratio
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Fluid Intake

- Fluid intake 2.5-3L/day
  - Insensible loss ≈ 500mL-1L/day
  - Water intake in food ≈ 800mL/day
  - Water from oxidation ≈ 300mL/day
- Fluid intake = Urine output
- Low urine volume:
  - Sweating
  - GI water loss
- Supersaturation influenced by urine volume + concentration of constituents

Date	Vol 24 Urine Volume (Preserved)	SS CaOx Calcium Oxalate Saturation	Ca 24 Calcium, Urine	Ox 24 Oxalate, Urine
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Ref. Interval	500-4000	6.00-10.00	<200	20-40
Units	mL/24 hr		mg/24 hr	mg/24 hr

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Hypercalciuria-Complex and Multifactorial

- Genetics
- Site of abnormality
  - Increased GI absorption
    - 1,25 Vitamin D
  - Skeletal resorption
    - Primary Hyperparathyroidism
      - Serum ↑PTH, Vitamin D, ↓Phosphorus, ↑ Calcium
    - Secondary Hyperparathyroidism
      - Serum ↑PTH, ↓ Vitamin D, Normal/High Phosphorus, Low/Normal Calcium

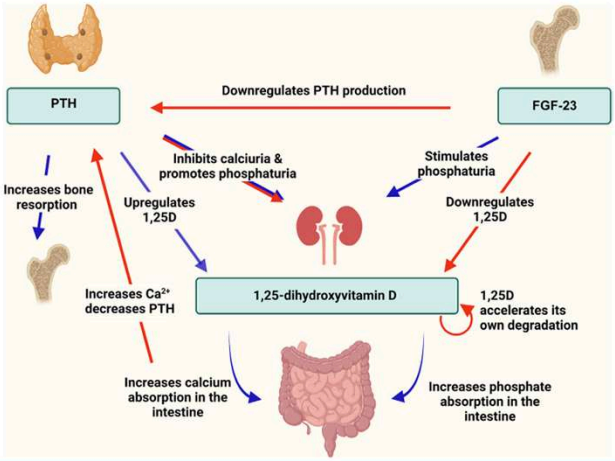

Figure 1. Axis of PTH, FGF-23, and 1,25-dihydroxyvitamin D. PTH, FGF-23, and 1,25$(OH)_2$D interact and regulate one another via classic negative endocrine feedback loops that affect calcium and phosphate transport in the kidney, bone, and intestine. Created with Biorender. Abbreviations: 1,25D, 1,25-diydroxyvitamin D; FGF-23, fibroblast growth factor-23; PTH, parathyroid hormone.

Calcium and Phosphate Disorders: Core Curriculum 2024. AJKD Vol 83 | Iss 2 | February 2024

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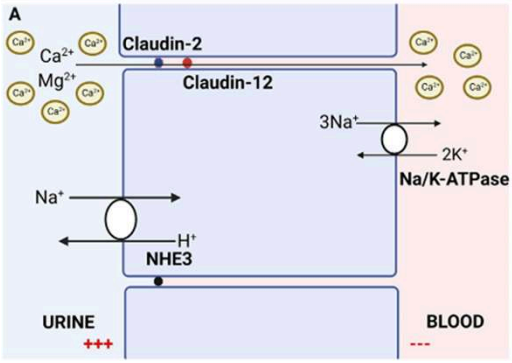
Proximal Tubule Calcium Handling

- Normal paracellular reabsorption:
  - passive diffusion
  - solvent drag
  - electrochemical gradient

Am J Physiol Renal Physiol 316: F966–F969, 2019

- High urine sodium ↓ paracellular calcium reabsorption
- High sodium intake is rarely the sole driver
- For every 100 mmol (or 2.3 g) of sodium about 1 mmol (or 40 mg) calcium is excreted

Pediatr Nephrol (2007) 22:1659–1673



Calcium and Phosphate Disorders: Core Curriculum 2024. AJKD Vol 83 | Iss 2 | February 2024

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Vitamin D and Calcium Supplementation

- Vitamin D did not show increased risk of stone disease despite increasing urinary calcium
  - Hypercalcemia, hypercalciuria, and kidney stones in long-term studies of vitamin D supplementation: a systematic review and meta-analysis. Am J Clin Nutr 2016;104:1039–51
  - Monthly high-dose vitamin D supplementation does not increase kidney stone risk or serum calcium: results from a randomized controlled trial. Am J Clin Nutr 2019;109:1578–1587
- Calcium supplementation has varying effects on urine calcium
  - Taken with food it has been shown to lower urine oxalate and phosphate
  - Taken alone increases urine calcium
  - Calcium and Vitamin D Supplementation and Their Association with Kidney Stone Disease: A Narrative Review. Nutrients 2021, 13, 4363

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Hyperoxaluria

- **Primary:**
  - Inborn error of glyoxylate metabolism leading to oxalate overproduction
- **Secondary:**
  - High dietary intake
  - Vitamin C
    - 1,000mg/d can increase oxalate excretion by 6-13mg/day
    - Kidney Int Rep. 2020 Jul 16;5(10):1815–1822.
  - Enteric hyperoxaluria
    - Roux-en-Y gastric bypass, Crohn's disease, cystic fibrosis, short bowel syndrome
    - Undigested fatty acids reach the large intestine and combine with calcium which leads to increased luminal oxalate
    - *CJASN* 16(3):p 487-495, March 2021.
- **Management:**
  - Review diet
  - Combine calcium supplements/dairy products
  - Enteric cause-bile acid sequestrants

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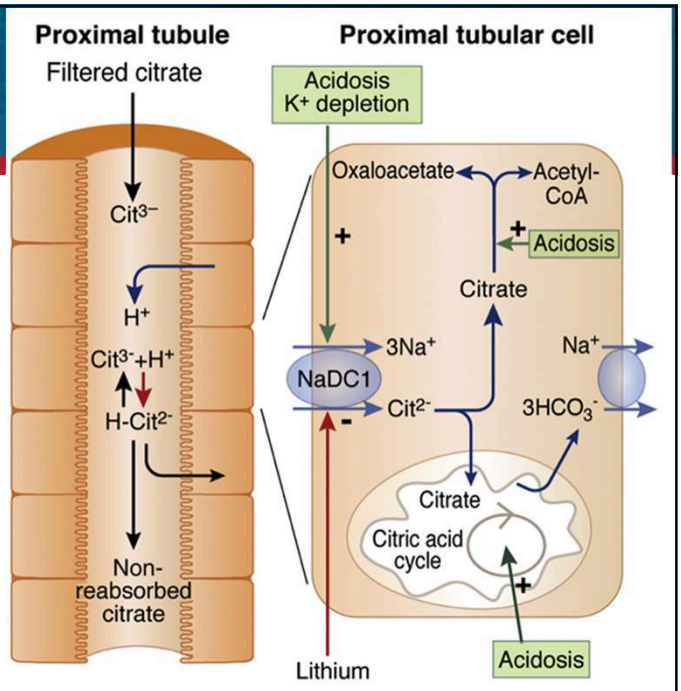
Citrate

- Most ingested citrate is converted to bicarbonate in the liver
- Complexes with tubular calcium
  - ↑ calcium solubility
  - ↓ free calcium in the urine
  - ↓ calcium supersaturation
  - Prevents crystal agglomeration and growth

Rev Urol. 2009;11(3):134-144

- Trivalent: not reabsorbed
- Bivalent: is reabsorbed



Urol Clin N Am 52 (2025) 329–342

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Hypocitraturia Etiologies

- Hypokalemia
  - Some even say dropping the serum potassium from 4.2 to 3.7 could even lead to hypocitraturia despite “normal” serum potassium
  - Encourage higher potassium diet

Table 1
A list of potential etiologies for the development of hypocitraturia

Etiologies of Hypocitraturia	
Acid-base disturbances	Distal (Type 1) renal tubular acidosis Gastrointestinal malabsorption Exercise Other systemic metabolic conditions
Chronic kidney disease	
Dietary factors	High animal protein High sodium Low fruits/vegetables Starvation
Drugs	Angiotensin-converting enzyme inhibitors Amphotericin Thiazide diuretics Topiramate
Exercise	—
Genetic polymorphisms	—
Glycogen storage disorders	—
Hyperaldosteronism	—
Hypokalemia	—
Idiopathic	—
Urinary tract infection	—

Hypocitraturia Diagnosis and Treatment. Urol Clin N Am 52 (2025) 329–342

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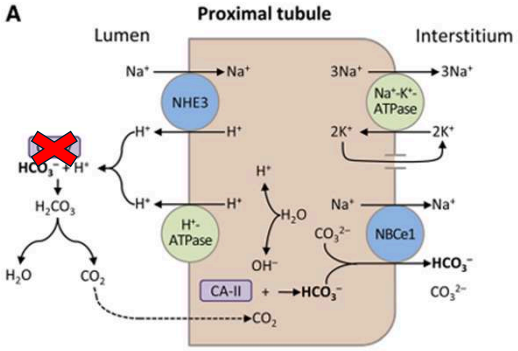
Carbonic Anhydrase Inhibitors

$$CO_2 + H_2O \rightleftarrows H_2CO_3 \rightleftarrows HCO_3^- + H^+$$

- **Topiramate and Zonisamide**
  - Used for weight loss, migraine, and seizure prophylaxis
- Calcium phosphate stones due to alkaline urine and hypocitraturia
- ≈1.5-2 time higher risk of a symptomatic kidney stone
- 2-3% of patients experience a symptomatic stone event during the first 3 years

Do Topiramate and Zonisamide Cause Kidney Stones? AJKD Vol 85 | Iss 6 | June 2025



Renal Tubular Acidosis and Management Strategies: A Narrative Review. Adv Ther (2021) 38:949–968

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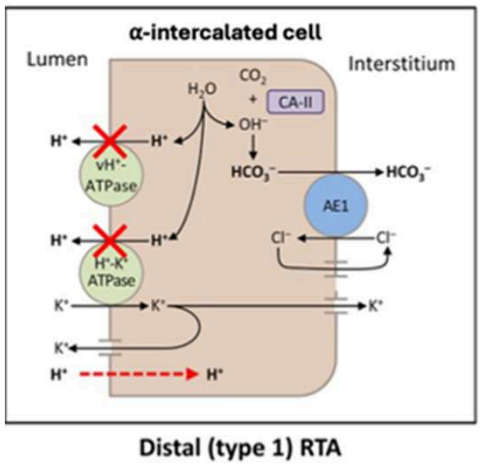
Distal Renal Tubular Acidosis



Distal (type 1) RTA

Box 2. Selected Causes of Distal (Type 1) Renal Tubular Acidosis

Classic Distal Renal Tubular Acidosis
- Sjogren syndrome
- Systemic lupus erythematosus
- Nephrocalcinosis
- Primary biliary cirrhosis
- Sarcoidosis

Voltage-Dependent Distal Renal Tubular Acidosis
- Triamterene
- Amiloride
- Pentamidine
- Trimethoprim sulfamethoxazole
- Urinary tract obstruction
- Sickle cell nephropathy
- Chronic pyelonephritis

Membrane Failure
- Amphotericin B
- Lithium

Genetic Disorders

Renal Tubular Acidosis: Core Curriculum 2025 Am J Kidney Dis. 85(4):501-512.

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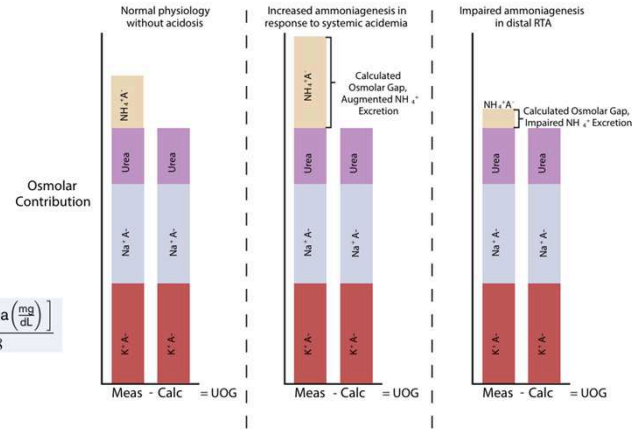
Distal Renal Tubular Acidosis

- Ammonium
  - Important osmole in the urine
  - Is accounted for in the measured urine osmolality but not calculated
  - Normal excretion in response to acidosis will increase the urine osmolal gap >200 mOsm/kg

$$\text{Urine Osmolal Gap} = \text{Measured Osmolality} - 2 \times (\text{Urine } [Na^+] + \text{Urine } [K^+]) + \frac{\text{Urine } \left[\text{Urea } \left(\frac{mg}{dL}\right)\right]}{2.8}$$



Renal Tubular Acidosis: Core Curriculum 2025 Am J Kidney Dis. 85(4):501-512.

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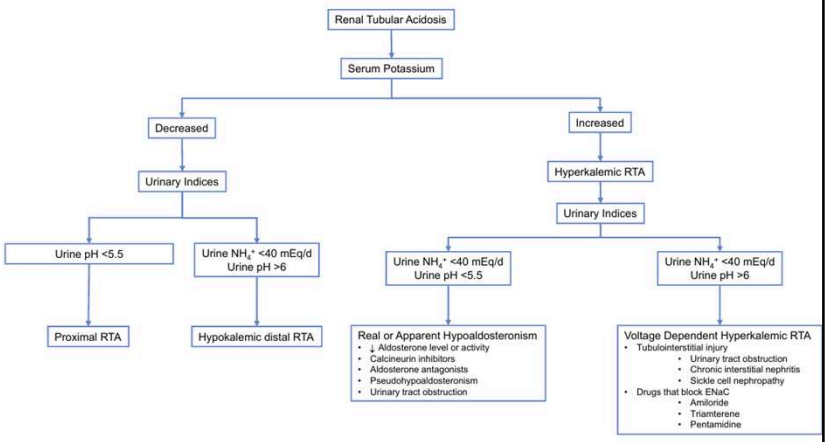
Distal Renal Tubular Acidosis Diagnosis

- **<u>Urine anion gap in not accurate</u>**
- Insufficient ammonium excretion
  - 24-hour urine ammonium excretion < 40 mEq/day
  - Urine osmolar gap < 150 mOsm/kg



Renal Tubular Acidosis: Core Curriculum 2025 Am J Kidney Dis. 85(4):501-512.

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Distal Renal Tubular Acidosis Diagnosis

- Low citrate
- High urine pH
- 24-hour ammonium <40mEq/d
- Low serum CO_2
  - Total CO_2
    - Bicarbonate 95%
    - Dissolved CO_2, carbonate ions, and carbamino compounds 5%

Renal Tubular Acidosis: Core Curriculum 2025 Am J Kidney Dis. 85(4):501-512.

Vol 24	SS CaOx	Ca 24	Ox 24	Cit 24	SS CaP	pH	SS UA	UA 24
1.08	4.12	68	34	<21	0.11	7.165	2.18	0.357
1.12	4.37	68	41	57	0.13	7.266	2.62	0.490

Na 24	K 24	Mg 24	P 24	Nh4 24	Cl 24	Sul 24	UUN 24	PCR
149	62	130	0.691	18	180	35	7.66	0.8
152	64	168	0.700	'22	175	34	11.26	1.0

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Animal Protein

- Breakdown creates an acid load → hypocitraturia
- Limiting animal protein to 0.8g-1.0g/kg/day
- This is one of the last factors I focus on for patients

Date	Na 24	K 24	Mg 24	P 24	NH4 24	Cl 24	Sul 24	UUN 24	PCR
	Sodium, Urine	Potassium, Urine	Magnesium, Urine	Phosphorus, Urine	Ammonium, Urine	Chloride, Urine	Sulfate, Urine	Urea Nitrogen, Urine	Protein Catabolic Rate
12/30/2025	314	57	162	1717	18	261	37	12.31	0.8
08/19/2025	99	74	73	1019	45	124	52	14.63	0.9
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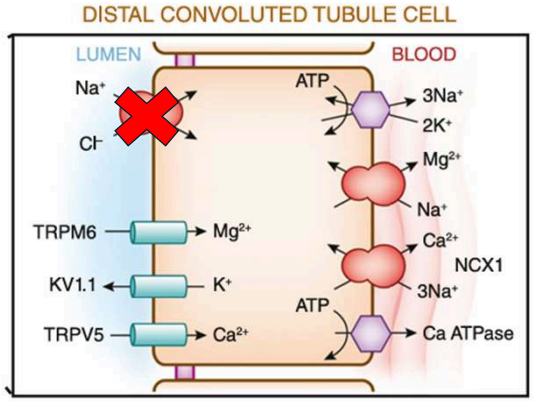
Thiazide Diuretics

- Two proposed mechanisms:
  - ↑ proximal sodium and water reabsorption due to volume depletion → to ↑ calcium resorption
  - Increased distal calcium reabsorption
    - ↑ calcium into the tubular cell via TRPV5 in the luminal membrane
    - Enhanced extrusion out of the tubular cell via the Na-Ca exchanger in the basolateral membrane



Renal Control of Calcium, Phosphate, and Magnesium Homeostasis Clin J Am Soc Nephrol 10: 1257–1272, July, 2015

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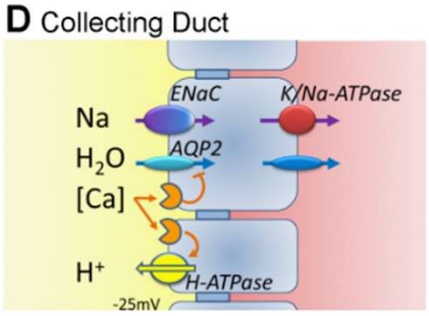
Potassium Sparing Diuretic: Amiloride

- Two possible mechanisms:
  - Animal models suggest an ↑ calcium reabsorption in the distal convoluted tubule
  - ↑ proximal tubular reabsorption of calcium similar to thiazides
- *Post hoc analysis*
  - Urine collection before, 3 and 6 hours after 20mg Amiloride
  - 80% decrease urine calcium excretion as early as 3 hours post amiloride
  - high-Na/low-K (250 (4600mg)/40mmol (1500mg)/day) diet

Acute decrease of urine calcium by amiloride in healthy volunteers under high-sodium diet. Nephrol Dial Transplant (2022) 37: 298–303



Ways of calcium reabsorption in the kidney Am J Physiol Renal Physiol 310: F1337–F1350, 2016

So maybe high dose Amiloride is more helpful in the high sodium intake patients?

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Uric Acid

Date	Vol 24 Urine Volume (Preserved)	SS CaOx Calcium Oxalate Saturation	Ca 24 Calcium, Urine	Ox 24 Oxalate, Urine	Cit 24 Citrate, Urine	SS CaP Calcium Phosphate Saturation	pH pH, 24 hr, Urine	SS UA Uric Acid Saturation	UA 24 Uric Acid, Urine
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Units	mL/24 hr		mg/24 hr	mg/24 hr	mg/24 hr				mg/24 hr

✓Verified by Repeat Analysis

- Uric acid normally crystallized in acidic urine
- Common inpatients with type 2 diabetes and obesity
- Hyperuricosuria and/or low urinary pH are the major risk factors for uric acid stone formation
- Goals of urinary pH are >6.0–6.5

Kidney Stone Prevention. Advances in Nutrition 14 (2023)555–569

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Cystinuria

- 1% of all kidney stones
- Autosomal recessive, rarely autosomal dominant
- Cystine
  - Amino acid
  - Formed from breakdown of amino acid methionine
- Impairment of renal cystine transport → decreased proximal tubular reabsorption → increased urinary cystine excretion
- Management:
  - Urine volume >3L
  - Low sodium diet <2,000mg/day
  - Urine pH >7- Cystine solubility increases by up to threefold at this pH
  - Thiol containing medications-Tiopronin/D-penicillamine
    - Increases cystine solubility

Kidney Stone Pathophysiology, Evaluation and Management: Core Curriculum 2023 AJKD Vol 82 | Iss 5 | November 2023