

"اللَّهُمَّ لَا سَهْلَ إِلَّا مَا جَعَلْتَهُ سَهْلًا، وَأَنْتَ تَجْعَلُ الْحَزْنَ إِذَا شِئْتَ سَهْلًا"

Kidney Stones

Biochemistry Team 437



Color index:
Doctors slides
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Extra information
Highlights

Renal block

EDITING FILE

Objectives:

By the end of this lecture, the students will be able to:

- Discuss the general physiological and pathological factors that favor kidney stones formation
- List the types of kidney stones, their chemical constituents and characteristics
- Identify the etiological causes of each type of kidney stone
- Discuss the diagnosis, treatment and prevention of kidney stones

Overview:

- Introduction
- Conditions causing kidney stone formation
- Types of kidney stones:
 - Calcium salts
 - Uric acid
 - Mg ammonium PO₄
 - Cystine
 - Other (xanthine, etc.)
- Laboratory investigations

Introduction:

When a molecule is normally present in the soluble form, but its concentration is too much to the point where it can no longer be solubilized, it precipitates. when these precipitations crystalize and become big, they make kidney stones.

What are kidney stones?

- Renal calculi (kidney stones) are formed in renal tubules, ureter or bladder.
- Composed of metabolic products present in glomerular filtrate. “urea , creatinine, electrolytes”
- These products are in high **concentration**¹ near² or above maximum solubility³.

¹ If the amount of the solute increase, or the amount of water decreases, the concentration of the solute becomes very high therefore creating stones

² if the conc. Is above maximum solubility, it will precipitate directly. If it was near maximum solubility, any stagnation or change in ph will make it precipitate.

³ maximum solubility is the maximum amount of solute the solvent can solubilize, for example,if we keep adding salt (sodium) to a glass of water. The water will reach a limit which cannot accept any more salt and it accumulates at the bottom of the glass.

Causes of kidney stone formation:

- High conc. of metabolic products in glomerular filtrate.
- Changes in urine pH. “ normal is between [4.5 → 6.5]”
- Urinary stagnation.
- Deficiency of stone-forming inhibitors in urine.

Causes of kidney stone formation

High conc. of metabolic products in glomerular filtrate is due to:

Changes in urine pH due to:

Urinary stagnation is due to:

Deficiency of stone-forming inhibitors:

- Low urinary volume (with normal renal function) due to restricted fluid intake.
- Increased fluid loss from the body.¹
- Increased excretion of metabolic products forming stones.
- High plasma volume (high filtrate level).²
- Low tubular reabsorption from filtrate.

¹ Sweating, diuretics, type 2 diabetes
² because it affects the ability of the tubules to reabsorb metabolic products.

- Bacterial infection.
- Dietary, metabolic acidosis/alkalosis
- Precipitation of salts at different pH:
 - A persistently **acidic** urine promotes **uric acid** precipitation. "PH Below 5.5"
 - A persistently **alkaline** "PH above 8" urine (due to upper urinary tract infection) promotes **Mg Ammonium Phosphate** crystals (Struvite stones).

The bacteria will release an enzyme called urease that converts urea to ammonia and alkalizes the urine.

Obstruction of urinary flow.

These substances are present normally in the urine to inhibit stone formation by different mechanisms.² a deficiency in them will lead to stone formation.

¹Majority of stones are calcium stones
² citrate binds to calcium and affects its solubility, and glycoproteins prevents the crystals from attaching to a certain place in the tubules to form stones

- ³Tubular acidosis: Not enough excretion of H⁺ ions
- ⁴hypocitraturia is less citrate in the urine

- Citrate, pyrophosphate, glycoproteins inhibit growth of calcium¹ phosphate and calcium oxalate crystals.
- In type I renal tubular acidosis³, hypocitraturia⁴ leads to renal stones.

Types of kidney stones

- 1) Calcium¹ : Oxalate or Phosphate (Most common form of stones).
- 2) Magnesium ammonium phosphate (H_4MgNO_4P) → Forms “ Struvite ” stones.
- 3) Uric acid/Urate
- 4) Cystine → Is the least common type of stones
- 5) Other types of uncommon stones include those induced by drugs or “ Xanthine ”

We will discuss each stone now in the next slides.

¹ Salt stones are formed mostly in which type of urine?

Alkaline urine. Because 80% of the stones are Ca^{++} stones and calcium stones are formed in alkaline urine

Calcium Salt Stones

- 80% of kidney stones contain calcium (mostly Ca-oxalates , Ca-PO_4)
- The type of salt depends on :
 - Urine pH
 - Availability of oxalate
- General appearance:
 - White, hard, radio-opaque¹
 - Calcium oxalate: present in ureter (small)
 - Calcium PO_4 : staghorn in renal pelvis (large)

¹ Radiopaque: appears on X-ray



Calcium oxalate stones

Causes of Calcium Salt Stones

1) Hypercalciuria:

Increased urinary calcium excretion

- Men: > 7.5 mmols/day
- Women > 6.2 mmols/day

Tip: you don't have to memorize these numbers

- A) Due to hypercalcemia¹ (most often due to primary* hyperparathyroidism²)
- B) Sometimes, ca⁺ stones are found with no hypercalcemia

2) Hyperoxaluria³:

- A) Causes the formation of calcium oxalates without hypercalciuria
- B) Diet rich in oxalates "Nuts, tomatoes, spinach, fries, potato chips"
- C) Increased oxalate absorption in fat malabsorption⁴

3) Primary hyperoxaluria:

- A) Due to inborn errors
- B) Urinary oxalate excretion: > 400 $\mu\text{mol}/24$ Hours

¹ caused by:

- Increase intestinal absorption
- Decrease in kidney reabsorption
- Bone resorption
- Hyperparathyroidism

² Parathyroid hormone is released when calcium is decreased in the body, it works on both the kidneys and the bones.

- In the bones: increase resorption "release of calcium"
- In the kidneys: increase the reabsorption of calcium "but not enough to prevent stones"

*primary: idiopathic

³Oxalate binds to calcium and makes stones, even if the calcium level is not high

⁴ undigested fat in the intestine - when the fat is not absorbed e.g. due to surgery- oxalate absorption will increase, so there will be an increase in oxalate in the blood which will be excreted into the urine, causing increase of oxalate in the urine

Treatment of Calcium Salt Stones

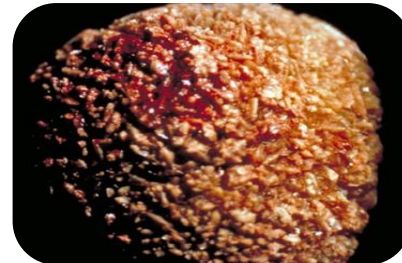
- Treatment of primary causes such as infection, hypercalcemia, hyperoxaluria
- Oxalate-restricted diet
- Increased fluid intake (if no glomerular failure)
- Acidification of urine (by dietary changes [eating meats](#))
 - Calcium salt stones are formed in alkaline urine

Uric acid stones

- About 8% of renal stones contain uric acid
- May be associated with hyperuricemia (with or without gout)
- Form in acidic urine ¹

General appearance :

- Small, friable², yellowish
- May form staghorn (if big **and mixed**)
- Radiolucent (plain x-rays cannot detect)
- Visualized by ultrasound or i.v. pyelogram



¹meat consumption makes the urine more acidic while fruit consumption alkalizes the urine
²crumbles easily

Uric acid stones

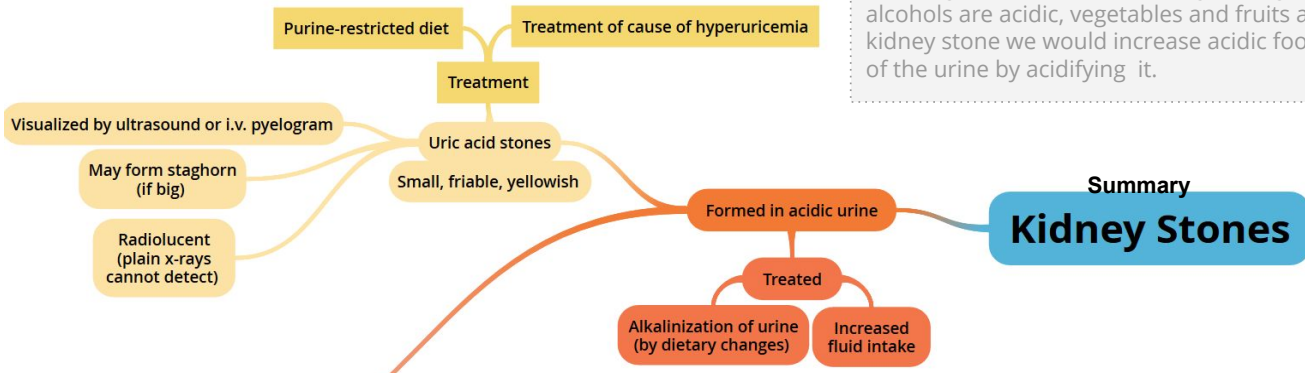
Treatment:

- Treatment of cause of hyperuricemia.
- Purine-restricted diet
Because it's the origin of Uric acid

- Alkalinization of urine (by dietary changes: **Eating Vegetables**)
- Increased fluid intake

Eating **Vegetable and fruits** > Alkalinization of urine > For acid stones
 Eating **Meat** > Acidification of urine > For Alkaline stones

An option To treat any kidney stone is to affect the urines acidity or alkalinity this can be achieved by dietary changes. (Meats and alcohols are acidic, vegetables and fruits are alkaline.) in this type of kidney stone we would increase acidic foods to correct the alkalinity of the urine by acidifying it.



Mg ammonium PO₄ stones

(Also called struvite kidney stones)

- Infection is prime factor to struvite stones.
- Bacterial infection leads to increase in urease activity
- Urease will metabolize urea into ammonia, which will change the PH to alkaline which leads to Mg stone formations.

- About 10% of all renal stones contain Mg amm. PO₄

- Commonly associated with staghorn calculi
- 75% of staghorn stones are of struvite type

- Associated with chronic urinary tract infection.
 - Microorganisms (such as from *Proteus genus*) that has urease activity that metabolize urea into ammonia
 - Causing urine pH to become alkaline leading to stone formation

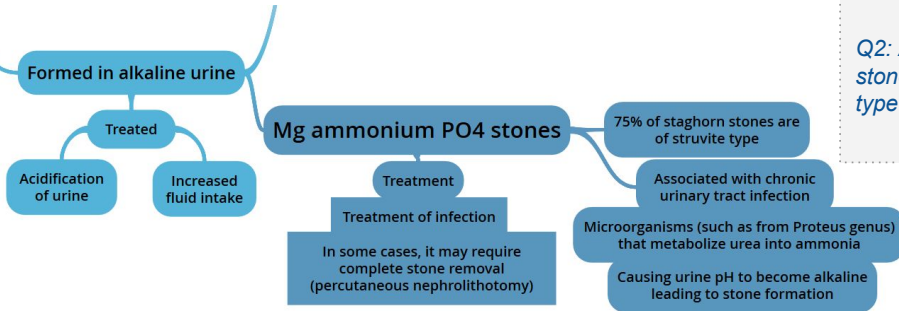
Mg ammonium PO₄ stones

Treatment:

- Treatment of infection
- Urine acidification
- Increased fluid intake
- In some cases, it may require complete stone removal (percutaneous nephrolithotomy)

Summary

Kidney Stones

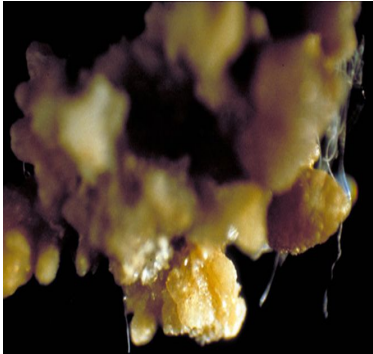


Q1: A patient has staghorn stones with no UTI, what is the most likely type of stone?

A. Calcium phosphate

Q2: A patient has a staghorn shaped stone and a UTI, what is the most likely type of stone?

A. Struvite stone



Cystine stones

Characteristics

- Cystine is a dipeptide that is less soluble.
- Cystine stones are caused by an inherited disease that inhibits cystine absorption

1- A rare type of kidney stone

2- Due to homozygous cystinuria

3- Form in acidic urine

4- Soluble in alkaline urine

5- Faint radio-opaque

Treatment

1- Increased fluid intake

2- Alkalinization of urine (by dietary changes)

3- Penicillamine (binds to cysteine to form a compound more soluble than cystine)

Eating **Vegetable** > Alkalinization of urine > For acid stones
Eating **Meat** > Acidification of urine > For Alkaline stones

Laboratory investigations of kidney stones

If stones has formed and removed: “either surgically or normally”

Chemical analysis of the stones will help us in 2 things

- 1) Identify the cause
- 2) Advise the patient to prevent it from happening again and to stop future recurrence “a patient that makes a stone is very likely to make more stones, so prevention is important”

If stones had NOT yet formed:

- Investigation may help to contribute in knowing CAUSES or factors that may help form the stone:
 - Serum calcium , uric acid , PTH (parathyroid hormone) analysis
 - Urinalysis → Volume , calcium , oxalate , and cystine levels
 - Urine pH > 8 suggest UTI → **Mg ammonium phosphate “ Struvite ” stones**
- Urinary tract imaging :
 - CT , ultrasound , and I.V Pyelogram

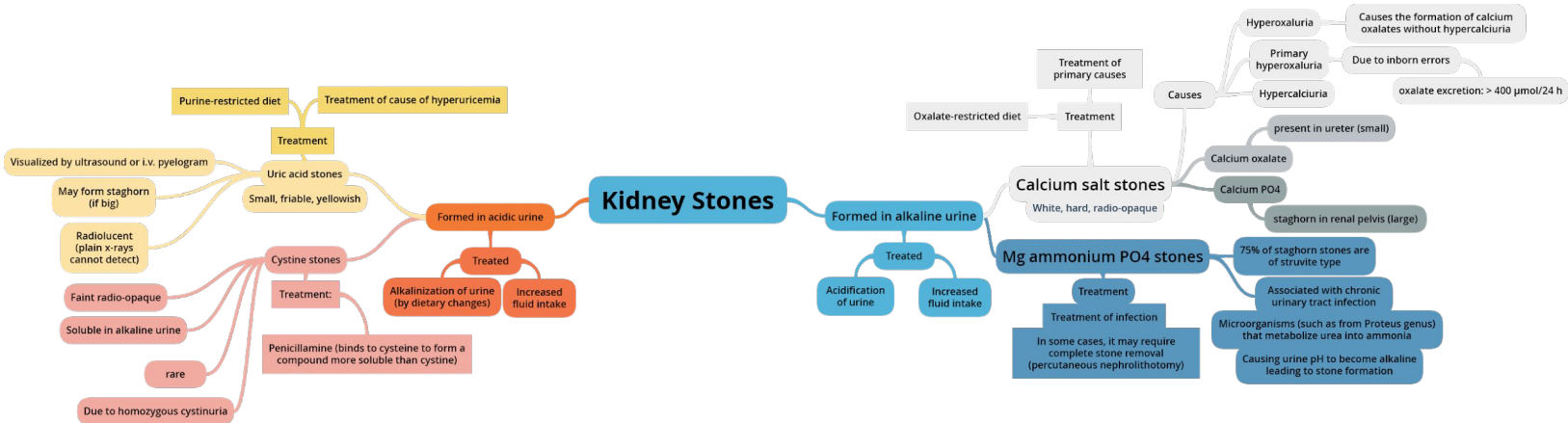


I.V Pyelogram

Summary of types of kidney stone

From Team 436

TYPE	PH level at which stones are formed	Appearance on X-ray
Calcium salts Need high pH to form stones	Alkaline urine	radio-opaque
Uric acid Need low pH to form stones	Acidic urine	Radio-lucent
Mg Ammonium Po4 Need high pH to form stones	Alkaline urine	Faint radio-opaque
Cystine Need low pH to form stones	Acidic urine	Faint radio-opaque
Xanthine Need low pH to form stones	Acidic urine	Radio-lucent



MCQs:

1- What is the cause of kidney stone formation in case of bacterial infection?

- A) Urine stagnation
- B) High metabolic conc.
- C) Change in urine PH
- D) Deficiency in stone forming inhibitors

2- Most common type of kidney stones is ...?

- A) Phosphate
- B) Calcium
- C) Magnesium
- D) Uric acid

3- A patient came to you with severe flank pain and haematuria you suspected kidney stones a plan x ray of the kidneys showed nothing you asked for ultrasound and you find small stones in the kidney, after extraction of the stones they appeared to be small friable and yellowish. What is the type of stone?

- A) Uric acid stone
- B) Calcium salt stone
- C) Mg ammonium PO_4 stones
- D) Glucose stones

4- Which of the following types of kidney stones are also called struvite kidney stones?

- A) Uric acid stone
- B) Calcium salt stone
- C) Mg ammonium PO_4 stones
- D) Glucose stones

5- Calcium oxalate stones are mainly formed in the?

- A) Renal Pelvis
- B) Ureter
- C) Urethra
- D) Minor calyx

6- Which of the following doesn't inhibit the formation of growth of calcium phosphate and calcium oxalate crystals?

- A) Citrate
- B) Pyrophosphate
- C) Glycoproteins
- D) G6PD

D-9
B-5
C-4
A-3
B-2
C-1

SAQ:

SAQ/ In treatment of calcium salt stones why do we treat it by the acidification of urine (by dietary changes)?

- ~ Because Calcium salt stones are formed in alkaline urine, so by the acidification of the urine we stop the formation of the stones.

Girls team

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- لبلى الصباغ
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- أرجوانة العقل
- ربناذ الغربى
- رزان الزهرانى
- لبان المنع
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