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2025 Stone Disease

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Associate Professor of Urology
Mayo Clinic Arizona

1

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DISCLOSURES

- Consultant for:
  - Boston Scientific
  - BD
  - Olympus
  - Dornier
  - Mendaera
  - Avvio
- Investor:
  - Sonomotion
- Grants:
  - Calyxo, Inc.

2

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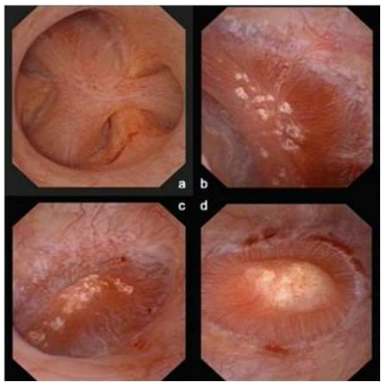
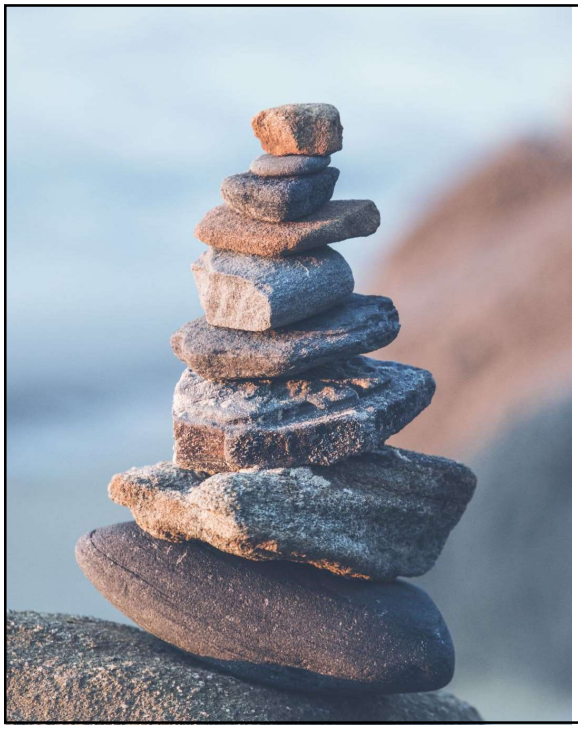
Epidemiology and Pathophysiology

- Upper tract stones were more common in men by 2 to1 —ratio is decreasing
- Whites have highest incidence compared with Asians, Hispanics, African Americans
- Prevalence shows geographic variability; highest in the Southeast—STONE BELT
- Prevalence increases with age, peak incidence between 20-60 years
- Randall's plaques: subepithelial deposits of Calcium Apatite (phosphate) in BM of collecting ducts of thin loops of Henle
- Crystals erode through urothelium
- Calcium oxalate nucleation and growth in collecting system, dependent on concentrations of minerals, promoters, and inhibitors



Daudon et al 2011

3



Stones are a chronic disease!

- 15-30% recurrence rates
- Up to 50% recurrence in 5 years

4

Kidney stones are associated with other medical conditions/ medications

Gastrointestinal conditions: IBD, chronic diarrhea, celiac, pancreatic insufficiency	GI surgeries: bowel resection, malabsorptive bariatric surgeries	Rheumatological conditions: Sjogren's, sarcoidosis
Primary renal disorders: polycystic kidney disease, medullary sponge kidney, renal tubular acidosis	Medications: topiramate, zonisamide, acetazolamide, PPIs, steroids Supplements: Vitamin C, Turmeric, Calcium Carbonate	Endocrine disorders: primary hyperparathyroidism, bone resorptive conditions, metabolic syndrome, insulin resistance

5

Stone Risk Factors / Cystine Screening: Negative (01/24/2022)

DATE	SAMPLE ID	Vol 24	SS CaOx	Ca 24	Ox 24	Cit 24	SS CaP	pH	SS UA	UA 24
01/22/22	S26848133	1.31	3.71	98	24	303	1.67	6.717	0.21	0.626
01/21/22	S26848134	1.65	3.13	133	24	280	1.98	7.158	0.07	0.669
REFERENCE RANGE		0.5 - 4L	6 - 10	male <250 female <200	20 - 40	male >450 female >550	0.5 - 2	5.8 - 6.2	0 - 1	male <0.800 female <0.750

Dietary Factors

DATE	SAMPLE ID	Na 24	K 24	Mg 24	P 24	Nh4 24	Cl 24	Sul 24	UUN 24	PCR
01/22/22	S26848133	146	40	94	0.786	28	142	25	6.88	1.1
01/21/22	S26848134	237	50	91	0.842	25	225	23	7.23	1.1
REFERENCE RANGE		50 - 150	20 - 100	30 - 120	0.6 - 1.2	15 - 60	70 - 250	20 - 80	6 - 14	0.8 - 1.4

Normalized Values

DATE	SAMPLE ID	WEIGHT	Cr 24	Cr 24/Kg	Ca 24/Kg	Ca 24/Cr 24
01/22/22	S26848133	49.0	1256	25.6	2.0	78
01/21/22	S26848134	49.0	1140	23.3	2.7	117
REFERENCE RANGE				male 11.9-24.4 female 8.7-20.3	<4	male 34-196 female 51-262

6

7

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HYPERCALCIURIA

Absorptive

Renal Leak

1º Hyper PTH

urinary Ca^{++}

8

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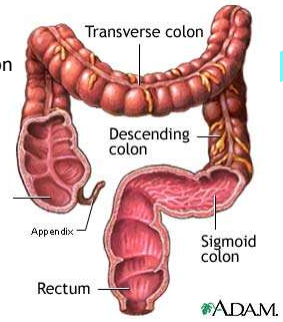
Absorptive Hypercalciuria

1,25-Dihydroxyvitamin D3 most potent stimulator of intestinal calcium absorption

Calcium absorption Occurs in small intestine



Ca^{++}

↑ GI Ca^{++} absorption

↑ serum Ca^{++}

↑ urinary Ca^{++} ↓ PTH

- Type I – Diet unresponsive
- Type II – Responds to limiting dietary Ca++
- *** AUA Guidelines – no need to distinguish types ***

Preminger, AUA; 2013

9

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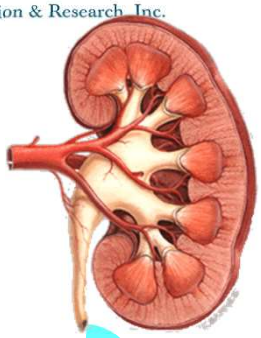
Renal Hypercalciuria: "Renal Leak"



urinary Ca^{++} → ↓ serum Ca^{++}

↑ PTH

Ca^{++}

↑ GI Ca^{++} absorption ↑ bone resorption

Preminger, AUA; 2013

10

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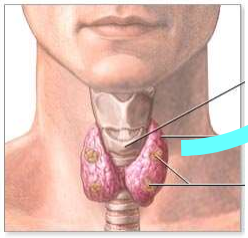
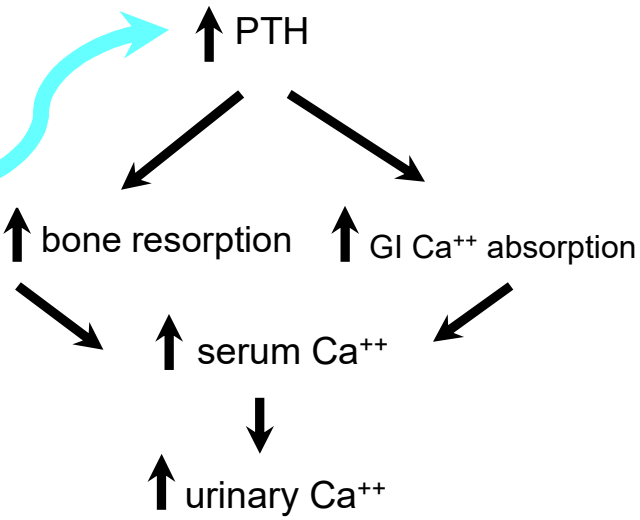
Resorptive Hypercalciuria: "Primary Hyperparathyroidism"





•PTH stimulates 1α-hydroxylase in the proximal tubule of the kidney to convert 25-dihydroxyvitamin D3 to 1,25(OH)2D3

Preminger, AUA; 2013

11

Primary Hyperparathyroidism

- Suspect when serum calcium his high
- Calcium Phosphate stones
- Measure Vitamin D
  - Low Vitamin D may mask 1°hyperPTH
- Treatment – parathyroidectomy

12

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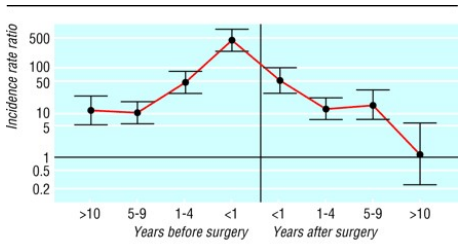
Risk of renal stone events in primary hyperparathyroidism before and after parathyroid surgery: controlled retrospective follow up study

- 674 pts PHT, 2021 population controls
- **Risks of stone was 40.6 x before surgery** and 16.9 x after surgery
- Pts with stones before surgery had 27 x risk of post-op stones
- **Risks of stones normalized with controls after 10 years**



Mollerup, et al. BJM 2002; 325: 807-813.

13

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Differential Diagnosis of Hypercalciuria

	Absorptive	Renal	Resorptive
Serum ca			Elevated
Parathyro			Stimulated (primarily)
Fasting u calcium°			Elevated
Intestinal calcium absorption	Elevated (primary)	Elevated (secondary to high PTH)	Elevated (secondary to high PTH)

Metabolic Workup
- Check:
  - Serum Calcium
  - PTH

Guideline

°Not routinely recommended—new AUA guideline, 2014

14

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Differential Diagnosis of Hypercalciuria

	Absorptive	Renal	Resorptive
Serum calcium	No		evated
Parathyroid function	Su		mulated rimarily)
Fasting urinary calcium°	No		evated
Intestinal calcium absorption	Elevated (primary)	Elevated (secondary to high PTH)	Elevated (secondary to high PTH)

Only need to find the 1º hyperPTH patients

*treat the other 2 with thiazides

°Not routinely recommended—new AUA guideline, 2014

15

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HYPERCALCIURIA
ROLE OF SODIUM

- Oral sodium intake is a major determinate of renal calcium excretion
- An increased sodium intake of 100 mEq / day will increase urinary calcium 50 mg / day

16

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HYPERCALCIURIA

ROLE OF SODIUM

- Oral sodium intake is a major determinate of renal calcium excretion
- An increased sodium intake of 100 mEq / day will increase urinary calcium 50 mg / day

U_{Ca}	U_{Na}
230 mg/day (nl<200)	300 mEq/day (nl<200)
	200 mEq/day

17

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HYPERCALCIURIA

ROLE OF SODIUM

- Oral sodium intake is a major determinate of renal calcium excretion
- An increased sodium intake of 100 mEq / day will increase urinary calcium 50 mg / day

U_{Ca}	U_{Na}
230 mg/day (nl<200)	300 mEq/day (nl<200)
180 mg/day	200 mEq/day

18

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HYPERCALCIURIA
ROLE OF SODIUM

- Oral sodium intake is a major determinate of renal calcium excretion
- An increased sodium intake of 100 mEq / day will increase urinary calcium 50 mg / day
- Excess urinary sodium will also block the hypocalciuric action of thiazides
- Reduce sodium intake to 100 mEq/d or 2300 mg/day

19

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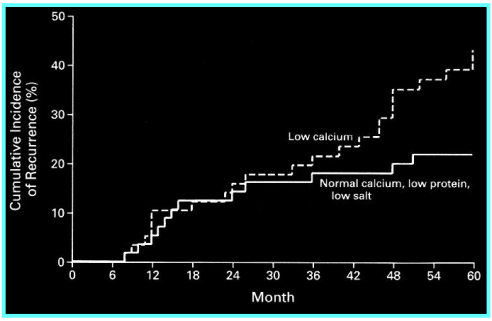
HYPERCALCIURIA
ROLE OF CALCIUM

- Lower calcium diet associated with increased risk of stone disease*
  - Insufficient calcium to bind dietary oxalate in the gut
- Calcium supplement users were 20% more likely to form stones (older women)
- Recommended dietary calcium 1000-1200 mg/day



Curhan et al 1997
Borghi,et al 2002
Preminger, AUA; 2013

20

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Calcium Supplements: If they are going to take Calcium which one?

- Calcium citrate: "Citracal"
- Over-the-counter preparation
  - Calcium citrate 950 mg
  - Elemental calcium 200 gm
- Provides increased intestinal calcium absorption
- Prevents supersaturation of stone-forming salts
- A more "stone-friendly" calcium supplement

Preminger, AUA; 2013

21

Hypercalciuria – Treatment?

22

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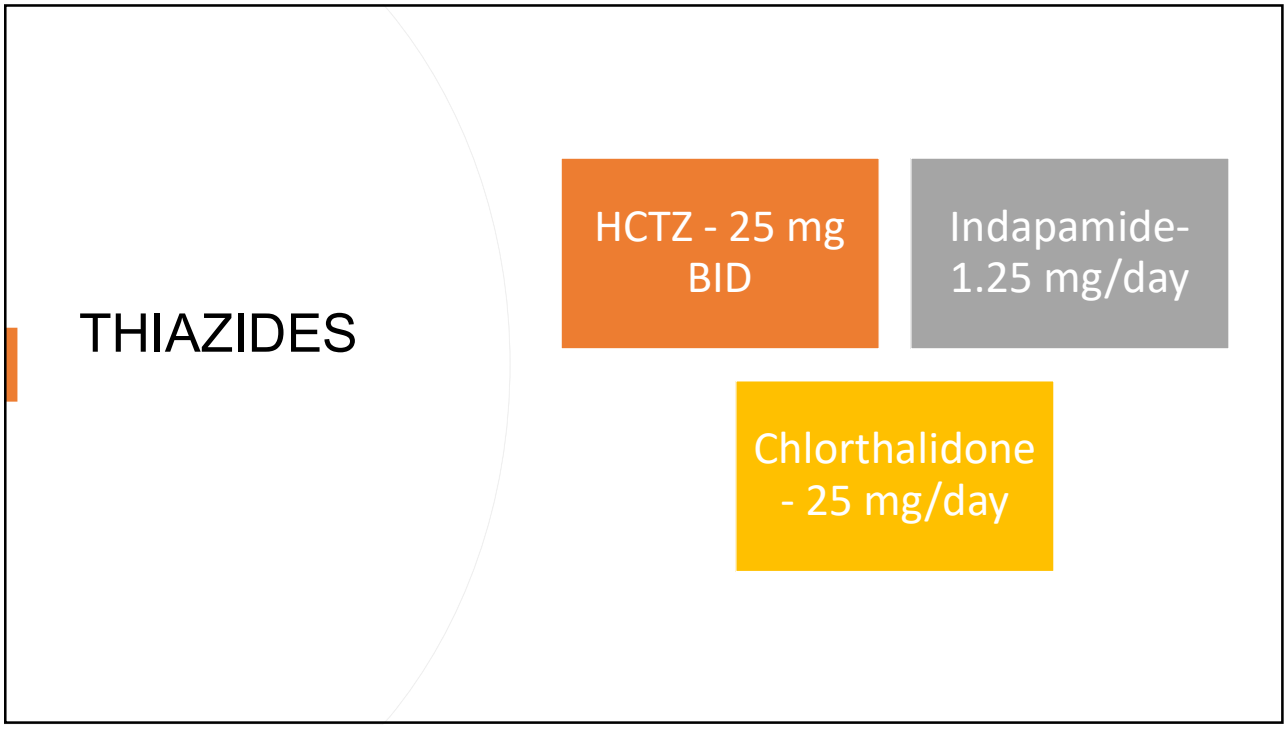


24

THIAZIDES

HCTZ - 25 mg BID

Indapamide- 1.25 mg/day

Chlorthalidone - 25 mg/day

*Supplement with K Citrate or K Chloride

* Must be in combo with dietary sodium restriction

25

THIAZIDES

Side Effects	Countermeasures
Hypokalemia	Potassium sparking diuretic / supplement
Hypocitraturia	Potassium citrate supplementation
Hyperuricosuria	Purine restriction / allopurinol
Hyperglycemia	Monitoring
Hair loss	
Pancreatitis	

* Side effects 1/3 patients

26

Follow-up

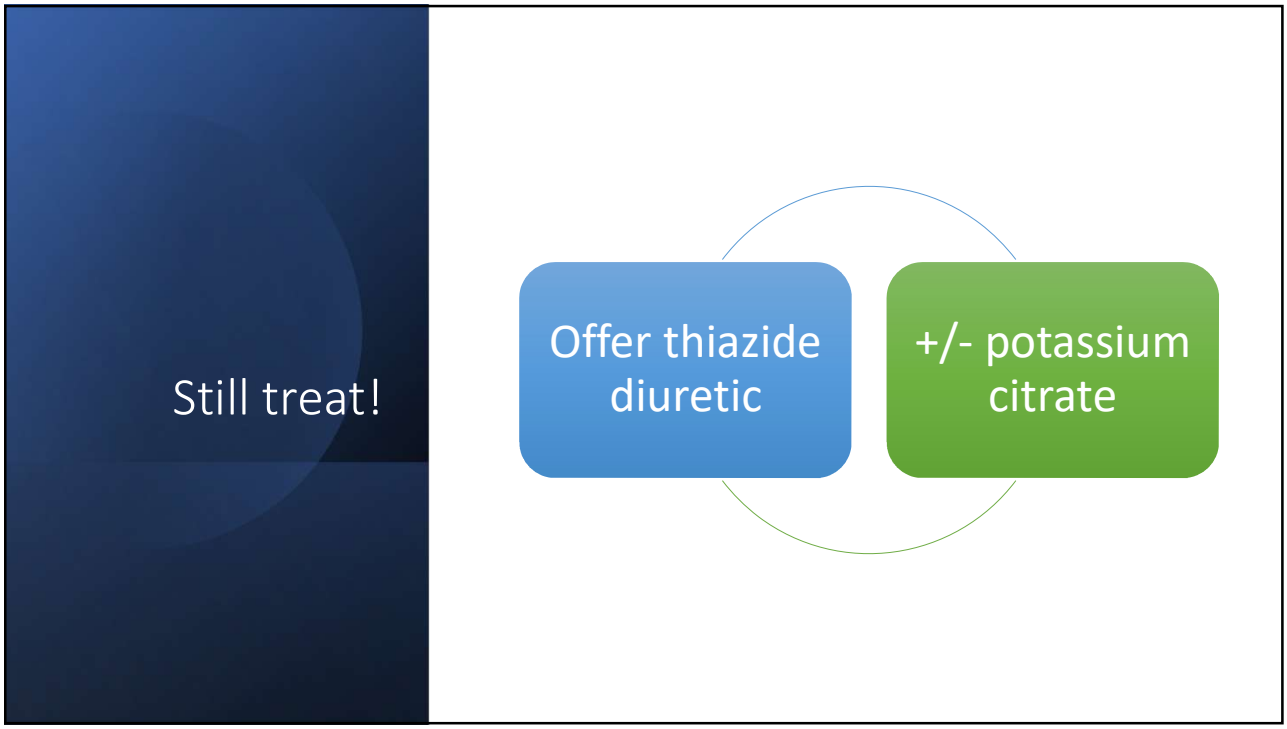
- Order single 24-hour urine within 6 months of initiation of treatment to assess response to dietary and/or medical therapy

27

Scenario

- Recurrent calcium stones
- 24-hour urine is normal
- Persistently making stones
- ??

28



29

30

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METABOLIC EVALUATION

CLASSIFICATION

Hypercalciuria	60%
Hypocitraturia	**39%**
Hyperuricosuria	35%
Hyperoxaluria	8%
1^0 HPT	3%
RTA	2%

Levy & Pak, 1995

31

Urinary Citrate

Citrate is protective

- Chelates calcium ions
- Inhibits crystal nucleation

Low urinary citrate (< 450 mg/day)

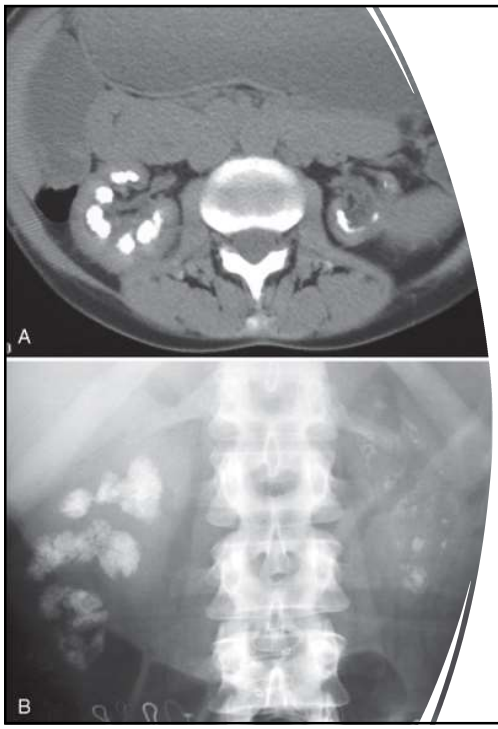
- Iatrogenic (ex. Thiazides)
- Idiopathic

Hypokalemic hyperchloremic metabolic acidosis

H^+

into the urine

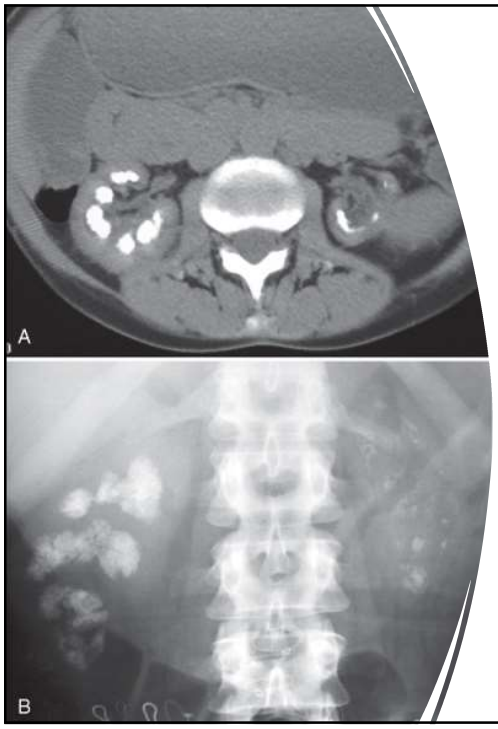
32



Renal Tubular Acidosis

- Only Type I associated with stones
- DDx of medullary nephrocalcinosis:
  - Medullary sponge kidney
  - RTA
  - Hyperparathyroidism
  - Milk Alkali Syndrome (calcium and antacids to treat dyspepsia → alkalosis and calcium phosphate stones)
- Rx –

33



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- DDx of medullary nephrocalcinosis:
  - Medullary sponge kidney
  - RTA
  - Hyperparathyroidism
  - Milk Alkali Syndrome (calcium and antacids to treat dyspepsia → alkalosis and calcium phosphate stones)
- Rx – potassium citrate
  - Titrate to correct metabolic acidosis

34

Hypocitraturia Treatment

Dietary
- Lemon/Orange juice
- OTC supplements
- Increase fruits/vegetables and limit non-dairy animal protein

K Citrate
- Urocit K – start 10-20 mEq BID
  - GI upset
  - Caution in renal failure
- Liquid Polycitra-K
  - GI malabsorption

Na Citrate
- Less GI upset
- Cheap
- Increase urinary sodium

35

36

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Etiology

Uric acid is the end product of purine metabolism

3 sources

Cellular RNA from cell turnover	Metabolic hepatic synthesis	Dietary intake of high purine foods

Manish KC and SW Leslie. StatPearls. 2023.

37

37

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Etiology – Uric Acid

Endogenous UA synthesis – 300mg – 400mg daily

Diet responsible < 50% daily total Uric Acid

- Typical Western diet 10 mg/kg body weight
- Higher purine diet → increase UA production **≠ UA stones**
  - Ammoniagenesis intact → adequate urinary pH buffering
  - Higher UA → calcium oxalate stones

Manish KC and SW Leslie. StatPearls. 2023.

38

Etiology

Idiopathic:

Low urine pH

Diabetes

Metabolic syndrome (Defect in renal ammoniagenesis and/or excretion)

Obesity

CKD (insufficient urinary ammonium excretion)

Acquired:

Gout

Chronic diarrhea (low urinary volume, hypocitraturia)

Cancer (high cell turnover)

Dietary factors (organ meats, poultry, fish)

Medications (probenecid, losartan)

Congenital:

Lesch-Nyan

Von-Gierke

Wilson's

Sickle Cell

Manish KC and SW Leslie. StatPearls. 2023.

39

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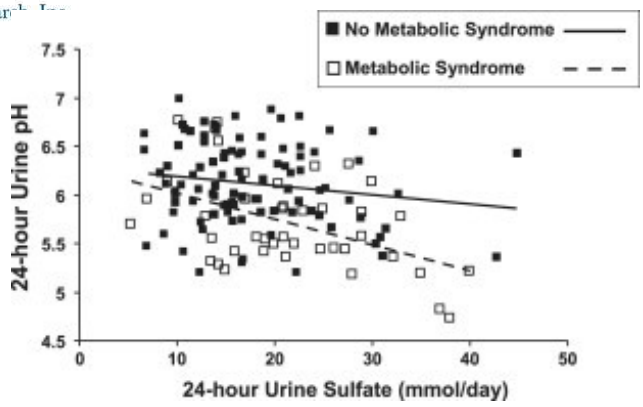

Maalouf, Journal of Renal Nutrition. 2011.

40

Rx - Hyperuricosuria (urine uric acid > 0.7 g/day)

- Avoid non-dairy animal protein
- Allopurinol 300 mg daily
  - xanthine oxidase inhibitor
  - Side effects – elevated LFTs, rash, cytopenias

****calcium stone formers with hyperuricosuria & normal urinary calcium****

41

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Uric acid stones are a pH issue

Uric acid stones are NOT a uric acid issue

42

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Uric Acid Stones - Rx

Potassium citrate – 90-120 mEq daily

Sodium bicarbonate

Sodium citrate

Potassium bicarbonate

Goal is for pH > 6

43

43

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OTC Option – "Sur Recipe":

1 tsp baking soda

1 lemon/line squeezed

½ orange

Mix & wait 15 minutes (bubbles)

Drink daily

44

45

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METABOLIC EVALUATION

CLASSIFICATION

Hypercalciuria	60%
Hypocitraturia	39%
Hyperuricosuria	35%
Hyperoxaluria	**8%**
1^0 HPT	3%
RTA	2%

Levy & Pak, 1995

46

PATHOGENESIS

- Disorders of Biosynthetic Pathways
  - 1° Hyperoxaluria
- Dietary
  - Excess dietary consumption
  - Vitamin C
  - Low Ca diet
- Enteric Hyperoxaluria
  - Inflammatory bowel disease
  - Small bowel resection
  - Bariatric surgery
  - Chronic diarrhea

47

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Stone Risk Factors / Cystine Screening: Negative (01/23/2023)

DATE	SAMPLE ID	Vol 24	SS CaOx	Ca 24	Ox 24	Cit 24	SS CaP	pH	SS UA	UA 24
01/20/23	S27090444	3.05	1.90	17	161	<46	0.03	5.590	0.37	0.270
01/18/23	S27090443	2.13	1.68	8	173	<32	0.01	5.382	0.69	0.269
REFERENCE RANGE		0.5 - 4L	6 - 10	male <250 female <200	20 - 40	male >450 female >550	0.5 - 2	5.8 - 6.2	0 - 1	male <0.800 female <0.750

Dietary Factors

DATE	SAMPLE ID	Na 24	K 24	Mg 24	P 24	Nh4 24	Cl 24	Sul 24	UUN 24	PCR
01/20/23	S27090444	154	38	101	1.493	30	129	14	8.93	1.2
01/18/23	S27090443	98	33	69	1.476	32	63	23	9.77	1.3
REFERENCE RANGE		50 - 150	20 - 100	30 - 120	0.6 - 1.2	15 - 60	70 - 250	20 - 80	6 - 14	0.8 - 1.4

Normalized Values

DATE	SAMPLE ID	WEIGHT	Cr 24	Cr 24/Kg	Ca 24/Kg	Ca 24/Cr 24
01/20/23	S27090444	56.3	592	10.5	0.3	28
01/18/23	S27090443	56.3	654	11.6	0.1	12
REFERENCE RANGE				male 11.9-24.4 female 8.7-20.3	<4	male 34-196 female 51-282

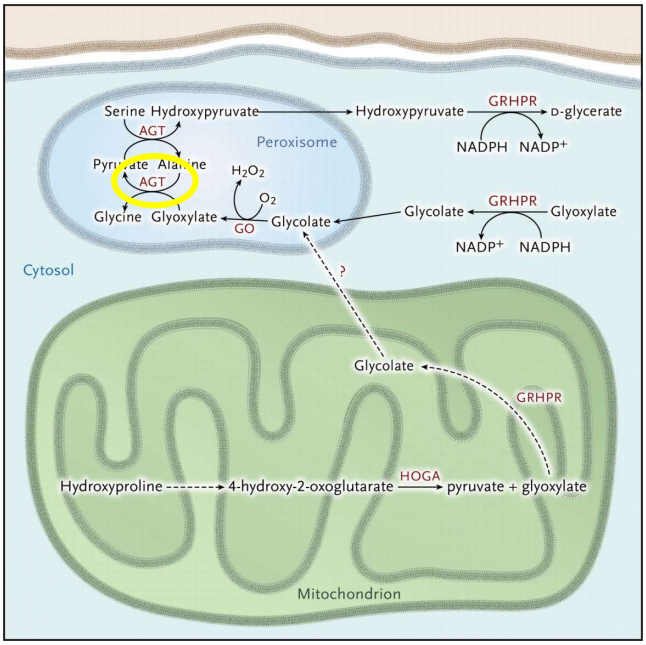
Consider Genetics Consult!

48

PRIMARY HYPEROXALURIA

- Congenital Autosomal Recessive
- Hepatic enzyme deficiency
  - Type I: Alanine-glyoxalate aminotransferase (AGT)
    - Pyridoxine (B6) is a co-factor for AGT
  - Type II: Glyoxylate reductase/hydroxypyruvate reductase (GR/HPR)
  - Type III: HOGA
- Very early age of onset
- Rx pyridoxine, fluids, urocitK
- Renal failure is inevitable
  - Only treatment option is combined liver / kidney transplant

49

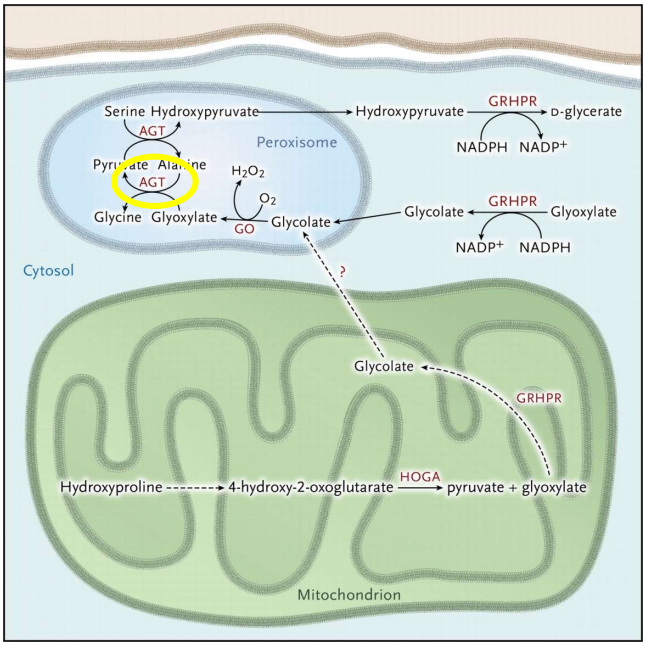


Cochat P, Rumsby G. N Engl J Med 2013;369:649-658.

Type 1 – defect in AGT

Glyoxylate → AGT → Glycine

50

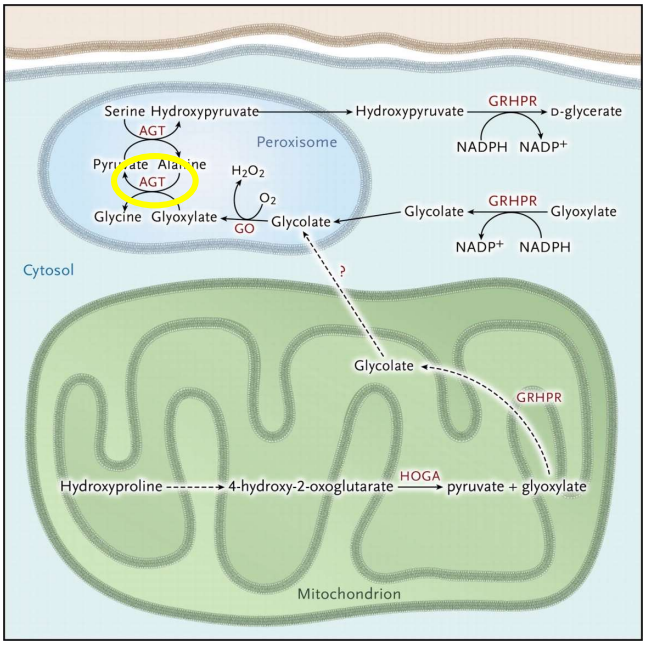


Cochat P, Rumsby G. N Engl J Med 2013;369:649-658.

Type 1 – defect in AGT

Glyoxylate → Glycine

51



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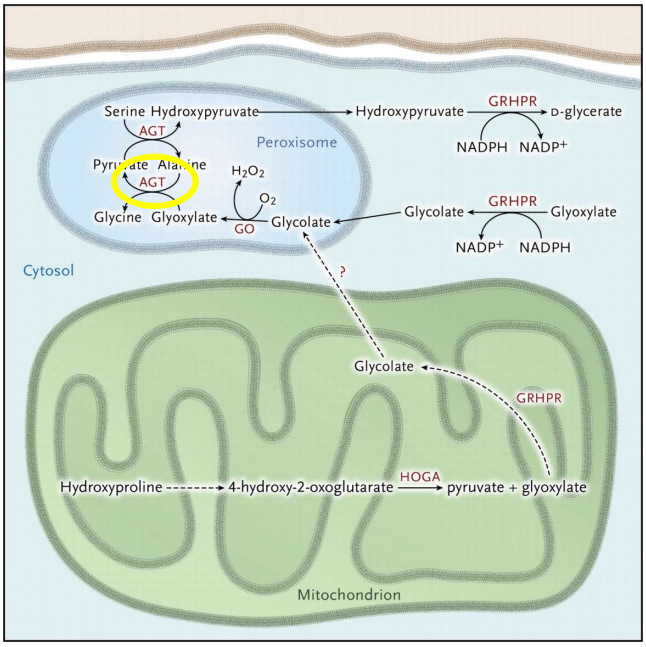
Type 1 – defect in AGT

Glyoxylate → Glycine

52



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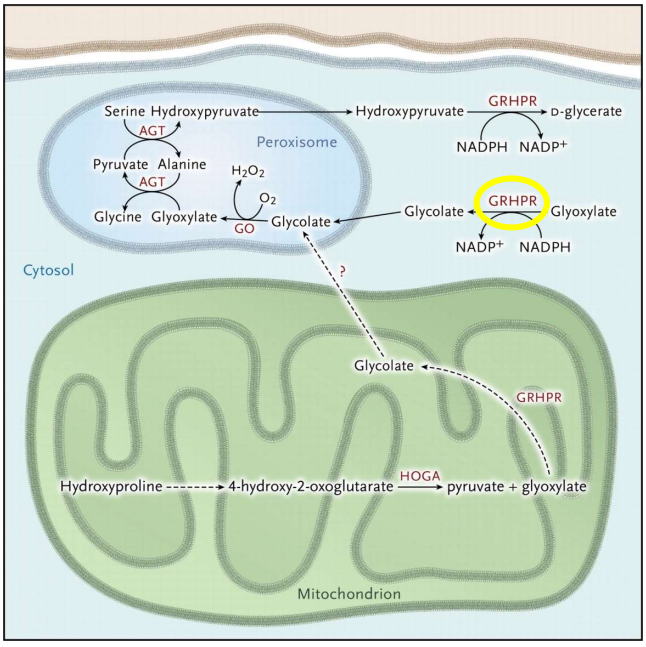
Type 1 – defect in AGT

Glyoxylate → LDH → Oxalate

53

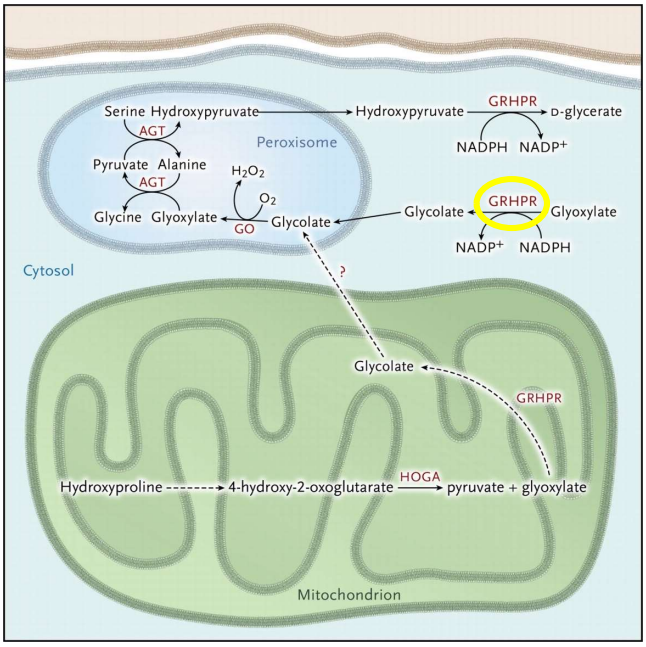


Cochat P, Rumsby G. N Engl J Med 2013;369:649-658.

Type 2 – defect in GPHGR

Glyoxylate → GRHPR → Glycolate

54



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Type 2 – defect in GPHGR

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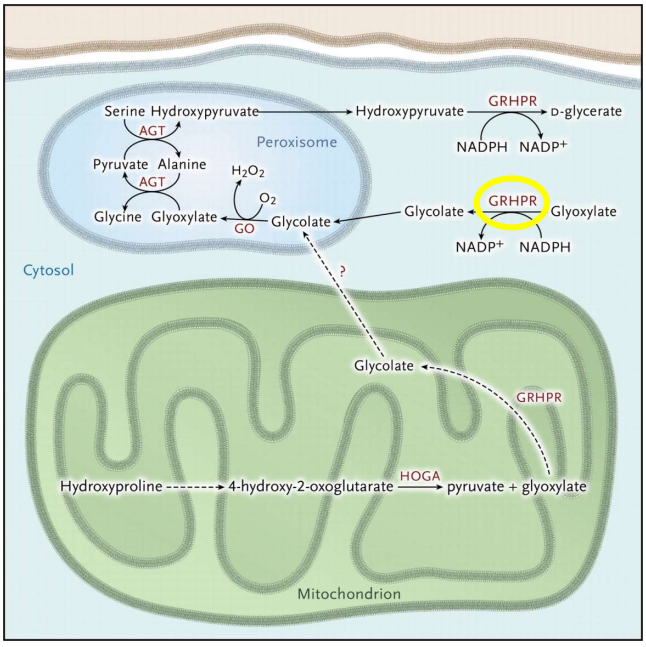
55



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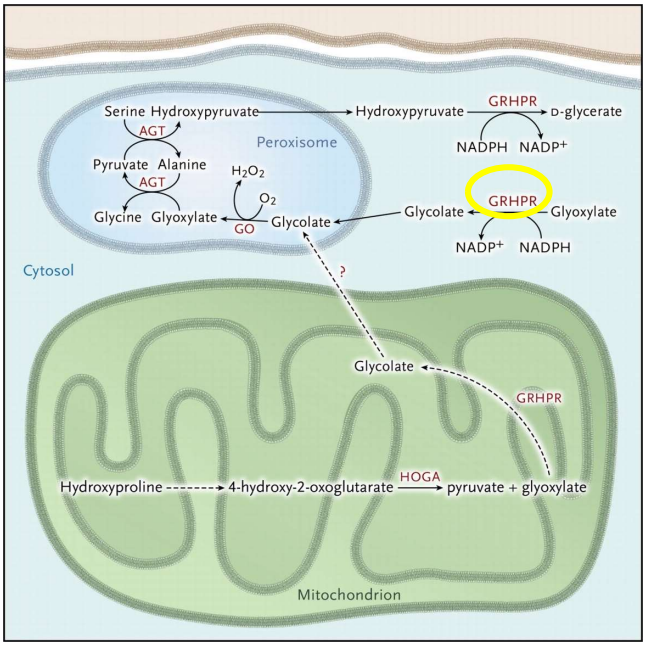
56



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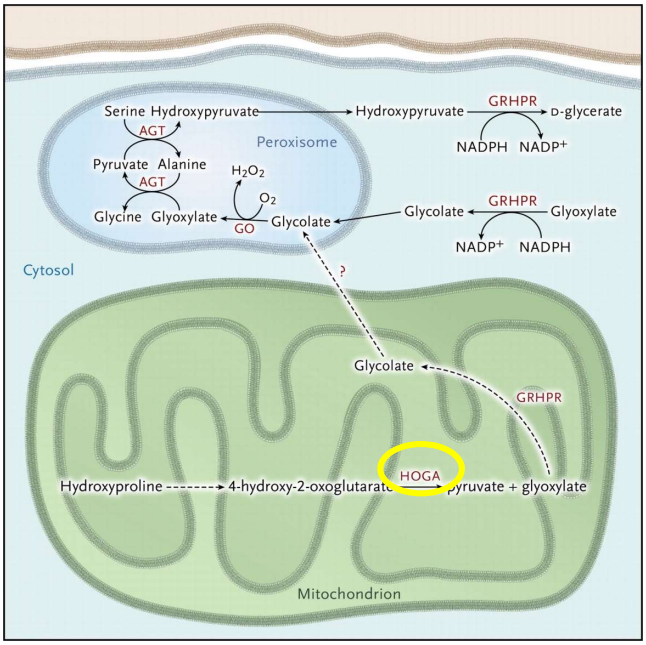
Glyoxylate → LDH → Oxalate

57



Cochat P, Rumsby G. N Engl J Med 2013;369:649-658.

Type 3 – defect in HOGA

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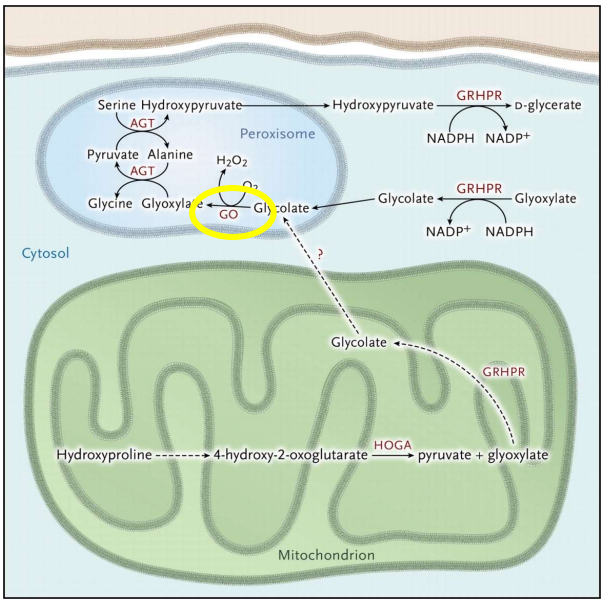
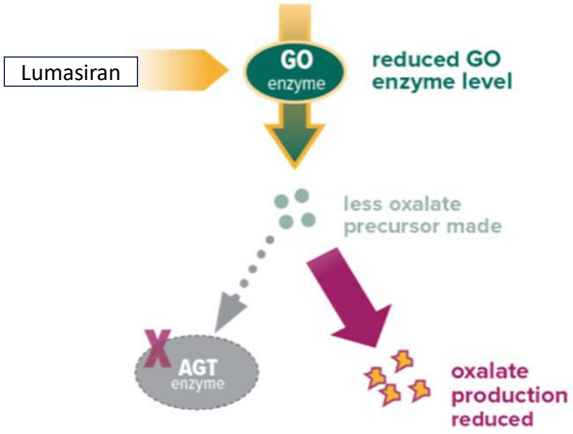
58



Cochat P, Rumsby G. N Engl J Med 2013;369:649-658.

Rx – RNA interference (RNAi)
Monthly subcutaneous Rx



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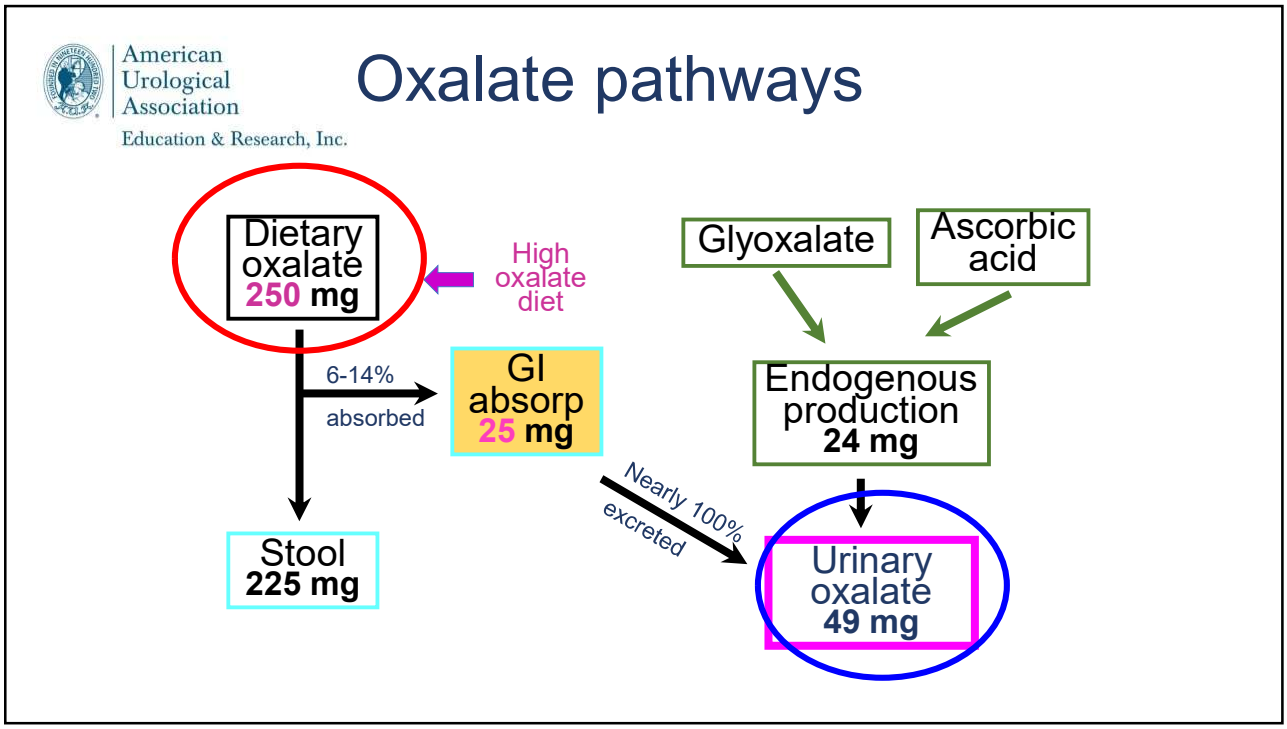
59

PATHOGENESIS

- Disorders of Biosynthetic Pathways
  - 1° Hyperoxaluria
- **Dietary**
  - **Excess dietary consumption**
  - **Vitamin C**
  - **Low Ca diet**
- Enteric Hyperoxaluria
  - Inflammatory bowel disease
  - Small bowel resection
  - Bariatric surgery
  - Chronic diarrhea

60



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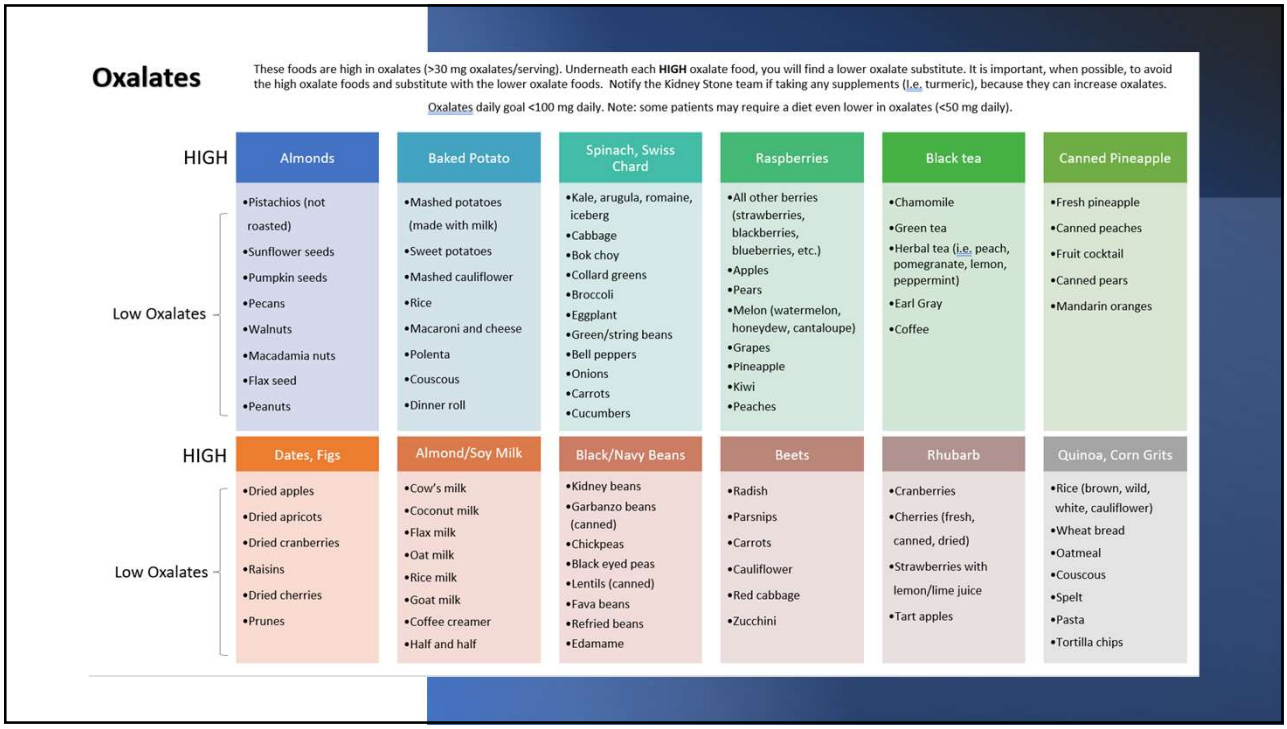

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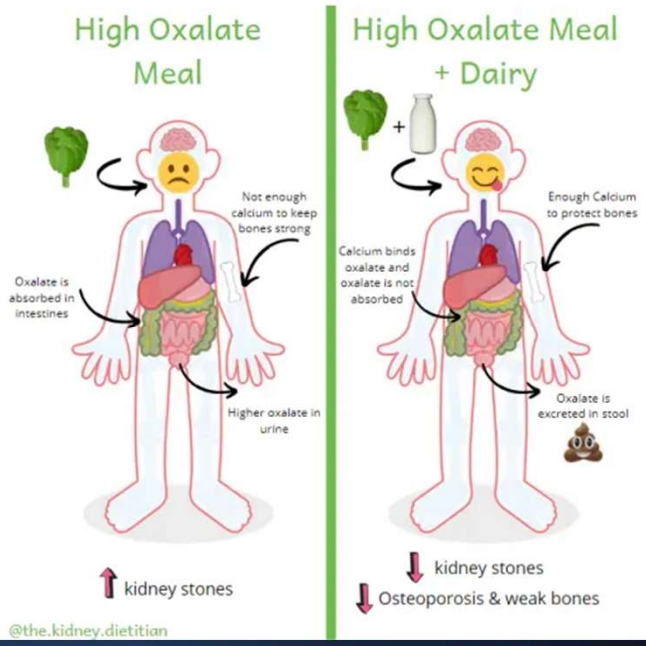

Calcium + Oxalate

63

Vitamin C – avoid it!

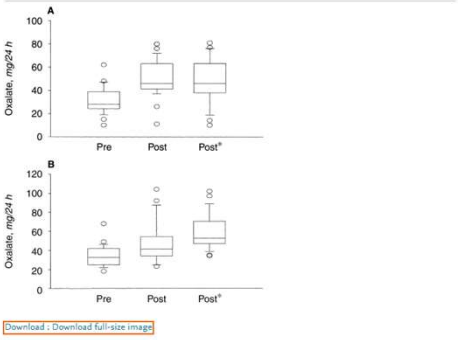

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Figure 2. **Box plots of urinary oxalate pre- and post-vitamin C with or without acid preservation in calcium stone-forming patients taking supplements of either 1 gram (*A*) or 2 grams (*B*).** The horizontal lines in the box denote the 25th, 50th, and 75th percentile values. The error bars denote the 5th and 95th percentile values. The symbols below the 5th percentile error bar denote the zero and 1st percentile values and the symbols above the 95th percentile error bar denote the 99th and 100th percentile.

Clinical Trial > Kidney Int. 2003 Mar;63(3):1066-71. doi: 10.1046/j.1523-1755.2003.00815.x.

Effect of vitamin C supplements on urinary oxalate and pH in calcium stone-forming patients

Alessandra Calábria Baxmann [1], Claudia De O G Mendonça, Ita Pfeferman Heilberg

Affiliations + expand

PMID: 12631089 DOI: 10.1046/j.1523-1755.2003.00815.x

64

PATHOGENESIS

- Disorders of Biosynthetic Pathways
  - 1° Hyperoxaluria
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  - **Bariatric surgery**
  - **Chronic diarrhea**

65

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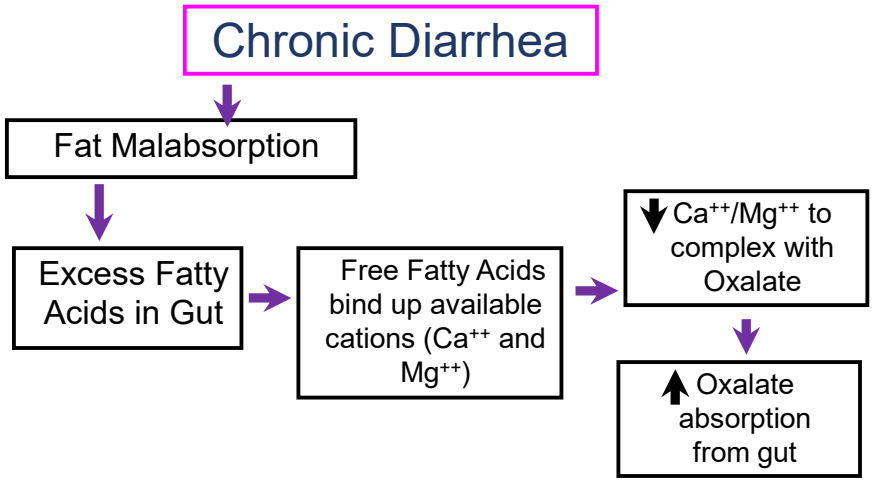
ENTERIC HYPEROXALURIA



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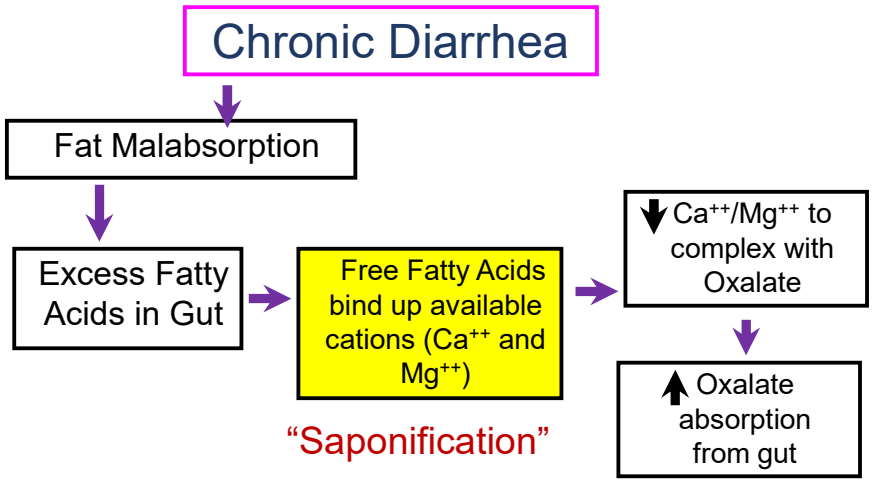
ENTERIC HYPEROXALURIA



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ADDITIONAL RISK FACTORS
FROM CHRONIC DIARRHEA

- Reduced urine output
  Fluid loses from the intestinal tract
- Hypocitraturia
  Metabolic acidosis
  Hypokalemia
- Hypomagnesiuria
  Impaired intestinal magnesium absorption

68

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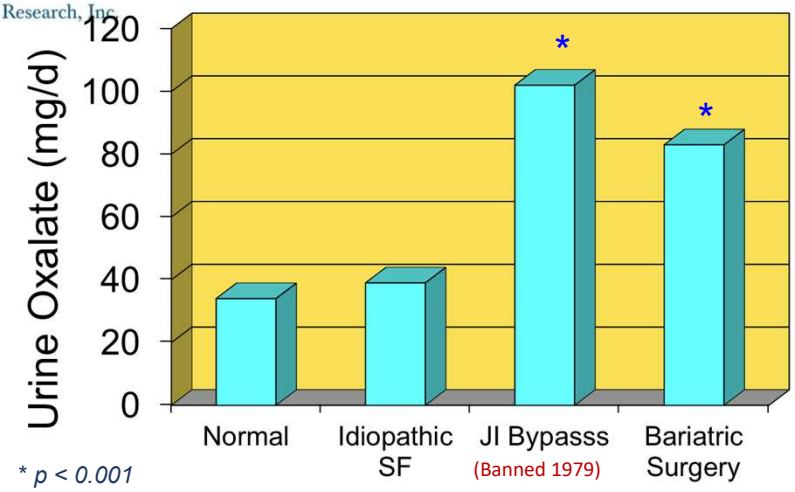
BARIATRIC SURGERY



* $p < 0.001$

Asplin & Coe, 2007

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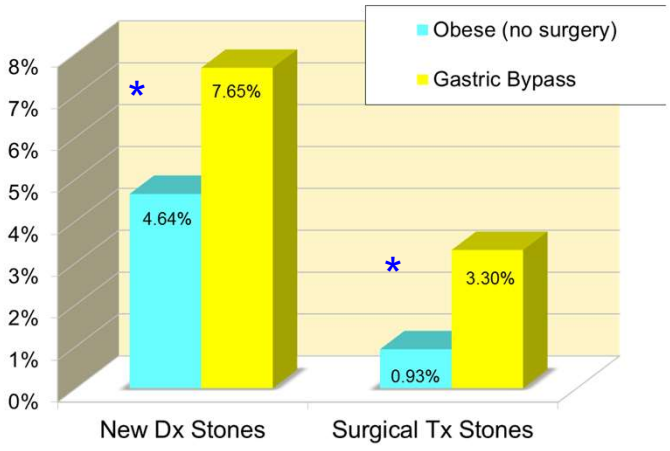
IMPACT OF BARIATRIC SURGERY

DEVELOPMENT OF STONE DISEASE



* $p < 0.0001$

Matlaga, et al, 2009

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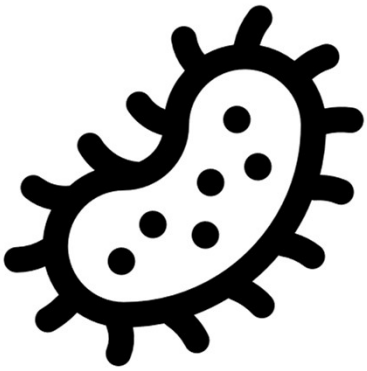

Oxalobacter formigenes

- Oxalate-degrading bacteria in large intestine
- Degrades oxalate
- Some stone formers have lower colony counts
- Cystic fibrosis patients – chronic antibiotics

71

Recommendations - hyperoxaluria:

- Low oxalate diet / meet with dietician
- 1,000 – 1,200 mg calcium a day with meals
- Consider calcium citrate with meals (esp. enteric hyperoxaluria)
- Avoid Vitamin C
- Pay special attention to bariatric surgery pts

72

73

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- Struvite (magnesium ammonium phosphate) or carbonate apatite calculi
- Often staghorns
- Urine pH > 7.5
  - Urea split to NH_3
- Produced by urea-splitting organisms
  - Proteus
  - Pseudomonas
  - Klebsiella
  - Staph

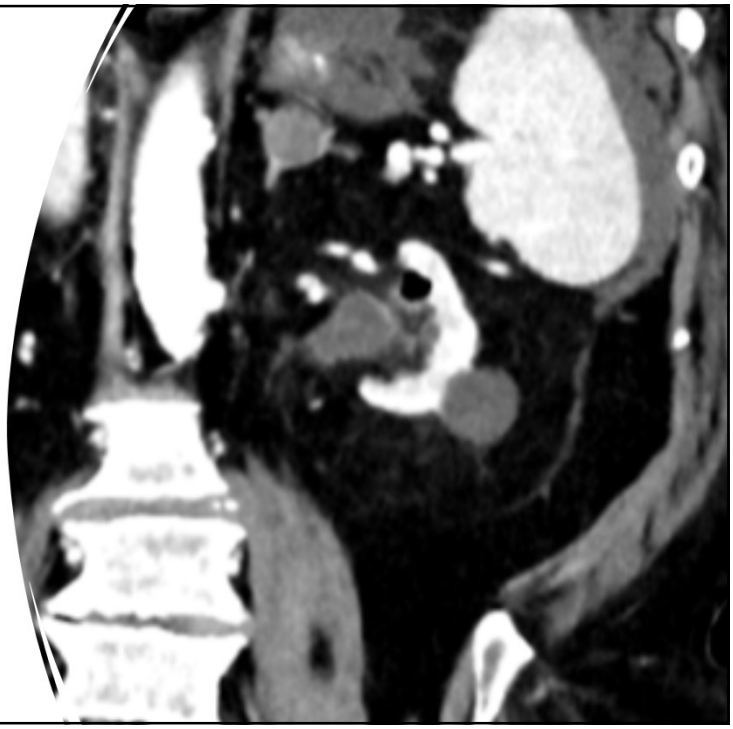
NOT E.Coli

74

74

What radiologic finding would indicate E. Coli?

- Air!
- Emphysematous Cystitis
- Emphysematous Pyelitis
- Emphysematous Pyelonephritis



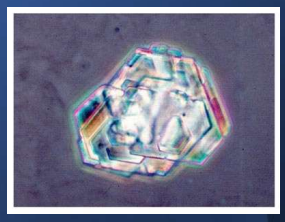
75

Infection Stone Treatment

- Complete elimination through surgery
- Monitor and prevent recurrent infection
  - Even if stone is treated monitor with UA/Culture (AUA guidelines)
- Acetohydroxamic acid (AHA, Lithostat®)
  - A urease inhibitor 250mg TID
  - Reduces urine pH and urea levels
  - Only use after all surgical options have been exhausted
  - **15% DVT**, poorly tolerated, rarely used in practice

76

76

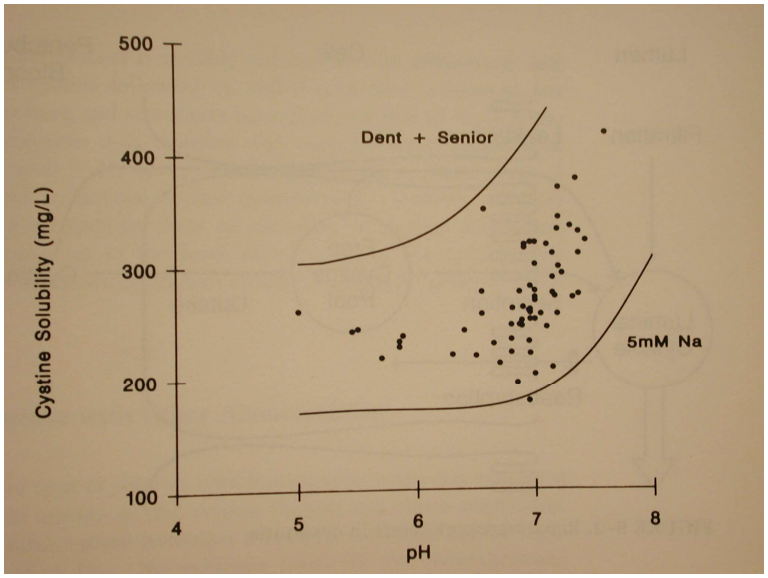


Cystinuria

- AR inborn error of metabolism, M=F
- Mutation of SLC7A9 and SLC3A1 result in abnormal proximal tubule transport (reabsorption) of COLA amino acids
- Diagnosis: stone analysis, positive cyanide-nitroprusside test (purple), or 24 hr. urine
- Homozygotes: > 400 mg/day (nl. < 18)
- Heterozygotes 100-400 mg/day
- Genetic counseling a must
- pKa is 7.5

77

Cystine Solubility Curve



78

Treatment of Cystinuria

- Methionine a precursor; diet unpalatable
- Forced diuresis; sodium and protein restriction°
  - Urine output goal 4L/day
- Alkalinize to keep urine pH > 7

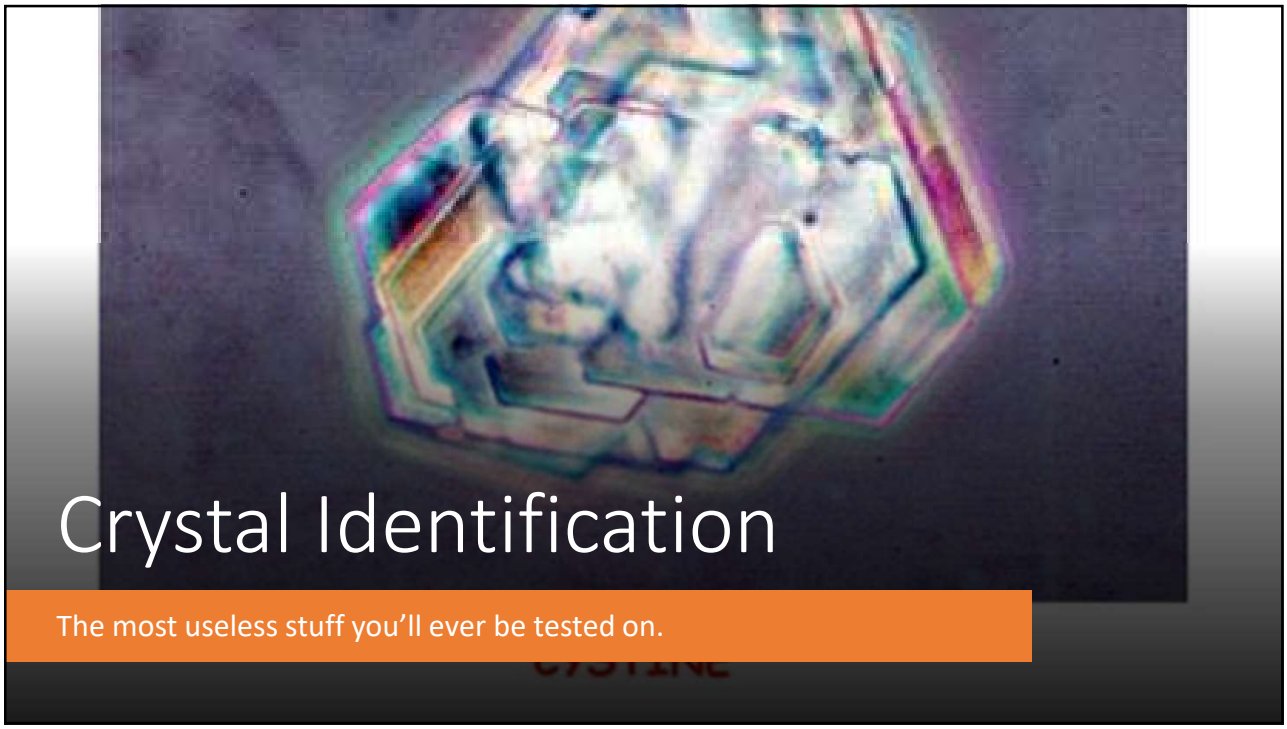
- °2014 AUA guideline recommendation

79

Treatment of Cystinuria

- Chelating agents to bind -SH group of cysteine:
  - D-penicillamine, Captopril, Tiopronin
- Keep cystine < 250 mg/day
- D-penicillamine: more toxic—GI upset, rash, arthralgias, bone marrow suppression, nephrotic syndrome
- Tiopronin (α-mercaptopropionylglycine):
  - Mechanism: forms a disulfide bond to increase solubility
  - Side effects: GI, fatigue, rash, hematologic, loss of taste, proteinuria
  - Monitoring: CBC, LFTs, Urine for protein

80



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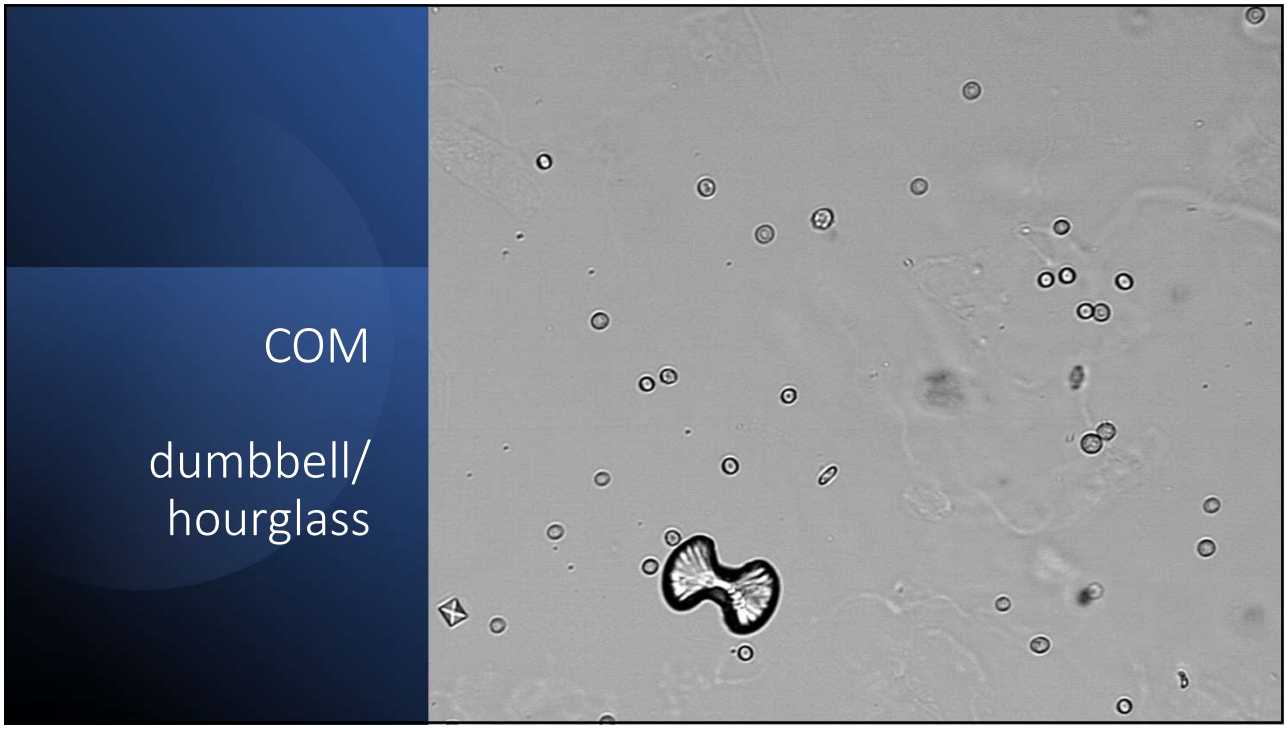

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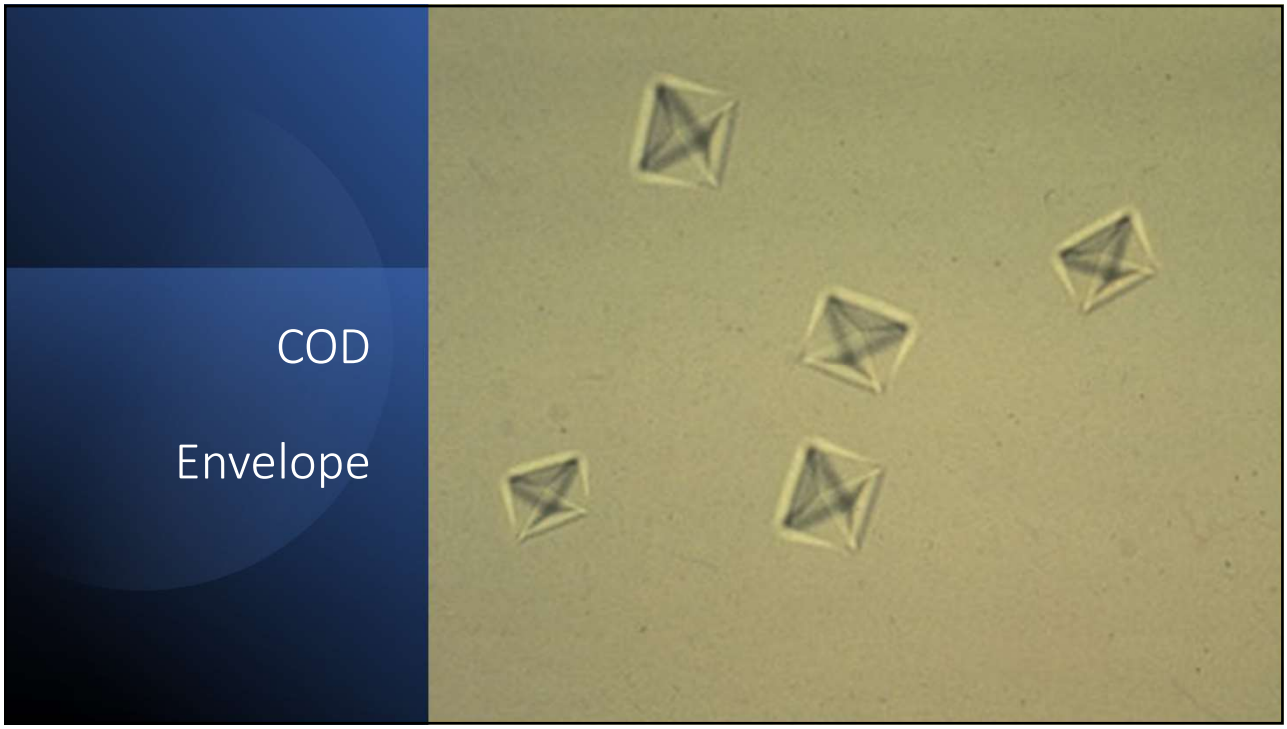

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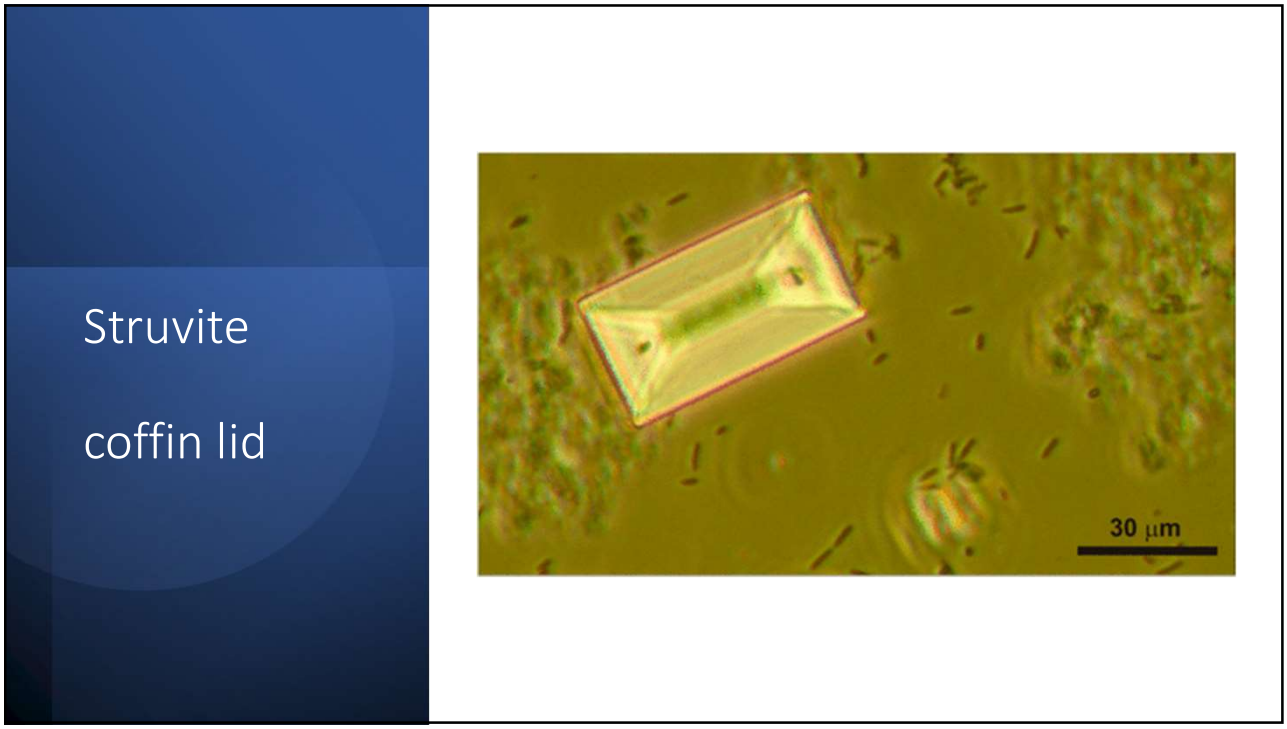
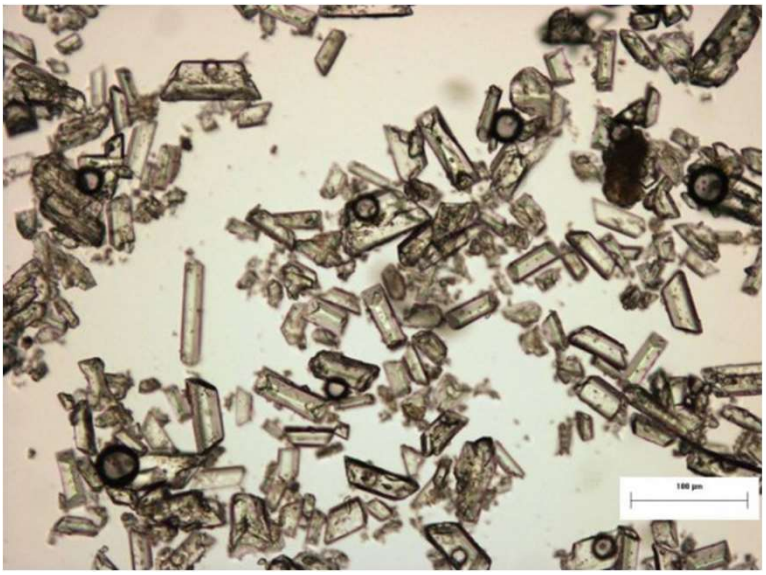


84

Carbonate Apatite

Amorphous



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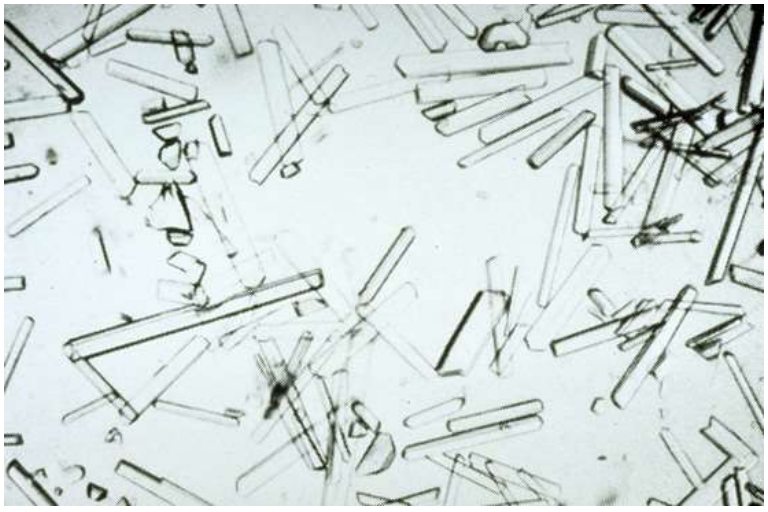
Brushite

needle shaped



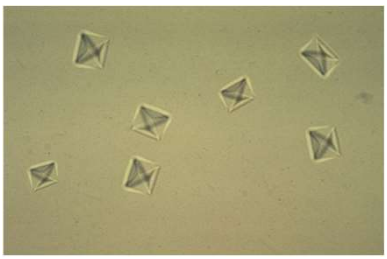
86

Crystal identification

- Cystine: hexagonal
- COM: dumbbell, hourglass
- COD: envelope
- Apatite: amorphous
- Brushite: needle-shaped
- Struvite: coffin lid
- Urate: irregular plates

COM

COD



87

Basic workup of stones

88

Lab Evaluation

CBC:

- Leukocytosis: mild (< 15K) common with colic; > 15K or left shift indicative of infection

Serum creatinine:

- Can be elevated due to dehydration or obstruction

High uric acid: gouty diathesis

High serum calcium: indicative of hyperparathyroidism

Hypokalemia and decreased CO2: distal (type 1) RTA

89

Basic workup of stones - Imaging

90

Radiographic Stone Appearance/ Stone Type (Etiology)

Densely radio-opaque:

- Calcium oxalate (Most common type 80%)
- Calcium phosphate (RTA, HPTH, Alkalinization)

Faintly opaque

- Struvite
- Cystine

Radiolucent

- Uric acid
- Triamterene (Triamterene therapy)
- Xanthine (Xanthinuria)
- Silica (Magnesium trisilicate therapy)
- 2,8-Dihydroxyadenine
- Crixivan

91

Ultrasonography

- Not reliable for small stones
- 30% detection rate in pts with colic
- Can miss intermittent obstruction or mild hydro (forniceal rupture can lead to this)
- Resistive index: (peak systolic—diastolic velocity)/peak systolic velocity
  - > 0.7 = acute ureteral obstruction
  - Difference of 0.04 from contralateral kidney also indicative
  - Especially helpful during pregnancy
- Absent or diminished ureteral jets may indicate obstruction
- Twinkling artifact: rapid random change in colors on stones and deep to stones detected by autocorrelation Doppler using an autoregressive method (Bailey et al, U. of Washington)

92

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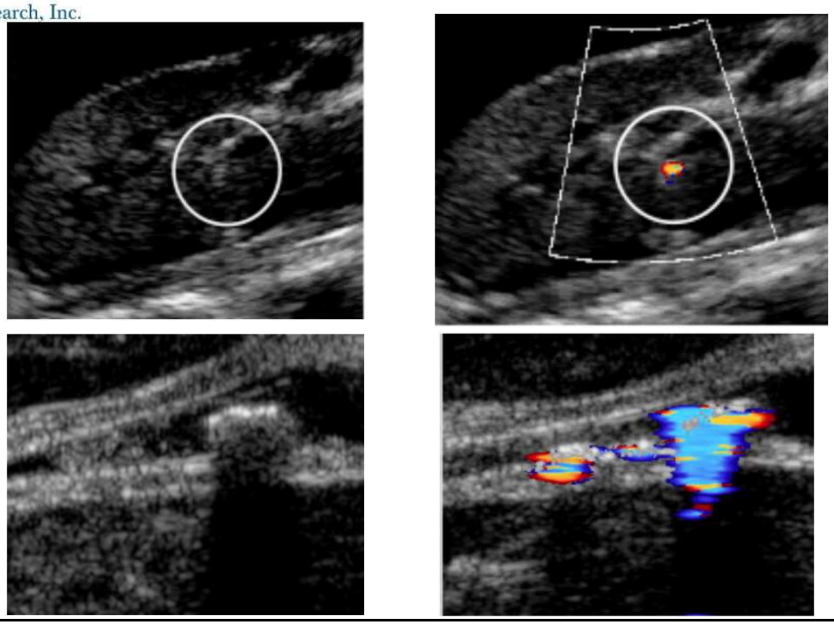
B mode vs Color Doppler



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CT Scan

Advantages

- Rapid and readily available
- 95% sensitivity
- Avoids IV contrast, contrast nephropathy and allergies
- Stone volume can be measured
- Density of stone useful in predicting stone composition and hardness
- Can rule out other causes of flank/abdominal pain such as appendicitis and AAA
- Secondary signs: perinephric stranding, reduced ipsilateral parenchymal density, renal enlargement from ipsilateral interstitial edema

Disadvantages

- Can not assess renal function or functional obstruction (except delayed nephrogram)
- $$$
- High radiation dose—can not be used for following stone progression*
- Can miss indinavir and atazanavir stones
- Small distal stones can be difficult to define—prone CT helpful for this
- Shape and size not as accurate as KUB

94

Imaging/Diagnosis of Ureteral Calculi

- Noncontrast CT preferred method for initial diagnosis
- Renal US and KUB acceptable in known opaque stone formers
- Low dose CT (< 4mSv) preferred if BMI < 30
- Pediatrics: renal US initially; low-dose CT if needed
- Pregnancy: 1st line renal US; 2nd line MRI without contrast in 1st trimester, low dose CT in 2nd/3rd (up to 5 rads not associated with fetal anomalies or fetal loss)

• Based on AUA Clinical Guidelines on Imaging for Ureteral Stones

95

HUD

Hounsfield units:

- **Uric acid: 200-500**
- Struvite: 500-1000
- Cystine: 900-1200
- Calcium phosphate: 1250-1650
- Calcium oxalate: 1000-2000

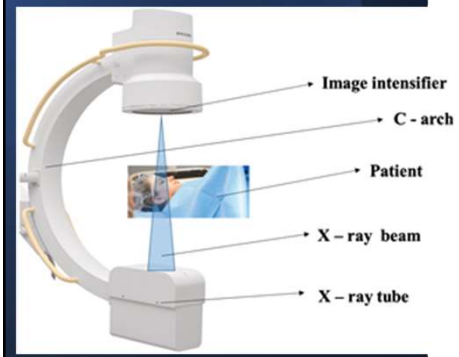
96

Radiation doses (mSv)

	Effective dose (mSv)	Reference
Ultrasound (US)		
Abdomen and pelvis US	0	
Magnetic Resonance Imaging (MRI)		
Abdomen and pelvis MRI	0	
Conventional Radiography (CR)		
KUB	0.7	A
KUB with tomograms	3.9	B
IVU	3.0	A, C
Computed Tomography (CT)		
Non-contrast CT, abdomen and pelvis	10.0	D,E
Without and with contrast CT, abdomen and pelvis (2-phase)	15.0	F
Without and with contrast CT, abdomen and pelvis (3-phase)	20.0	A
Non-contrast CT, abdomen and pelvis (low-dose protocol)	3.0	G

97

Decrease Radiation Fluoroscopy -



Collimate

Low-dose + pulsed

If image underpenetrated, increase the kVp rather than the mA

- kVp controls the penetrating power of the x-ray beam
- mAs control # of x-rays

X-ray tube below the table (max distance from the patient) and image intensifier above the table (close to the patient)

98

Guidelines – Surgical Management of Stones

A brief overview

99

Pre-op testing

- Non-contrast CT scan should be done prior to PCNL. *Strong Recommendation*
- Non-contrast CT scan should be offered to decide SWL versus URS
- May obtain a functional imaging study (DTPA or MAG-3) if clinically significant loss of renal function is suspected
- Urinalysis MUST be obtained prior to intervention. In patients with clinical or laboratory signs of infection, urine culture should be obtained
- CBC and platelet count if significant risk of hemorrhage or if anemia, thrombocytopenia, or infection; serum electrolytes and creatinine should be obtained if there is suspicion of reduced renal function
- If complex stones or anatomy, obtain contrast imaging if further definition of collecting system or ureteral anatomy is needed

100

Follow up Imaging

- Spontaneous passage: no further imaging needed in most patients
  - *trust but verify*
- ESWL: imaging recommended to rule out residual fragments and/or hydronephrosis
- URS: imaging recommended to rule out silent hydronephrosis

101

Adult Patient with Ureteral Stone

≤10 mm should offer observation; if distal should offer MET with α-blockers		

102

Important Prognostic Factors

Hydronephrosis: not by itself a determinant of need to intervene

- Lowers success rate of ESWL; less impact on URS

Stone size and location: predictive of stone passage

- Ueno et al (Urology, 1977): 286/520 (53%) ureteral stones pass spontaneously
  - Mean passed stone: 6.3 x 4.0 mm
  - Mean stone requiring procedure: 11.7 x 7.1 mm

Time to stone passage: Miller and Kane, J Urol 1999

- < 2 mm wide: 31 days
- 2-4 mm: 40 days
- 4-6 mm: 39 days

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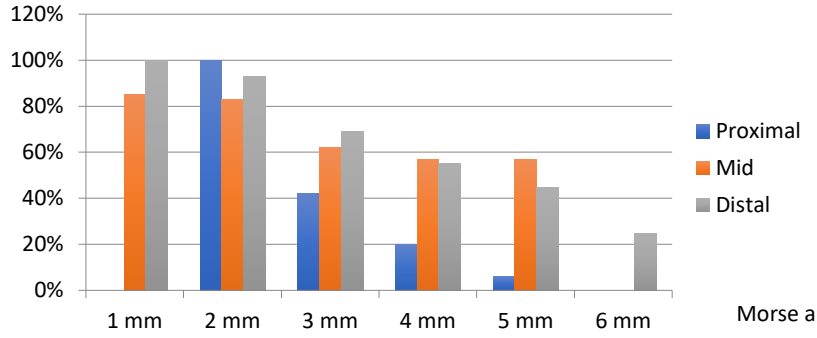
Spontaneous Stone Passage

Location/Size	1 mm	2 mm	3 mm	4 mm	5 mm	6 mm
Proximal		100%	42%	20%	6%	
Middle	85%	83%	55%	62%	57%	
Distal	100%	93%	69%	55%	45%	25%



Morse and Resnick, J Urol, 1991

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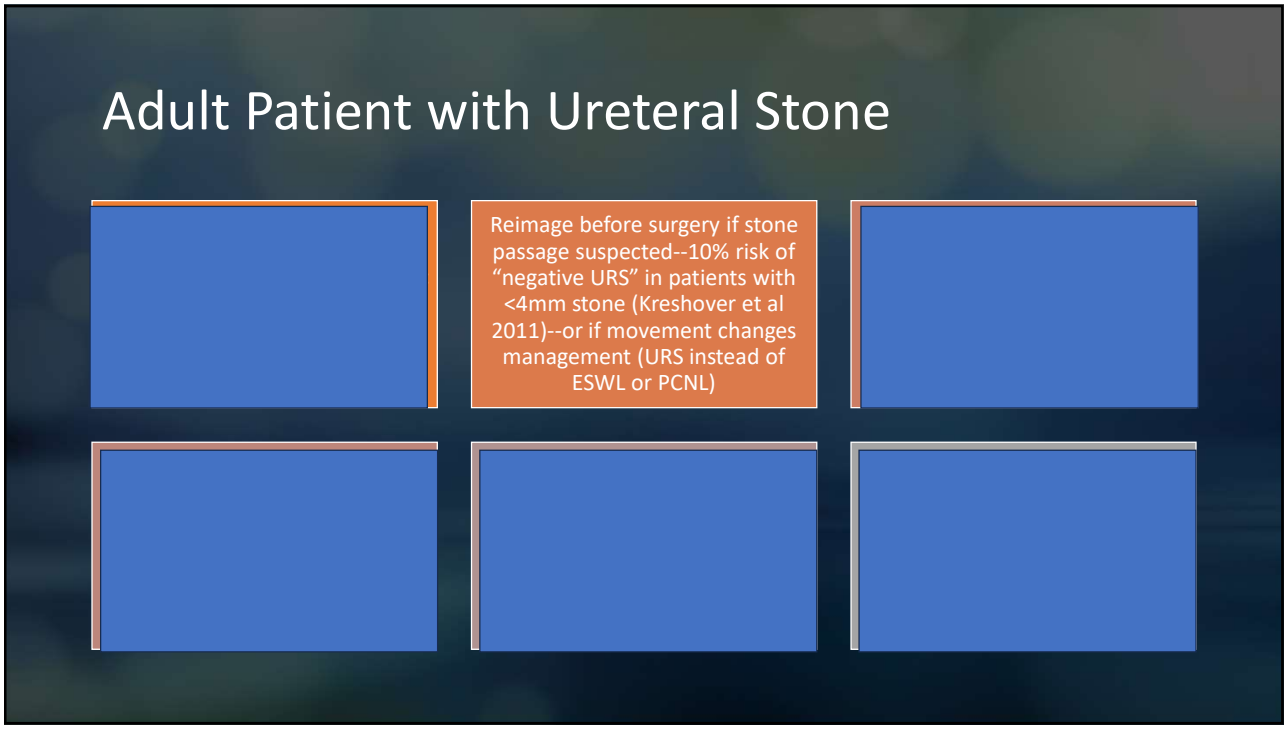

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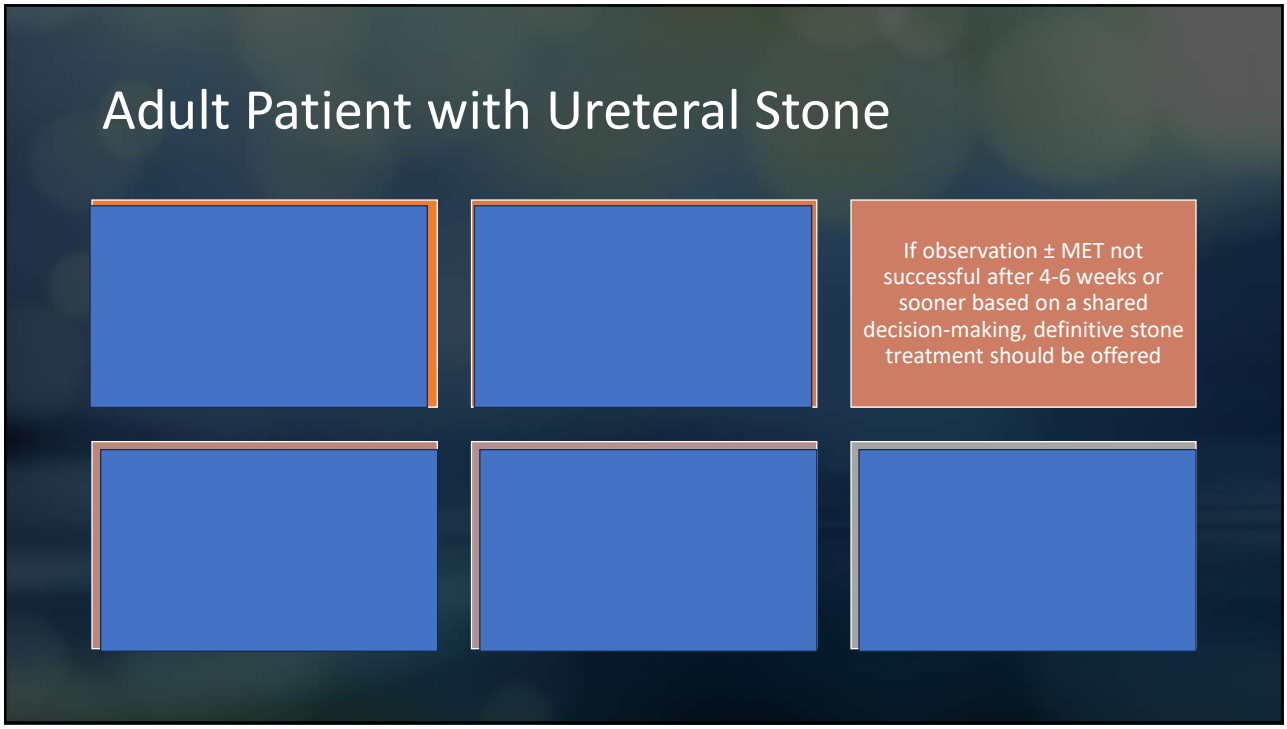

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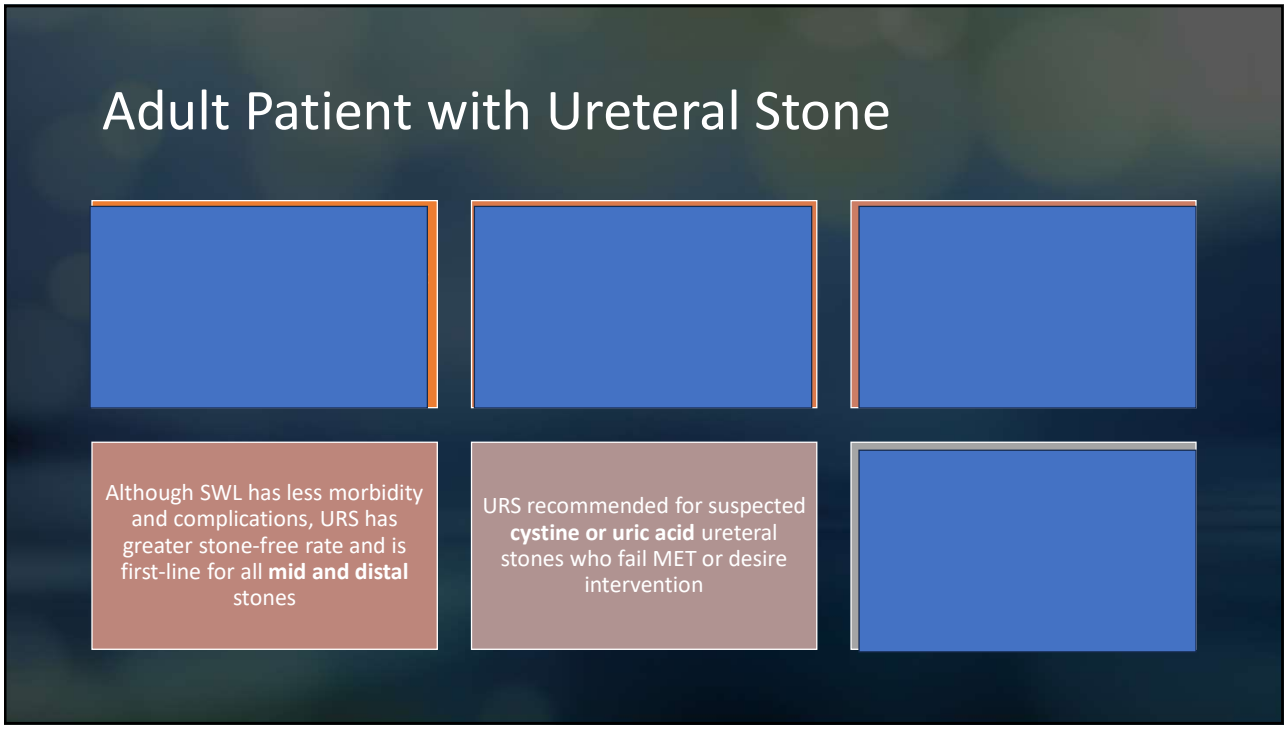

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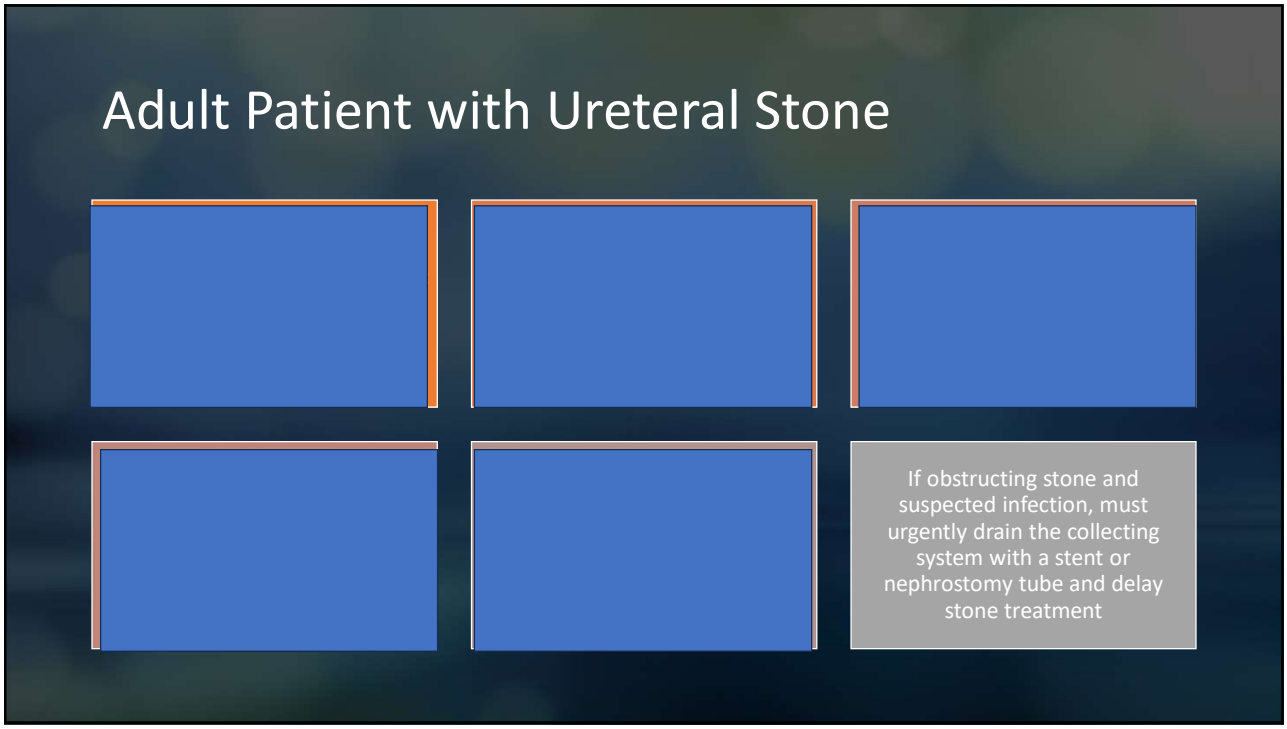

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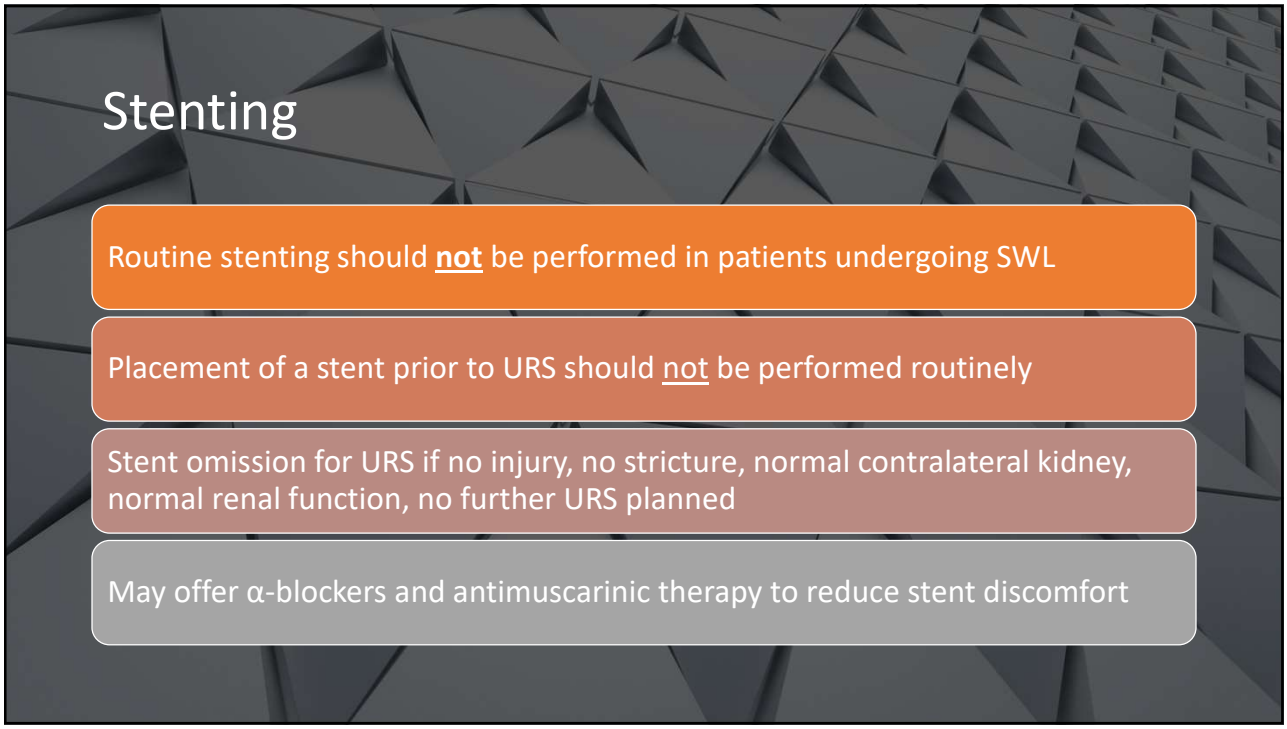

109

AUA Guidelines: Adult Patient with Renal Stone

Asymptomatic, non-obstructing caliceal stones: can offer active surveillance (exception: pilots, solitary kidney)

PCNL/URS:

- If uncomplicated and presumed stone-free, nephrostomy tube optional; flexible nephroscopy should be routine
- Must use normal saline irrigation for PCNL and URS.
- Staged URS may be offered if not candidate for PCNL
- Staghorn stones should be removed if comorbidities allow

SWL

- Should not be used if anatomic or functional obstruction of the collecting system or ureter distal to the stone
- Should not be first line for symptomatic caliceal diverticular stones
- α-blockers may facilitate passage of stone fragments following SWL

110

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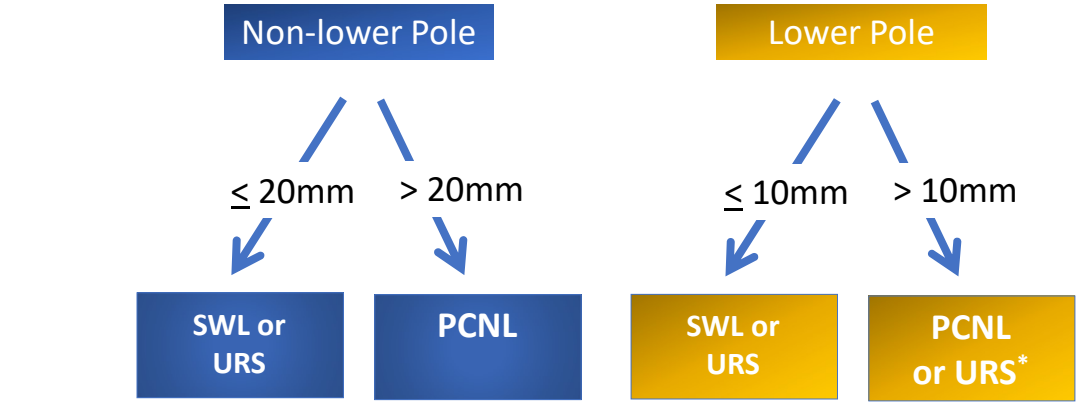
Symptomatic Renal Stones



Can offer treatment to patients with non-obstructing, symptomatic stones

*URS less morbid but lower SFR

From Sara Best

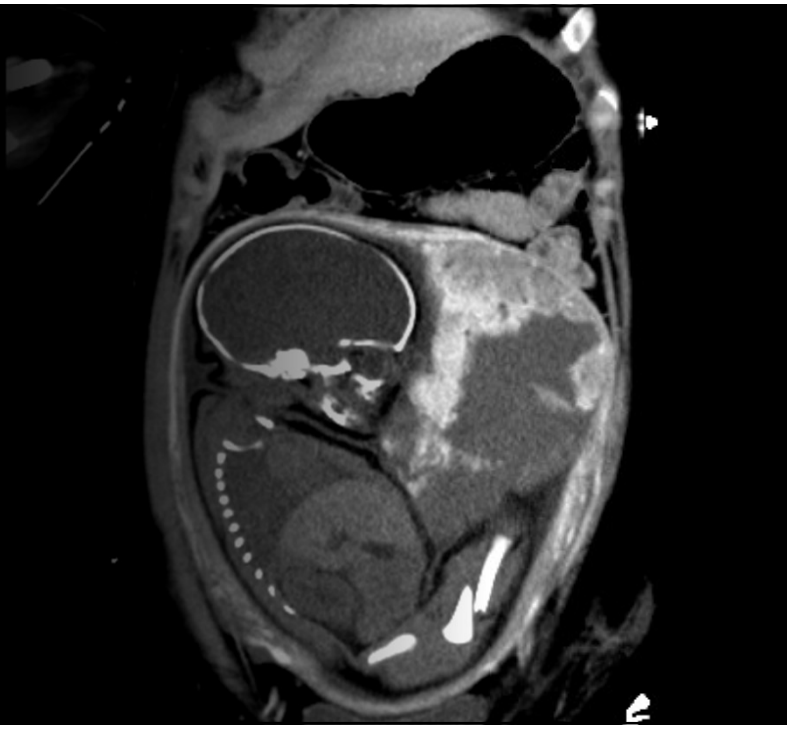
111

AUA Guidelines: Pediatric Stones

- Uncomplicated ureter stones ≤10 mm: offer observation ± MET
- URS or SWL if unlikely to pass the stone or if fails observation and/or MET
- Should not routinely place a stent prior to URS
- **Total renal stone burden ≤ 2 cm: offer SWL or URS first-line**
- **>20mm, both PCNL and SWL are acceptable; if SWL is utilized, clinicians should place an internalized ureteral stent or nephrostomy tube**
- Low-dose CT scan prior to PCNL
- Open/laparoscopic/robotic surgery for upper tract stones should not be done, except in cases of coexisting anatomic abnormalities
- Asymptomatic and non-obstructing renal stones: may utilize active surveillance with periodic ultrasonography

112

Pregnancy & Stones



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WHY?

Factors ↑ Stone Risk

- Increased GFR & RPF 20-25%
  - Increased filtered loads of Ca, Na, Uric acid
- Absorptive hypercalciuria 2/2 placental Vitamin D synthesis
- Stasis → infection → increased pH → CaPh stones

Factors ↓ Stone Risk

- ↑ excretion citrate, Mg, glycoproteins
- Forced diuresis from ↑ GFR & RPF
- Increased blood volume

Overall similar incidence in pregnant vs. non-pregnant women

1. Pedro et al. International Journal of Surgery 2016.
2. G. Massellii et al. Clinical Radiology 2015.

114

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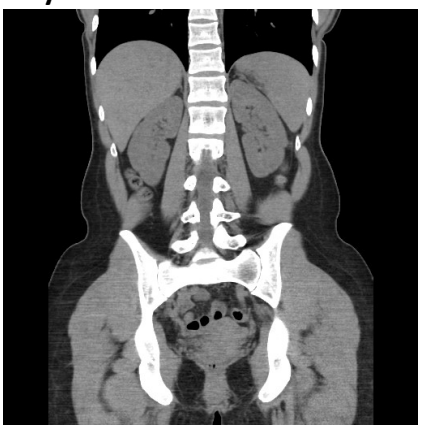
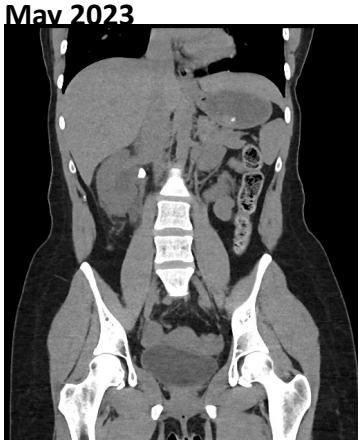
28-year-old F

May 2022



May 2023



115

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Why do we care?

Association with premature delivery

DRESCHER ET AL. UROLITHIASIS 2018.

116

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Urolithiasis. 2019 Oct;47(5):441-448. doi: 10.1007/s00240-018-1085-3. Epub 2018 Oct 27.

Antepartum nephrolithiasis and the risk of preterm delivery

Max Drescher [1], Robert H Blackwell [2 3], Parth M Patel [4], Paul C Kuo [3 5], Thomas M T Turk [2], Kristin G Baldea [2]

Affiliations + expand

- Pregnant women (CA & FL) admitted for delivery 2008-2011
- 2,750,776 deliveries
  - 3904 (0.14%) – antepartum nephrolithiasis
    - 71.4% managed conservatively
    - 20.6% urologic intervention
    - 8.0% PCNT

117

Preterm Delivery

No stone – Baseline 7.0% → 9.1% - conservative → 11.2% - urologic intervention → 19.6% - PCNT

Multivariable –
- Conservative (aOR 1.3)
- Intervention (aOR 1.5)
- PCNT (aOR 2.3)

DRESCHER ET AL. UROLITHIASIS 2018.

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Comparative Study > Obstet Gynecol. 2007 May;109(5):1099-104.
doi: 10.1097/01.AOG.0000259941.90919.c0.

Admission for nephrolithiasis in pregnancy and risk of adverse birth outcomes

Mia A Swartz [1], Mona T Lydon-Rochelle, David Simon, Jonathan L Wright, Michael P Porter
Affiliations + expand
PMID: 17470589 DOI: 10.1097/01.AOG.0000259941.90919.c0

- Washington state
- 2,239 women admitted for nephrolithiasis
  - 1.7 per 1,000 deliveries
- **Nearly double the risk of preterm delivery**

Table 3. Crude and Adjusted Odds Ratios for Birth Outcomes of Interest

Selected Birth Outcomes	Odds Ratio (95% CI)	Adjusted Odds Ratio (95% CI)
Preterm delivery	1.72 (1.46–2.04)	1.79 (1.51–2.13)*
Very preterm delivery	1.11 (0.67–1.83)	1.13 (0.68–1.88)†
Low birth weight	1.38 (1.11–1.71)	1.02 (0.79–1.33)‡
PROM	1.12 (0.97–1.30)	1.08 (0.93–1.26)‡
Preterm PROM	1.60 (1.00–2.60)	0.95 (0.57–1.59)‡
Infant death	0.84 (0.44–1.59)	0.74 (0.37–1.47)‡

PROM, premature rupture of membranes.
* Adjusted for age (3-year groupings), race, and payer.
† Adjusted for age (3-year groupings), race, payer, gestational age, and diagnosis of pyelonephritis.
‡ Adjusted for age (3-year groupings), race, payer, and gestational age.

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Table 4. Selected Potential Risk Factors for Preterm Delivery in Pregnant Women Admitted for Nephrolithiasis

Maternal Risk Factor	n (%)	Preterm Birth [OR (95% CI)]	*P* (Likelihood Ratio Test)
Procedures for kidney stone			.94
Controls	6,729 (75.5)	Referent	
Stone, no procedure	1,725 (19.4)	1.72 (1.42–2.08)	
Stone, had a procedure	453 (5.1)	1.69 (1.22–2.34)	
Trimester of admission			.93
Controls	6,729 (75.3)	Referent	
First trimester	101 (1.1)	2.04 (1.10–3.77)	
Second trimester	594 (6.7)	1.82 (1.37–2.40)	
Third trimester	1,512 (16.9)	1.76 (1.44–2.14)	

* Adjusted for maternal age, payer, and race.

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Multidisciplinary approach

Urology, **Obstetrics**, Radiology, Anesthesia, Neonatology

121

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Hydronephrosis

Obstructive vs physiologic?

122

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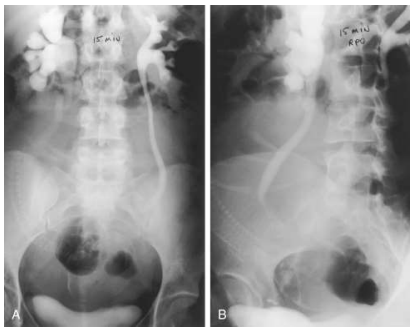
Physiologic Gestational Hydronephrosis

- 90% pregnant women beginning 6-11 weeks
  - R > L
- High levels of progesterone → relaxation of ureteric smooth muscle, decrease peristalsis
- Mechanical compression of the ureters



Pedro et al. International Journal of Surgery 2016.
Obstetrics: Normal and Problem Pregnancies. 7th Ed. 2017.

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Physiologic Hydronephrosis

- 0.2% admissions for symptomatic hydronephrosis
- Poor correlation between flank pain & hydro
- Calyceal rupture rare complication
- Conservative treatment should be favored
- Stent does not generally add benefit

*Slide content courtesy of Dr. Kaufman

Tsai YL et al. Acta Obstet Gynecol Scand. 2007.

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Imaging:

- 1st line – **ultrasound**
  - Renal arterial resistive index (RI)
    - = peak systolic velocity – end diastolic velocity
    - Not elevated by pregnancy
    - ↑ within 6 hours of acute obstruction
    - A difference ≥ 0.04 in RI between symptomatic kidney & opposite kidney 99% accurate for obstruction
    - RI ≥ 0.70 on symptomatic side 87% accurate

G. Massellii et al. Clinical Radiology 2015.

125

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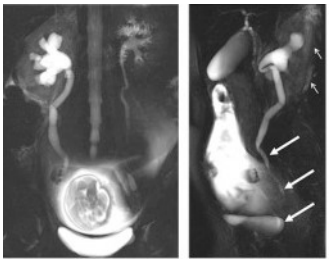
Imaging:

- 2nd line – **MRI** (without contrast)
  - Can detect a filling defect (stone) 50% of patients with stone on CT
    - + perinephric fluid, ureteral dilation → sensitivity 84%, specificity 100%, and accuracy of 86% (in general population)
- Cons:
  - Require radiology expertise
  - Limited visibility of small calculi
  - Patient discomfort
    - Lie patient on side contralateral to symptoms



G. Massellii et al. Clinical Radiology 2015.

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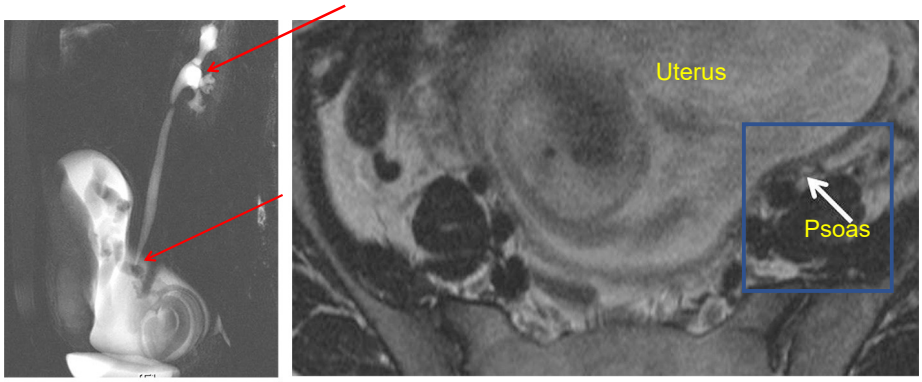
Physiologic Hydronephrosis:



G. Massellii et al. Clinical Radiology 2015.

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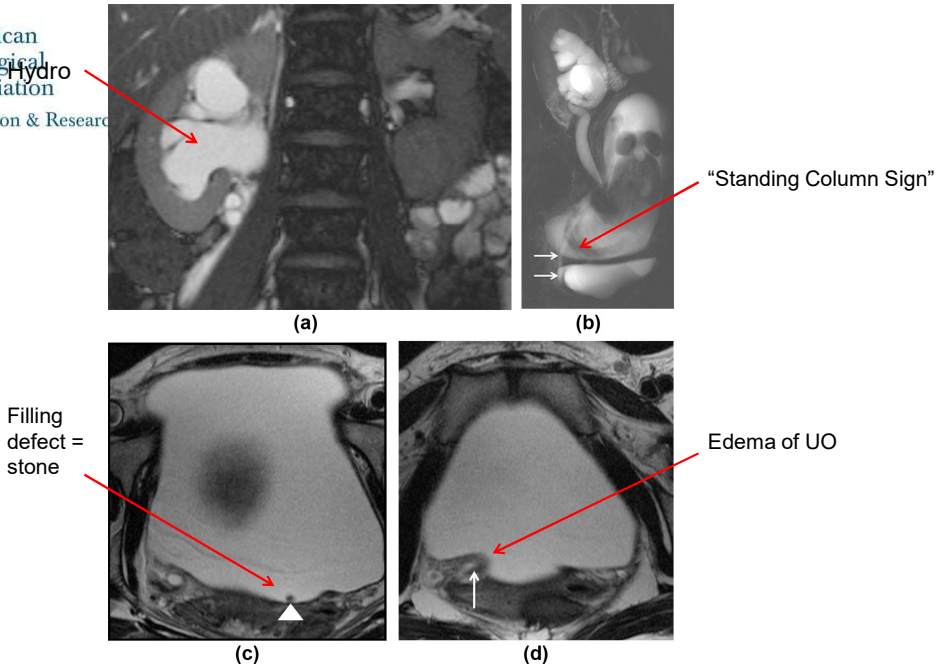

Masselli et al. Clijnical Radiology 2015

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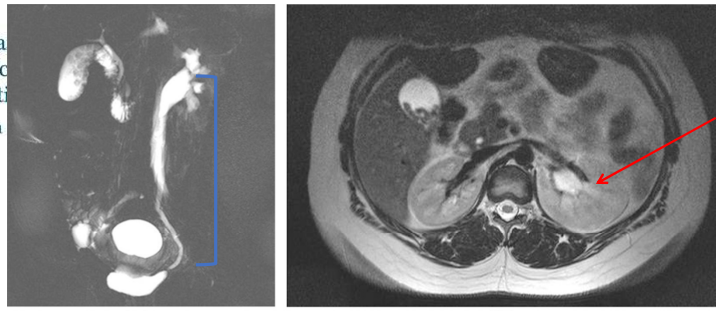
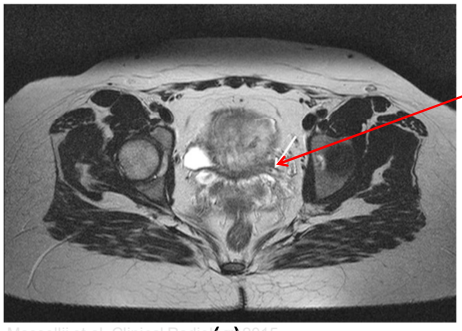


(a) (b)

Swelling & edema of L kidney + mild hydro



(c)

Filling defect in distal ureter = stone

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G. Massellii et al. Clinical Radiology 2015.

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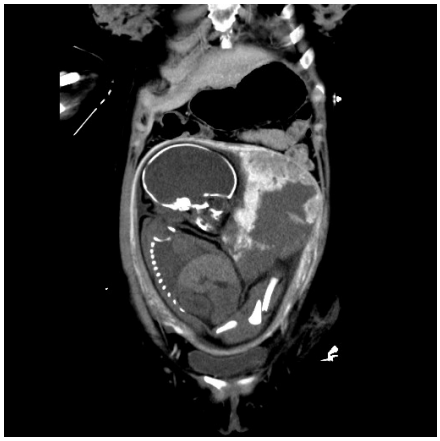
Imaging:

- 3rd line – **Low-dose non-contrast CT**
  - 98% sensitivity and specificity
- Cons:
  - Ionizing radiation
    - Highest teratogenic risks 1st trimester
    - Dose < 50 mGy considered safe
      - Low-dose protocol fetal exposure 4 mGy



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G. Massellii et al. Clinical Radiology 2015.

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ACOG:

use increased by 25% per year from 1997 to 2006 (1). Use of CT and associated contrast material should not be withheld if clinically indicated, but a thorough discussion of risks and benefits should take place (8). In the evaluation for acute processes such as appendicitis or small-bowel obstruction, the maternal benefit from early and accurate diagnosis may outweigh the theoretical fetal risks. If accessible in a timely manner, MRI should be considered as a safer alternative to CT

131

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Medical Expulsive Therapy Is Appropriate! (if no infection)

- 75-85% symptomatic stones will spontaneously pass[1]
  - Physiologic hydroureter
- **Hydration**, narcotics, Tamsulosin (Class B)[2]
  - No NSAIDS
- 52.4% risk of UTI with symptomatic urolithiasis → prophylactic antibiotics[3]

1. Obstetrics: Normal and Problem Pregnancies. 7th Ed. 2017
2. Cloutier et al. World J Urol 2019.
3. Korkes et al. J Bras Nefrol 2014.

132

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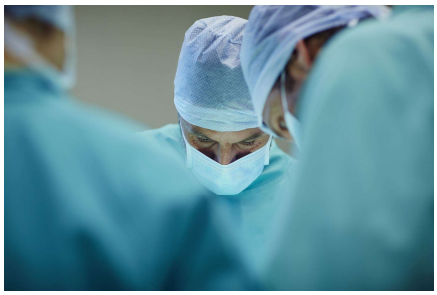
Surgical Management:

- Indications:
  - Infection*
  - Uncontrolled pain
  - Persistent vomiting
  - Obstetric concerns
  - Solitary kidney
  - Bilateral ureteral stones
  - Worsening clinical scenario



Pedro et al. International Journal of Surgery 2016.

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Surgical Management:

Drainage –
stent vs nephrostomy tube

Fine to offer to patients who fail observation!

Definitive stone treatment

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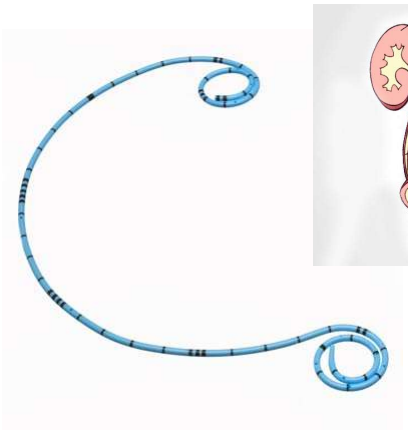
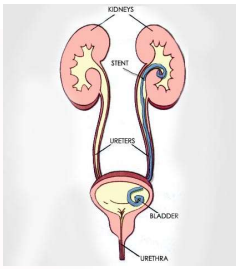
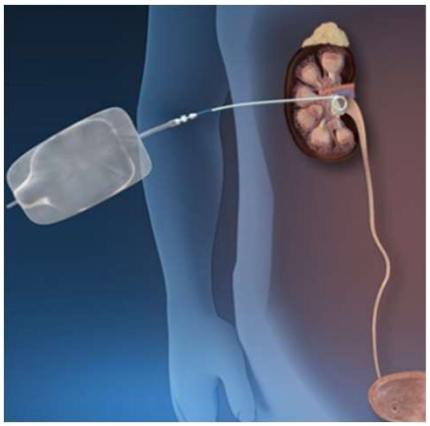
Stent vs. nephrostomy tube





HTTPS://WWW.UROLOGYSANANTONIO.COM/URETERAL-STENTS#POST/0



https://www.mykidneystone.com/en-US/life-after-surgery/nephrostomy-tube.html

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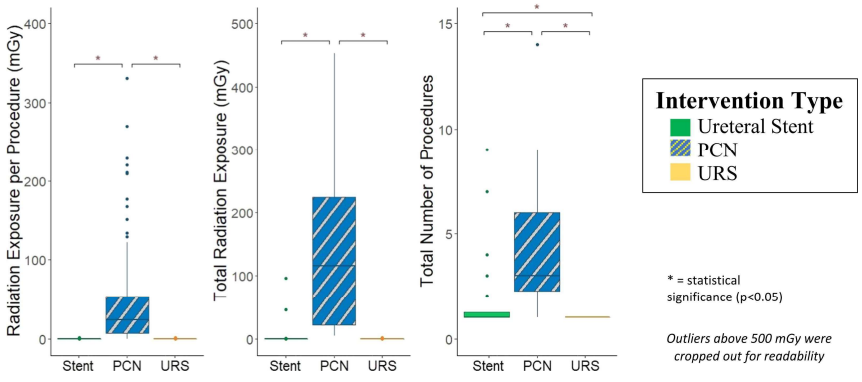
Radiation Exposure – stent vs nephrostomy tube



Mean duration between PCN exchanges – 16.5 days

Lyon et al. Urology 2023.

136

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Stent vs. nephrostomy tube

- 2,999 patients – ureteral stent
- 321 – PCN
  - Increased history of infection (UTI, pyelonephritis, sepsis)
  - Propensity matching to rid bias

World Journal of Urology (2023) 41:1721–1726
https://doi.org/10.1007/s00345-022-04111-2

TOPIC PAPER

A comparison of adverse pregnancy events between ureteral stents and percutaneous nephrostomy tubes in the treatment of nephrolithiasis during pregnancy: A propensity score-matched analysis of a large multi-institutional research network

Matthew M. Mason[1] · Sirpi Nackeeran[1] · Soum Lokeshwar[2] · Marisa R. Carino Mason[1] · Taylor Kohn[3] · Hemendra N. Shah[4] · Ranjith Ramasamy[4]

Received: 7 May 2022 / Accepted: 18 July 2022 / Published online: 31 July 2022

137

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Table 2 Propensity score adjusted outcomes following initial procedure

Outcomes	Stent ($n = 320$)		PCN ($n = 320$)		Stent vs. PCN odds ratio (95% CI)
	Number	Percent	Number	Percent	
Full-term uncomplicated vaginal delivery (O80)	71	22.2%	66	20.6%	1.097 (0.752–1.601)
Full-term uncomplicated c-section (O82)	15	4.7%	18	5.6%	0.825 (0.408–1.667)
Premature rupture of membranes (O42)	17	5.3%	19	5.9%	0.889 (0.453–1.743)
Premature labor or delivery (O42, O60)	67	20.9%	63	19.7%	1.08 (0.735–1.588)
Preterm labor without delivery (O60.00)	–	–	–	–	–
Preterm labor with delivery (O60.1)	23	7.2%	23	7.2%	1.0 (0.549–1.822)
Term delivery with preterm labor (O60.2)	–	–	–	–	–
False labor before 37 weeks (O47.0)	33	10.3%	32	10.0%	1.035 (0.62–1.729)
False labor after 37 weeks (O47.1)	21	6.6%	16	5.0%	1.334 (0.683–2.607)
Intrauterine infection (O41.1x)	10	3.1%	11	3.4%	0.906 (0.379–2.165)
Inpatient visit (99221–99223)	32	10.0%	69	21.6%	0.404 (0.257–0.635)
Emergency department visit (99281–99285)	158	49.4%	192	60.0%	0.650 (0.475–0.889)
Exchange procedure (52332, 52310, 52315, 50387, 50432, 50435)	124	38.6%	152	47.5%	0.700 (0.511–0.957)
UTI or pyelonephritis (N39.0, O23, N10)	148	46.3%	200	62.5%	0.516 (0.377–0.708)

Propensity score adjusted outcomes 1 week to 6 months following initial procedure
PCN Percutaneous nephrostomy tube, *UTI* Urinary tract infection
–: The number of outcomes was below the minimum privacy threshold of 10

138

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DEFINITIVE STONE TREATMENT

140

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ESW

- Only completely **noninva** treatment
- General anesthesia
- No ureteral stent
- **Lower stone free rate**
- Contraindicated in: **pregn** ulopathy, anticoagulants, UTI, strictu

www.storzmedical.com

141

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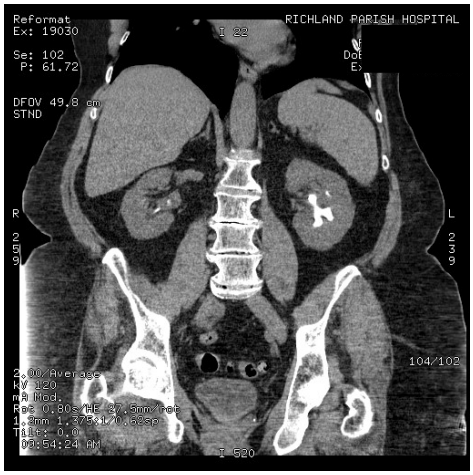
PCNL



- Treat through flank
  - **Supine**
- Much higher risk
- Technically safe in pregnancy (Ramachandra 2020), but rarely the answer

142

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Ureteroscopy

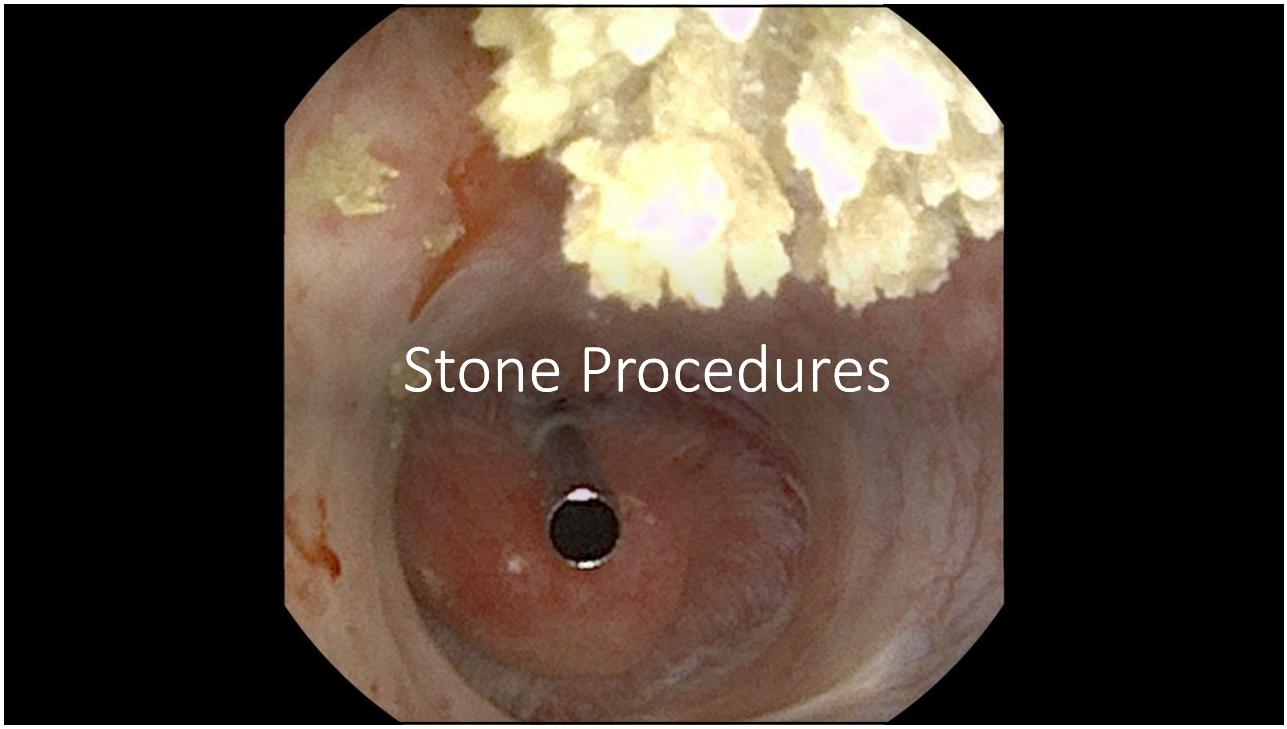
- The most common procedure
  - < 1% cases obstetrical complication (Pedro 2016)
- MAC or general anesthesia
- **2nd trimester preferred**
- Minimally invasive
- Ultrasound only vs. limit x-ray
  - Beam that projects posterior → anterior
- OK for anticoagulated patients
- Avoids multiple procedures (stent or PCN exchanges)
- Outpatient procedure
  - Ideal for almost* any stone

143

All Stone Patients

- Residual fragments should be treated especially if infection stones are suspected
- Stone analysis should be done
- Open/ laparoscopic /robotic surgery should not be offered first-line therapy except rare cases of anatomic abnormalities, large or complex stones, or those requiring concomitant reconstruction
- Safety guide wire should be used
- Antimicrobial prophylaxis should be done prior to stone intervention, based on prior urine culture results, the local antibiogram, and in consultation with the current Best Practice Policy Statement on Urologic Surgery Antibiotic Prophylaxis
- If purulent urine encountered, abort surgery, send culture and place drain
- If initial SWL fails, offer endoscopic therapy as the next treatment option
- URS should be first-line if uncorrected bleeding diatheses or if continuous anticoagulation/antiplatelet therapy needed

144



145

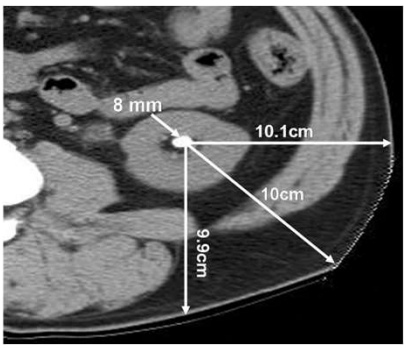
SWL

- Contraindications:
  - Pregnancy (fetal hearing loss)
  - Coagulopathy, antiplatelet therapy, anticoagulation
  - Distal stricture
- **No routine stenting**—pre, during, or post
- Consider alpha blockers as MET post SWL
- If fails, URS or PCNL should be next treatment

146

SWL

- Improving success:
  - SSD less than 10 cm
  - HU less than 1000
  - Stone size less than 1 cm



From Pareek et al. Urology. 2005

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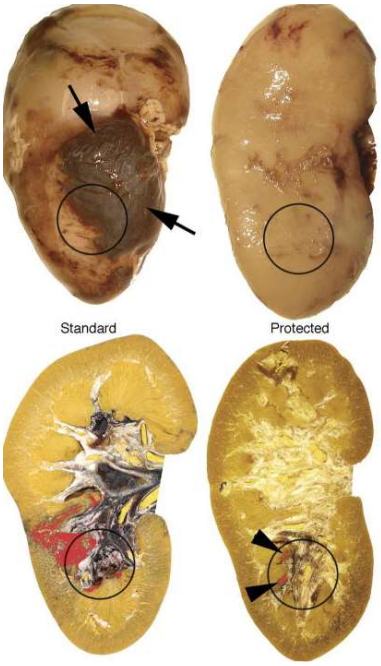
Shock Wave Sequence

- Timing and number of shock waves given at a specific power level
- **Power ramping**
  - Enhances stone breakage
  - Significantly decreases renal injury
- **Pause**
  - Pre-treating with 100 shocks and doing 3-4 min pause (renal afferent arteriolar constriction)
- **Rate** 60-90 SW/minute improves success rate
  - Cavitation
  - Rate 30 SW/minute protective against renal injury



Semin Nephrol. 2008 Mar;28(2):200-1

148

SWL – Complications

Acute Kidney Injury

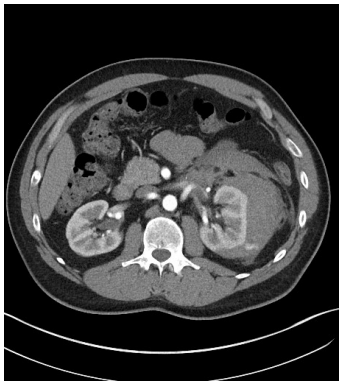
- Hematuria after 200 shockwaves
  - Shockwaves rupture blood vessels and damage renal tubules
    - Focal hemorrhage
    - Extravasation, pooling of blood
    - Necrosis of vascular wall
    - Inflammation
    - Renal papilla particularly susceptible
  - Etiology – violent collapse of cavitation bubbles

149

SWL – Complications

Hematoma

- 1-20%
- Newer lithotripters → small focal areas and high peak positive pressures → higher clinically significant hematoma rates
- Risk factors:
  - Age – 2x increase per decade
  - Obesity
  - Coagulopathies
  - Thrombocytopenia
  - Diabetes Mellitus
  - Coronary heart disease
  - Preexisting hypertension

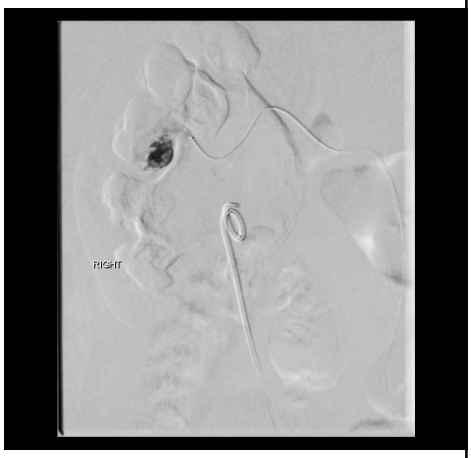


150

SWL – Complications

Hematoma

- Management:
  - Conservative management
  - Embolization



From Pareek et al. Urology. 2005

151

SWL – Complications

Steinstrasse

- 4-8%
- Management –
  - Tamsulosin & MET
  - Pain Control
  - Nephrostomy tube
    - May be better than stent
  - Ureteroscopy

From Garg et al 2018

152

SWL-Complications

- HTN: especially in elderly and with prior CKD
- DM ? Subsequent studies unable to corroborate Mayo Clinic data
- Renal damage: interstitial fibrosis has been demonstrated
- Increased stone recurrence
  - Fine sand debris remaining in kidney → nidus for new stone
- Induction of brushite stone disease
  - Loss of control over normal urinary pH 2/2 damage to microvessels and collecting duct → higher pH → brushite stones

153

Ureteroscopy

154

Ureteroscopy

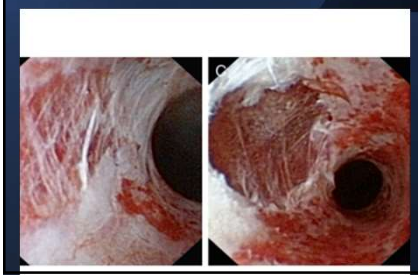
Ok to do on antiplatelet therapy, anticoagulation!

Don’t necessarily need to stent if uncomplicated

155

Ureteroscopy

Ureteral access sheaths



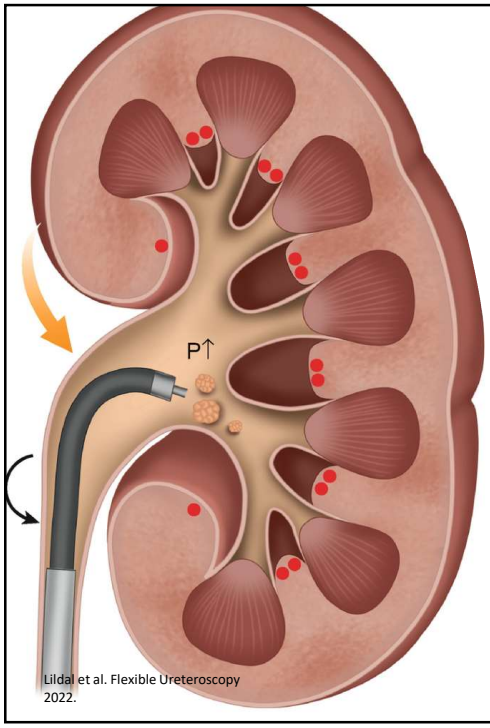
Injury not uncommon

No association between high-grade injury and long-term stricture

Decrease intrarenal pressure

- Higher IRP → risk of infection & damage

156



Lildal et al. Flexible Ureteroscopy 2022.

What is (normal) intrarenal pressure?

- Normal IRP – 0 to 15 mmHg (0-20 cmH20)
- Normal IRP during procedures – 20-40 mmHg (27-54 cmH20)
- NOT routinely measured during endourologic procedures

Chew et al. J Urology 2023.

157

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Pyelovenous backflow

Geara et al. Journal of Medical Case reports. 2010

158

American Urological Association
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Pyelovenous backflow

Geara et al. Journal of Medical Case reports. 2010

159

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What makes up IRP?

Inflow

Irrigation
- Hand pump, gravity, pressure bag, etc.

Working channel size

What's in the working channel?

Outflow

Ureteral access sheath
- Size
- Location

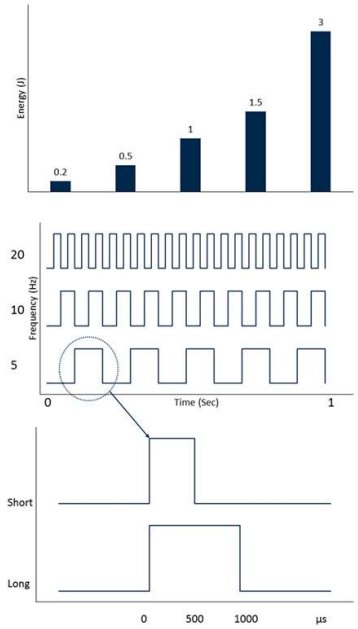
Compliance of the system

Ureteral size/stretch

160

Lasers

- Energy (J)
- Frequency (Hz)
  - # of pulses per second
- Power (W) = Energy x Frequency
- Pulse Width
  - Duration of a single pulse
  - Longer → less fiber burn back, less retropulsion



161

Lasers

- Dusting –
  - Lower power
  - Higher frequency
- Fragmentation –
  - Higher power
  - Lower frequency
- Holmium –
  - Gold standard
  - Wavelength 2100 nm
- Thulium Fiber Laser
  - Wavelength 1940 (closer to peak H20 absorption)
- Be careful of temperature!
  - potential for kidney damage > 43°C

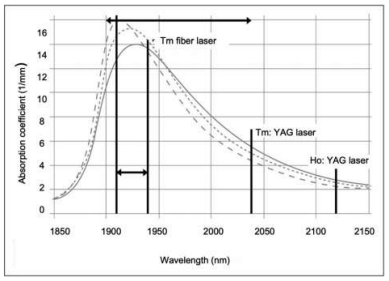


FIGURE 3. Lasers absorption in water.

162

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URS Intraop Complications

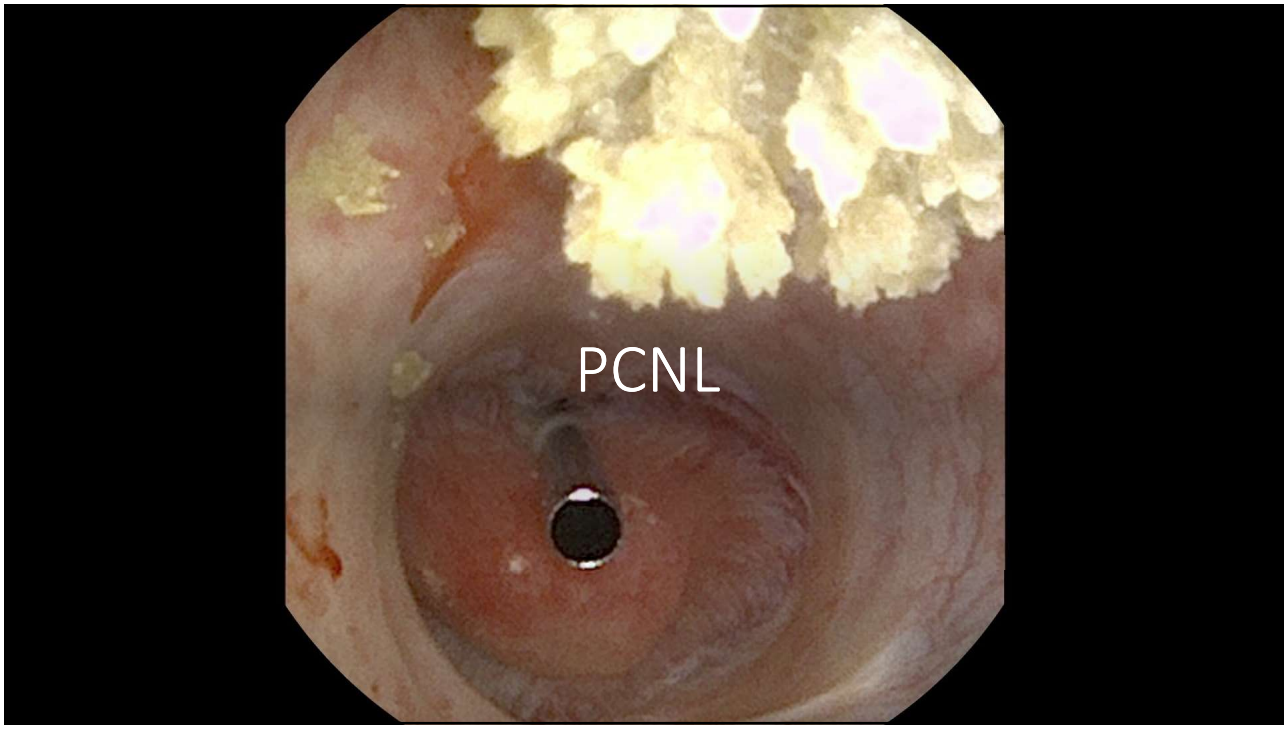
- Ureteral tear/perforation: majority heal with a stent; consider foley to prevent reflux/urinoma
- Avulsion: immediate repair if possible; if not, percutaneous nephrostomy
- Sepsis: use UAS; avoid high pressure
- Stricture – 1-3%; post-op imaging to avoid silent obstruction

163

Stricture Treatment

- UPJ/Ureteral/infundibular strictures
  - Can be diagnosed with retrograde studies to assess number and length of strictures
  - Can often be treated endoscopically, especially if < 1cm
    - Balloon dilation
    - Holmium laser incision
    - Cold knife incision
  - Longer or more complex strictures may require open or minimally invasive surgery
    - Excision and primary repair if simple
    - Ureteral reimplant, ileal ureter, kidney mobilization if necessary

164



165

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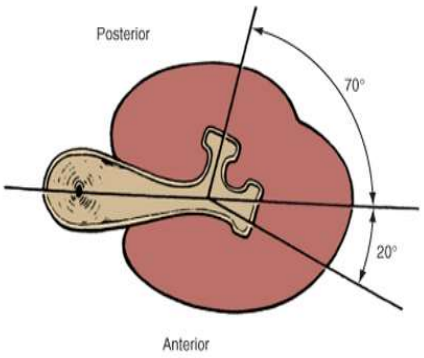
PCNL



- Techniques:
  - Prone
  - Supine
  - Fluoro guided
  - US guided
  - ECIRS
- Principles—it is all about the access
  - Posterolateral access: traditionally “Brodel’s Line”
    - Too anterior a puncture puts torque on kidney when doing prone access
    - Too medial a puncture risks vascular injury; renal artery is large, as it branches, the peripheral vessels get smaller; arteries are “end arteries”– injury → infarct
  - Avoid supracostal access when possible

166

PCNL Complications

- Sepsis -
  - Rate -0.3% - 8%
  - Treat high-risk patients with 7 days of antibiotics pre-op
  - Send cultures from the OR

167

PCNL Complications

- Bleeding -
  - risk of transfusion is 5%
  - immediate-place large NT and clamp; traditionally use Kaye tamponade catheter
  - delayed--AVF or pseudoaneurysm—get arteriogram and embolize—don't waste time! Usually a posterior or anterior segmental branch; rarely arcuate vessel

168

PCNL Complications

- Perforation of pelvis: if large, abort, place NT; return when nephrostogram shows resolution; fluid absorption can lead to compartment syndrome: elevated venous pressures, narrow pulse pressure, impaired venous return → shock
- Colon injury (brown): pull back NT into colon, place ureteral stent (separate wind and water); retrorenal colon in 0.6%; usually left side in thin females
- Duodenal injury (green) too deep: bowel rest/NG suction, TPN; pull NT back into renal pelvis
- Spleen/liver injury: rule out hepatosplenomegaly; use intraoperative US

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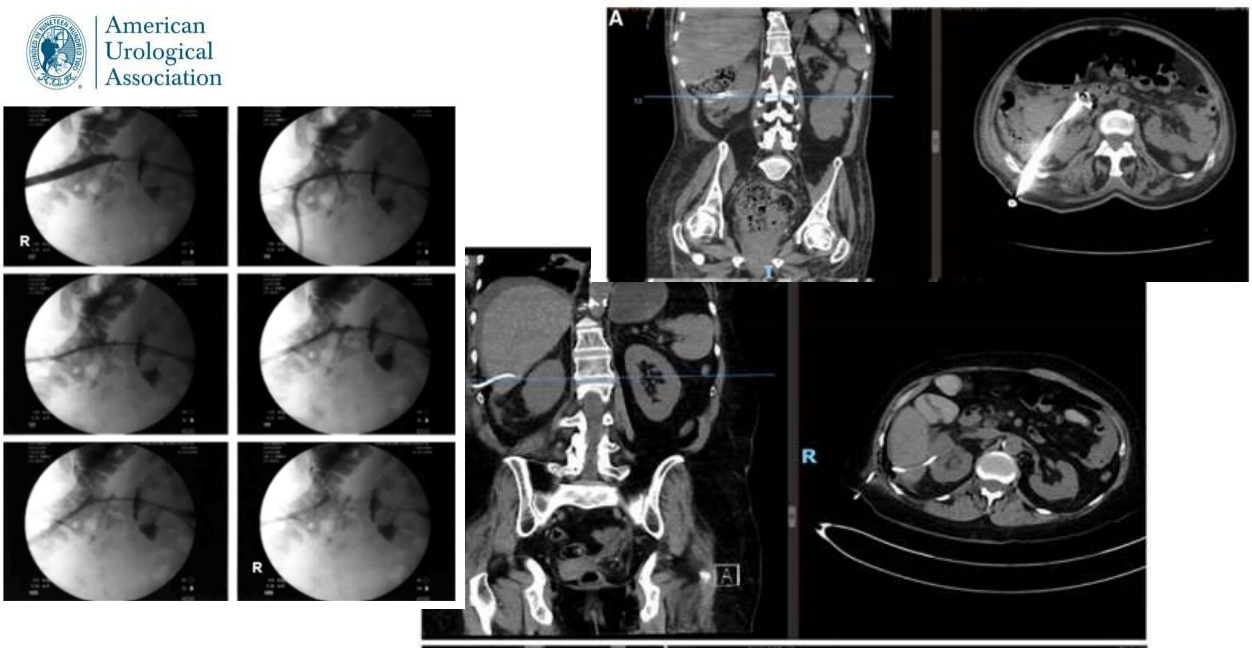


Okeke et al. J Endo Case Rep 2020

170

Pneumo, Hydro, or Hemothorax

R > L, 4% of supracostal access

Prevention

- Subcostal access
- Stay lateral with intercostal access
- Maintain sheath in collecting system
- Ultrasound-guided access

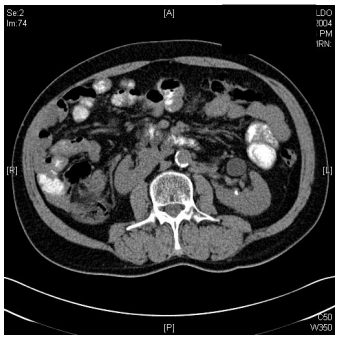
Management

- Early recognition
  - Survey nephrostomy tract upon exit
  - Scan the chest with C-arm (Pearle, 2000)
  - Observation vs. aspiration vs. thoracostomy
- Delayed recognition: VATS procedure

171

PCNL in Horseshoe Kidneys

- Preop CT to evaluate anatomy and vasculature critical
- Longer tract to kidney
- Kidneys are less mobile
- Increased likelihood of retro-renal colon
- Must do upper pole posterior calyx puncture
  - More medial and posterior than standard PCNL tract



172

DONE!

173

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ARS: Q1

A 34 male boxer who has his first kidney stone is consuming protein supplements to assist in building muscle mass and is on a keto diet. The following that are most likely to be found on his 24-hour urine test are:

A. Hypercalciuria, hyperuricosuria, hypocitraturia, urine pH 6.5
B. Hypercalciuria, hyperuricosuria, hypocitraturia, urine pH 5.0
C. Hypercalciuria, normal uric acid, normal citrate, urine pH 5.0
D. Normal urine calcium, normal uric acid, hypocitraturia, urine pH 6.5
E. Normal calcium, hyperuricosuria, hypocitraturia, urine pH 5.0

174

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Answer: Q1

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C. Hypercalciuria, normal uric acid, normal citrate, urine pH 5.0
D. Normal urine calcium, normal uric acid, hypocitraturia, urine pH 6.5
E. Normal calcium, hyperuricosuria, hypocitraturia, urine pH 5.0

High protein diets promote hypercalciuria, increased urine sulfate, hyperuricosuria, hypocitraturia, and low urine pH (acidosis)

175

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Answer: Q1

High protein diets promote hypercalciuria, increased urine sulfate, hyperuricosuria, hypocitraturia, and low urine pH (acidosis)

176

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ARS: Q2

The following are possible negative effects of thiazides EXCEPT:

a. Hair loss
b. Pancreatitis
c. Elevated HgA1c levels
d. Hyperkalemia
e. Gouty attacks

177

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Answer: Q2

The following are possible negative effects of thiazides EXCEPT:

a. Hair loss
b. Pancreatitis
c. Elevated HgA1c levels
✅ **d. Hyperkalemia**
e. Gouty attacks

178

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ARS: Q3

Q3. Thiazide diuretics are used for stone disease due to the following desired effect:

a. Reducing sodium resorption in the proximal tubule
b. Reducing phosphate resorption in the distal tubule
c. Enhancing phosphate resorption in the proximal tubule
d. Enhancing calcium resorption in the distal tubule
e. Reducing calcium resorption in the proximal tubule

179

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Answer: Q3

Normal calcium reabsorption occurs in the proximal tubules; thiazides exert their beneficial effect in patients with hypercalciuria by enhancing calcium reabsorption in the *distal* tubule.

180

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ARS: Q4

A 35-year-old male with Crohn's has his 5th stone episode. His stones have been calcium oxalate. Despite therapy for Crohn's, he continues to have bowel symptoms. The following that is least likely to be beneficial is:

A. Calcium supplements
B. Better management of Crohn's related symptoms
C. Magnesium supplements
D. Low oxalate diet
E. Thiazide diuretic

181

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Answer Q4

Answer to Question 4stone episode. His stones have been calcium oxalate. Despite therapy for Crohn's, he continues to have bowel symptoms. The following that is least likely to be beneficial is:

A. Calcium supplements
B. Better management of Crohn's related symptoms
C. Magnesium supplements
D. Low oxalate diet
✅ E. **Thiazide diuretic**

182

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ARS: Q5

A 42-year-old female has recurrent calcium oxalate stones that are a mixture of calcium oxalate monohydrate and calcium oxalate dihydrate. Her 24 hr urine test shows moderate hypercalciuria and hyperoxaluria. Urine pH is 6.0. The best treatment is:

A. Low calcium, low oxalate diet and a thiazide diuretic
B. Calcium 1200 mg daily, low oxalate diet, and a thiazide diuretic
C. Low calcium, low oxalate diet and potassium citrate
D. Calcium 1200 mg daily, vitamin B6, and a thiazide diuretic
E. Calcium 1200 mg daily, low oxalate diet, and potassium citrate

183

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Answer: Q5

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C. Low calcium, low oxalate diet and potassium citrate
D. Calcium 1200 mg daily, vitamin B6, and a thiazide diuretic
E. Calcium 1200 mg daily, low oxalate diet, and potassium citrate

This patient with recurrent stones has: hypercalciuria, best treated with a low sodium diet and thiazide diuretic, and hyperoxaluria, best treated with a low oxalate diet and 1200 mg of calcium daily in divided doses with meals (to bind oxalate in foods). In patients with stone disease, normal recommended daily doses are recommended, and not low calcium diets

184

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Answer: Q5

This patient with recurrent stones has: hypercalciuria, best treated with a low sodium diet and thiazide diuretic, and hyperoxaluria, best treated with a low oxalate diet and 1200 mg of calcium daily in divided doses with meals (to bind oxalate in foods). In patients with stone disease, normal recommended daily doses are recommended, and not low calcium diets

185

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ARS: Q6

A 55-year-old male with DMII, morbid obesity (BMI 35), hypertension, and hypercholesterolemia has recurrent uric acid stones.

The most likely abnormality on lab testing is:

A. Low urine volume

B. High urine uric acid

C. High serum uric acid

D. Low urine pH

E. High urine sodium

186

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Answer: Q6

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The most likely abnormality on lab testing is:

A. Low urine volume
B. High urine uric acid
C. High serum uric acid
✅ **D. Low urine pH**
E. High urine sodium

This patient has classic gouty diathesis. Diabetes and morbid obesity promote metabolic acidosis which leads to low urine pH. Although high urine and serum uric acid may be present, they are not the primary driver of stone formation in these patients.

187

American Urological Association Education & Research, Inc.

Answer: Q6

This patient has classic gouty diathesis. Diabetes and morbid obesity promote metabolic acidosis which leads to low urine pH. Although high urine and serum uric acid may be present, they are not the primary driver of stone formation in these patients.

188

American Urological Association Education & Research, Inc.

ARS: Q7

The same patient in the previous question most likely has which of the following findings:

A. Recurrent attacks of gout
B. Renal tubular acidosis
C. Disorder of purine metabolism causing uric acid overproduction
D. Elevated urinary uric acid level
E. Normal serum uric acid level

189

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Answer: Q7

The same patient in the previous question most likely has which of the following findings:

A. Recurrent attacks of gout
B. Renal tubular acidosis
C. Disorder of purine metabolism causing overproduction of uric acid
D. Hyperuricemia
✅ E. Normal serum uric acid level

190

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ARS: Q8

A 33-year-old actress has her 3rd stone episode. Upon questioning, she admits to taking over the counter laxative powders and stool softeners to maintain weight and treat chronic constipation. Her most likely stone composition is:

A. Xanthine
B. Uric acid
C. Struvite
D. Ammonium acid urate
E. Calcium phosphate

191

American Urological Association Education & Research, Inc.

Answer: Q8

A 33-year-old actress has her 3rd stone episode. Upon questioning, she admits to taking over the counter laxative powders and stool softeners to maintain weight and treat chronic constipation. Her most likely stone composition is:

A. Xanthine
B. Uric acid
C. Struvite
✅ **D. Ammonium acid urate—distal RTA like syndrome**
E. Calcium phosphate

192

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ARS: Q9

A 33-year-old female has recurrent calcium phosphate nephrolithiasis, and her CT is suggestive of medullary calcinosis. The most likely constellation of lab findings is:

A. High serum potassium, low serum CO2, low urine citrate, high urine calcium, urine pH of 7.5
B. Low serum potassium, high serum CO2, low urine citrate, high urine calcium, urine pH of 6.0
C. Low serum potassium, low serum CO2, low urine citrate, normal urine calcium, urine pH of 6.0
D. High serum potassium, high serum CO2, normal urine citrate, high urine calcium, urine pH of 7.5
E. Low serum potassium, low serum CO2, low urine citrate, high urine calcium, urine pH of 7.5

193

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Answer: Q9

A 33 year old female has recurrent calcium phosphate nephrolithiasis and her CT is suggestive of medullary calcinosis. The most likely constellation of lab findings is:

A. High serum potassium, low serum CO2, low urine citrate, high urine calcium, urine pH of 7.5
B. Low serum potassium, high serum CO2, low urine citrate, high urine calcium, urine pH of 6.0
C. Low serum potassium, low serum CO2, low urine citrate, normal urine calcium, urine pH of 6.0
D. High serum potassium, high serum CO2, normal urine citrate, high urine calcium, urine pH of 7.5

✅ **E. Low serum potassium, low serum CO2, low urine citrate, high urine calcium, urine pH of 7.5**

This patient has classic findings of distal (type 1) RTA where the distal tubule cannot excrete acid (ammonia) leading to metabolic acidosis.

194

American Urological Association Education & Research, Inc.

Answer: Q9

This patient has classic findings of distal (type 1) RTA where the distal tubule cannot excrete acid (ammonia) leading to metabolic acidosis.

195

American Urological Association Education & Research, Inc.

ARS: Q10

AHA (Lithostat, Acetohydroxamic acid) is a urease inhibitor used to treat patients with struvite stones. The following included side effect is:

A. Deep venous thrombosis
B. Hypertension
C. Hypotension
D. Visual disturbance
E. Cardiac toxicity

196

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Answer: Q10

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- B. Hypertension
- C. Hypotension
- D. Visual disturbance
- E. Cardiac toxicity

197

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ARS: Q11

A 48-year-old male who is quadriplegic from a motor vehicle accident is bedbound and develops infected struvite calculi and the stone cultures show Proteus Mirabilis. After best attempts at eradicating all stone burden, there are residual stones that can not be removed. The following that is **NOT** an acceptable treatment alternative is:

198

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Answer: Q11

A 48 year old male who is quadriplegic from a motor vehicle accident is bedbound and develops infected struvite calculi and the stone cultures show Proteus Mirabilis. After best attempts at eradicating all stone burden, there are residual stones that can not be removed. The following that is **NOT** an acceptable treatment alternative is:

A. L-methionine

✅ **B. N-acetyl-cysteine**

C. Acetohydroxamic acid

D. Chronic prophylactic antibiotic suppression

E. Methenamine with ascorbic acid

Proteus is a urea-splitting organism producing urease. If it can not be eradicated by removing all infected stones, urinary acidification with L-methionine or methenamine can help keep it from causing stone production and growth. Acetohydroxamic acid is a urease inhibitor. Chronic antibiotic suppression can decrease bacterial load and reduce stone growth.

199

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Answer: Q11

Proteus is a urea-splitting organism producing urease. If it can not be eradicated by removing all infected stones, urinary acidification with L-methionine or methenamine can help keep it from causing stone production and growth. Acetohydroxamic acid is a urease inhibitor. Chronic antibiotic suppression can decrease bacterial load and reduce stone growth.

200

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ARS: Q12

A 24-year-old man has recurrent cystine nephrolithiasis. Urine volume is more than 3 L per day. He is taking alpha-mercaptopropionylglycine and potassium citrate tablets three times per day with no side effects. He notes that his stools are filled with tablet-like material. His urine pH is 7.5. The best recommendation is:

201

American Urological Association Education & Research, Inc.

Answer: Q12

A 24-year-old man has recurrent cystine nephrolithiasis. Urine volume is more than 3 L per day. He is taking alpha-mercaptopropionylglycine and potassium citrate tablets three times per day with no side effects. He notes that his stools are filled with tablet-like material. His urine pH is 7.5. The best recommendation is:

- ☑ A. **Reassurance**
- B. Take the tablets before meals
- C. Evaluate for malabsorption
- D. Change Tiopronin to D-penicillamine
- E. Decrease the dose of potassium citrate

202

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ARS: Q13

A 24-year-old man has acute severe left flank pain. Urinalysis is normal. He denies a history of urinary stone disease or recent trauma. The next step is:

A. Reassurance
B. Noncontrast helical CT scan
C. Abdominal ultrasonography
D. IVP
E. MRI scan

203

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Answer: Q13

A clinical history of acute renal colic should not be dismissed due to a normal urinalysis without evidence of microhematuria. Noncontrast CT is a study of choice to confirm the diagnosis of nephro or ureterolithiasis

204

American Urological Association Education & Research, Inc.

Answer: Q13

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A. Reassurance
✅ **B. Noncontrast helical CT scan**
C. Abdominal ultrasonography
D. IVP
E. MRI scan

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205

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ARS: Q14

The expected Hounsfield unit assessment of a uric acid stone on a noncontrast CT scan is:

A. 100-500 HU
B. 500-700 HU
C. 900-1200 HU
D. 1250-1650 HU
E. 1800-2200 HU

206

American Urological Association Education & Research, Inc.

Answer: Q14

The expected Hounsfield unit assessment of a uric acid stone on a noncontrast CT scan is:

- ✅ A. **100-500 HU**
- B. 500-700 HU
- C. 900-1200 HU
- D. 1250-1650 HU
- E. 1800-2200 HU

The Hounsfield units for various stone types have been determined on CT scan evaluation. From the least to the most dense, the stones types are uric acid 100-500 HU, struvite stone 500-700 HU, cystine stone 900-1200 HU, calcium phosphate and calcium oxalate greater than 1000 HU.

American Urological Association Education & Research, Inc.

Answer: Q14

The Hounsfield units for various stone types have been determined on CT scan evaluation. From the least to the most dense, the stones types are uric acid 100-500 HU, struvite stone 500-700 HU, cystine stone 900-1200 HU, calcium phosphate and calcium oxalate greater than 1000 HU.

American Urological Association Education & Research, Inc.

ARS: Q15

A 38-year-old woman has severe right flank pain. She is afebrile, and urinalysis demonstrates pyuria and microhematuria. A helical CT scan demonstrates right perinephric fluid and right hydroureteronephrosis down to a 3 mm distal ureteral stone. The best treatment is:

209

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Answer: Q15

No need for intervention for forniceal rupture in the absence of evidence of infection

210

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ARS: Q16

The increased risk for calculus disease during pregnancy is associated with:

A. Increased parathyroid hormone levels
B. Absorptive hypercalcuria
C. Placental suppression of 1, 25-dihydroxycholecalciferol
D. Decreased urinary glycosaminoglycans
E. Decreased urinary citrate levels

211

American Urological Association Education & Research, Inc.

Answer: Q16

The increased risk for calculus disease during pregnancy is associated with

A. Increased parathyroid hormone levels
✅ **B. Absorptive hypercalcuria**
C. Placental suppression of 1, 25-dihydroxycholecalciferol
D. Decreased urinary glycosaminoglycans
E. Decreased urinary citrate levels

Placental vitamin D increases absorption of calcium

212

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Answer: Q16

Placental vitamin D increases absorption of calcium

213

American Urological Association Education & Research, Inc.

ARS: Q17

The physiologic change during the third trimester pregnancy that offers protection against kidney stone formation is:

A. Increased ureteral peristalsis
B. Increased ureteral dilation
C. Increased urinary citrate
D. Decreased urinary calcium
E. Decreased urinary uric acid

214

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Answer: Q17

The physiologic change during the third trimester pregnancy that offers protection against kidney stone formation is:

A. Increased ureteral peristalsis
B. Increased ureteral dilation
✅ **C. Increased urinary citrate**
D. Decreased urinary calcium
E. Decreased urinary uric acid

This balances the hypercalciuria

215

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Answer: Q17

This balances the hypercalciuria

216

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ARS: Q18

A 4-year-old boy with a family history of calcium oxalate stone disease is found to have a 12 mm calculus in the left renal pelvis with no hydronephrosis. He has had no urinary tract surgery. The first-line surgical approach to the stone is:

a. Shock wave lithotripsy
b. Shock wave lithotripsy with a ureteral stent
c. Mini-percutaneous nephrolithotomy
d. Ureteroscopy after pre-stenting
e. Robotic pyelolithotomy

217

American Urological Association Education & Research, Inc.

Answer: Q18

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✅ **a. Shock wave lithotripsy.**
b. Shock wave lithotripsy with a ureteral stent.
c. Mini-percutaneous nephrolithotomy.
d. Ureteroscopy after "pre-stinting" to dilate the ureter.
e. Posterior lumbotomy approach to pyelolithotomy.

Because the ureter in the child is very distensible, allowing passage of relatively large stone fragments, surgical approach of shock wave lithotripsy is the first line of treatment for most renal calculi in children. There is no strict upper limit of stone burden that could be managed with SWL in children, as there is in adults, although the larger of the burden is, the less likely it is that success will be achieved with one procedure.

218

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Answer: Q18

Because the ureter in the child is very distensible, allowing passage of relatively large stone fragments, surgical approach of shock wave lithotripsy is the first line of treatment for most renal calculi in children. There is no strict upper limit of stone burden that could be managed with SWL in children, as there is in adults, although the larger of the burden is, the less likely it is that success will be achieved with one procedure.

American Urological Association Education & Research, Inc.

ARS: Q19

For patients with a 1-cm proximal ureteral stone, placement of an internal stent at the time of the SWL will result in:

A. A higher stone free rate
B. A lower complication rate
C. Less hematuria
D. Increased irritative voiding symptoms
E. Reduced analgesic requirements

American Urological Association Education & Research, Inc.

Answer: Q19

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A. A higher stone free rate
B. A lower complication rate
C. Less hematuria
✅ D. **Increased irritative voiding symptoms**
E. Reduced analgesic requirements

A randomized study demonstrated that the stent placement at the time of SWL in patients with 1-2 cm solitary renal stones or proximal ureteral calculi less than 2 cm did not improve stone free or retreatment rates or lessen pain or hematuria. However, stent insertion was associated with an increase in irritative voiding symptoms.

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Answer: Q19

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ARS: Q20

Which of the following is associated with higher stone free rate for shockwave lithotripsy:

A. Lower shockwave rate
B. Large skin to stone distance
C. Higher Hounsfield unit density of stone
D. Placement of a ureteral stent at the time of SWL
E. Using highest power available

223

American Urological Association Education & Research, Inc.

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224

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ARS: Q21

A 56-year-old man with a solitary kidney and hypertension undergoes SWL for a 2-cm renal pelvic calculus. Immediately after the procedure, he has a blood pressure of 90/60 mmHg, gross hematuria, and flank pain. The CT scan reveals a 10 x 12 cm perirenal hematoma. His blood pressure stabilizes with fluid resuscitation and 2 units of packed RBCs. The next step is:

American Urological Association Education & Research, Inc.

Answer: Q21

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✅ A. Continued supportive therapy
B. Ureteral stent placement
C. Arteriography
D. Percutaneous drainage of the hematoma
E. Renal exploration

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ARS: Q22

For a given total energy in watts, the Holmium laser fiber settings that will lead to the least amount of retropulsion of a renal pelvis stone are:

A. Increased pulse energy, increased frequency, short pulse width
B. Decreased pulse energy, increased frequency, long pulse width
C. Increased pulse energy, decreased frequency, long pulse width
D. Increased pulse energy, increased frequency, long pulse width
E. Decreased pulse energy, increased frequency, short pulse width

227

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D. Increased pulse energy, increased frequency, long pulse width
E. Decreased pulse energy, increased frequency, short pulse width

Retropulsion is caused by high peak power. Long pulse width takes the same laser energy and delivers it over a longer period of time, reducing peak power. Decreasing pulse energy also reduces peak power. Frequency does not directly affect peak power.

228

American Urological Association Education & Research, Inc.

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ARS: Q23

A 35-year-old man returns for percutaneous nephrostomy tube removal five days after undergoing successful nephrolithotomy. As the catheter is being removed, brisk bleeding is noted. The best management is:

A. Compression of the nephrostomy site
B. Re-insertion of the nephrostomy tube
C. Surgical exploration
D. Angiography and embolization
E. Removal of the nephrostomy tube and observation

American Urological Association Education & Research, Inc.

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E. Removal of the nephrostomy tube and observation

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ARS: Q24

During PCNL, a collecting system perforation is noted. The first sign of significant extravasation of irrigant into the peritoneal cavity is:

a) Abdominal distension
b) Narrowed pulse pressures
c) Increasing ventilatory pressures
d) Hypertension
e) Bradycardia

American Urological Association Education & Research, Inc.

Answer: Q24

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a) Abdominal distension

✅ **b) Narrowed pulse pressures**

c) Increasing ventilatory pressures

d) Hypertension

e) Bradycardia

- Narrowed pulse pressures (rise in diastolic pressure) precede difficulty with ventilation, hypercarbia and a rise in central venous pressure.
- Extravasated irrigant increases abdominal pressure leading to decreased venous return and thus narrowing the pulse pressure.
- Distension is not appreciated in the prone position until later in the course

American Urological Association Education & Research, Inc.

Answer: Q24

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- Extravasated irrigant increases abdominal pressure leading to decreased venous return and thus narrowing the pulse pressure.
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ARS: Q25

Three days s/p a right PCNL, green fluid begins to drain through the nephrostomy tube. The patient is afebrile and there is no abdominal tenderness. Contrast instilled into the tube immediately outlines the second part of the duodenum. The tube is repositioned into the renal pelvis. The next step is:

235

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Answer: Q25

Three days s/p a right PCNL, green fluid begins to drain through the nephrostomy tube. The patient is afebrile and there is no abdominal tenderness. Contrast instilled into the tube immediately outlines the second part of the duodenum. The tube is repositioned into the renal pelvis. The next step is:

a) Upper GI Series
b) Surgical exploration
✅ c) **Nasogastric suction and parenteral nutrition**
d) Duodenoscopy and attempted closure
e) Placement of a peri-duodenal drain

236

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ARS: Q26

A 10 Fr nephrostomy tube was placed uneventfully to drain a pyonephrotic kidney. Follow-up nephrostogram reveals a 6 cm staghorn calculus. The percutaneous nephrostomy tube enters directly into the renal pelvis. At time of PCNL, optimal access is obtained via:

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Answer: Q26

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a) Dilating the established nephrostomy tract

b) A new percutaneous tract- inferior anterior calyx

✅ **c) A new percutaneous tract- inferior posterior calyx**

d) Getting as much stone out as possible through established tract then getting a new access

e) Getting as much stone out through established tract then bringing the patient back for ESWL

American Urological Association Education & Research, Inc.

ARS: Q27

A 65-year-old woman has one week of flank pain and malaise. A non-contrast CT scan is shown. The next step is:

A. Urine culture and metabolic stone evaluation
B. MAG-3 renal scan with furosemide
C. Percutaneous nephrostomy
D. PCNL
E. Ureteroscopy with laser lithotripsy

239

American Urological Association Education & Research, Inc.

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C. ✅ **Percutaneous nephrostomy**
D. PCNL
E. Ureteroscopy with laser lithotripsy

240

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ARS: Q28

30 hours after left PCNL, a 35-year-old man has a fever of 100.2°F, ileus, urine mixed with feces from the nephrostomy tube, and bloody stools. His WBC is 18,000/cu mm. Nephrostogram demonstrates the tube is transcolonic.

The best next steps are to administer parenteral antibiotics, prohibit food by mouth and:

241

American Urological Association Education & Research, Inc.

Answer: Q28

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a. Observe the patient.
✅ **b. Withdraw the nephrostomy tube into the colon.**
c. Place a second nephrostomy tube.
d. Perform a colostomy.
e. Close the bowel perforation

After withdrawing the nephrostomy tube into the colon, colonic fistulas usually seal in a few days if discovered promptly. In addition a double-J stent can be inserted; the point is to separate “wind” and “water”. Surgical closure or a colostomy should be reserved for those cases that have persistent fever and evidence of abscess formation

242

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