Urolithiasis

Prevalence, causes, pathogenesis, types and management.

“I will not cut for stone, even for patients in whom the disease is manifest; I will leave this operation to be performed by practitioners, specialists in this art…”

-Hippocratic Oath

Prevalence

- Stone incidence depends on **geographical, climatic, ethnic, dietary and genetic factors**.
- The recurrence risk is basically determined by the disease or disorder causing the stone formation
- Prevalence rates for urinary stones vary from 1% to 20%.
- In countries with a high standard of life such as Sweden, Canada or the USA, renal stone prevalence is notably high (> 10%).
- In the West there has been a steady rise in the incidence of calculi in the kidney and ureter, interrupted only by two World Wars, from which it is argued that stones reflect affluence (wealth) and overfeeding with re-fined sugar and protein.

ureterovesical junction

- The upper urinary tract is affected in most cases.
- Bladder stones are found in a small proportion of men with bladder outflow obstruction, and in endemic areas.
- The prevalence of stones changes with age and is lower in women, although the male:female ratio is becoming more equal.

- The ureter is narrow at 3 sites:

1. At the ureteropelvic junction.
2. At the point where the ureter crosses over the iliac vessels.
3. In the ureterovesical zone.

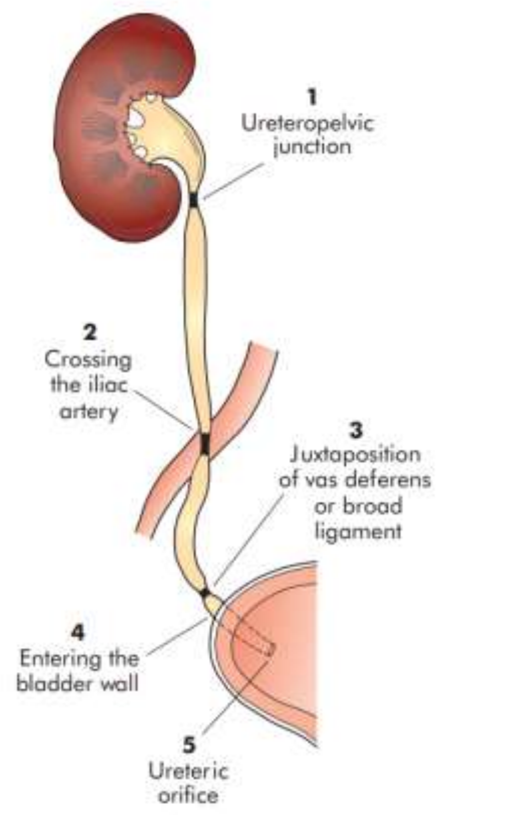
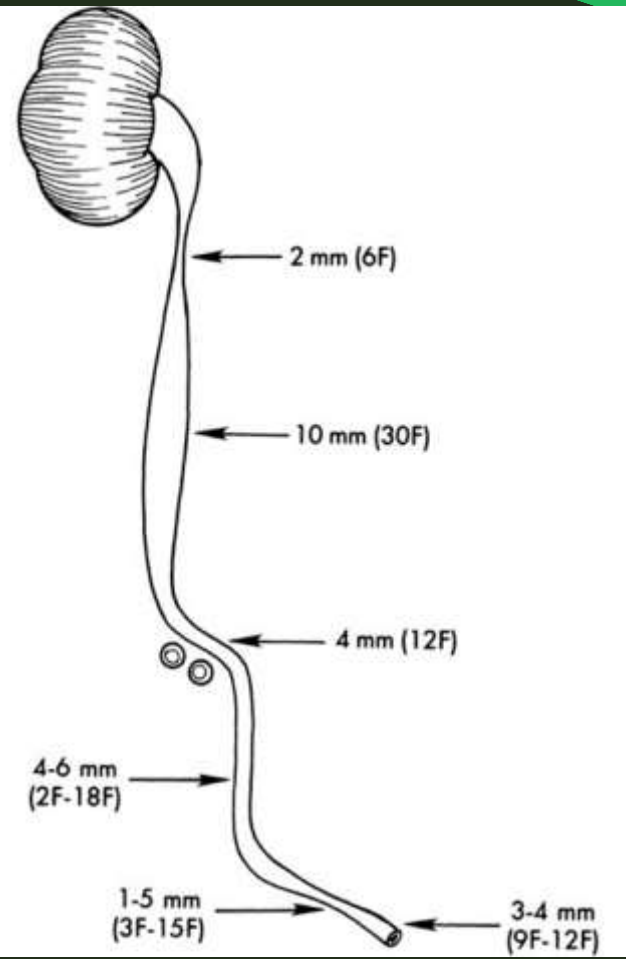


Figure 75.28 Normal anatomical narrowings (1–5) of the ureter.



- F = French
- The **French scale** or **French gauge** system is commonly used to measure the size of a catheter.
- Fr=1/3 mm.

Classification

- Urinary stones can be classified according to size, location, X-ray characteristics, aetiology of formation, composition, and risk of recurrence.

Kidney → nephrolithiasis
↳ parenchyma
in excretion organs → urolith
of [illegible]

Kidney →
in parenchyma →
nephrolithiasis

Stones classified by aetiology:

Non-infection stones
Calcium oxalate
Calcium phosphate
Uric acid
Infection stones
Magnesium ammonium phosphate
Carbonate apatite
Ammonium urate
Genetic causes
Cystine
Xanthine
2,8-Dihydroxyadenine
Drug stones

Stone classified by chemical composition

Chemical name	Mineral name	Chemical formula
Calcium oxalate monohydrate	Whewellite	$CaC_2O_4.H_2O$
Calcium oxalate dihydrate	Weddelite	$CaC_2O_4.2H_2O$
Basic calcium phosphate	Apatite	$Ca_{10}(PO_4)_6.(OH)_2$
Calcium hydroxyl phosphate	Carbonate apatite	$Ca_5(PO_4)_3(OH)$
b-tricalcium phosphate	Whitlockite	$Ca_3(PO_4)_2$
Carbonate apatite phosphate	Dahllite	$Ca_5(PO_4)_3OH$
Calcium hydrogen phosphate dihydrate	Brushite	$CaHPO_4.2H_2O$
Calcium carbonate	Aragonite	$CaCO_3$
Octacalcium phosphate		$Ca_8H_2(PO_4)_6.5H_2O$
Uric acid	Uricite	$C_5H_4N_4O_3$
Uric acid dihydrate	Uricite	$C_5H_4O_3.2H_20$
Ammonium urate		$NH_4C_5H_3N_4O_3$
Sodium acid urate monohydrate		$NaC_5H_3N_4O_3.H_2O$
Magnesium ammonium phosphate hexahydrate	Struvite	$MgNH_4PO_4.6H_2O$
Magnesium acid phosphate trihydrate	Newberyite	$MgHPO_4.3H_2O$
Magnesium ammonium phosphate monohydrate	Dittmarite	$MgNH_4(PO_4).H_2O$
Cystine		$[SCH_2CH(NH_2)COOH]_2$
Xanthine		
2,8-Dihydroxyadenine		
Proteins		
Cholesterol		

By size:

- Stone size is usually given in one or two dimensions, and stratified into those measuring up to 5, 5-10, 10-20, and > 20 mm in largest diameter.

By location:

- Stones can be classified according to anatomical position:
- Kidney: upper, middle or lower calyx; renal pelvis
- Ureter : upper, middle or distal ureter
- Urinary bladder.

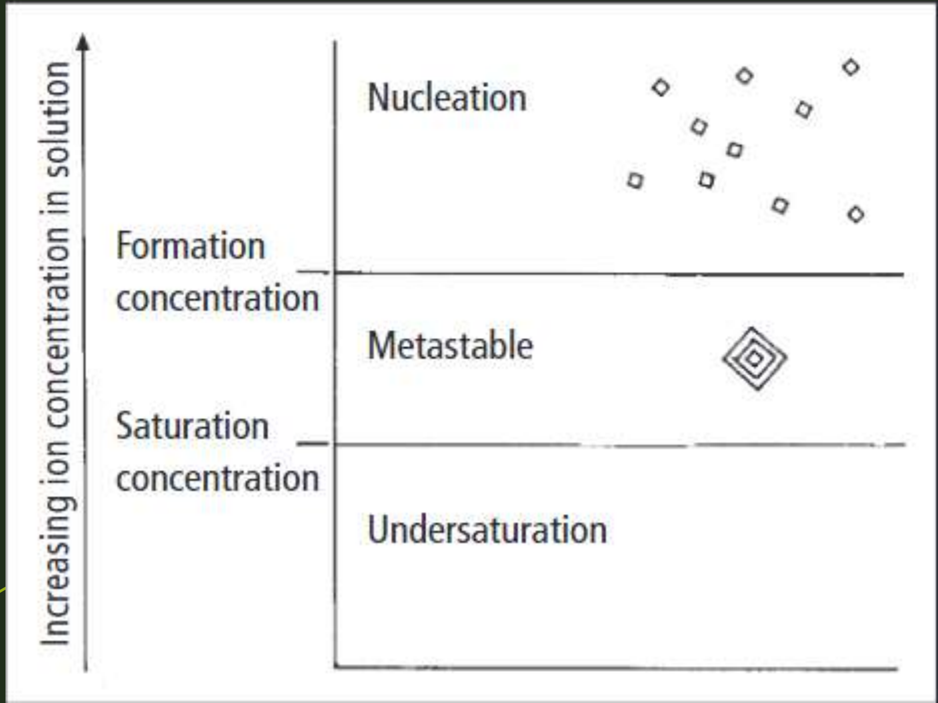
By X-ray characteristics: [kidney-ureter-bladder (KUB) radiography]

Radiopaque	Poor radiopacity	Radiolucent
Calcium oxalate dehydrate	Magnesium ammonium phosphate	Uric acid
Calcium oxalate monohydrate	Apatite	Ammonium urate
Calcium phosphates	Cystine	Xanthine
		2,8-Dihydroxyadenine
		Drug-stones (Section 4.11)

Pathogenesis

- Salt added to water continues to dissolve until no more will do so: this is the saturation concentration, which is measured by the solubility product of the concentration of ions making up the salt.
- In urine, a metastable solution forms, which does not precipitate crystals even though the saturation concentration has been exceeded, unless the solution is left undisturbed for a longtime, or is seeded with a nucleus

  on which stones can precipitate.



- If the concentration exceeds that of the metastable region, crystals precipitate to make their own nuclei – nucleation. Human urine is always metastable with respect to the main crystalline components of stones; calcium and oxalate.
- The metastable state is influenced by temperature, the presence of colloids, the rate of flow of the urine, the concentration of the solutes and the presence of anything which can act as a nucleus, e.g., dead papillae, necrotic carcinoma, a non-absorbable suture, a fragment of catheter, or a previously existing fragment of stone.

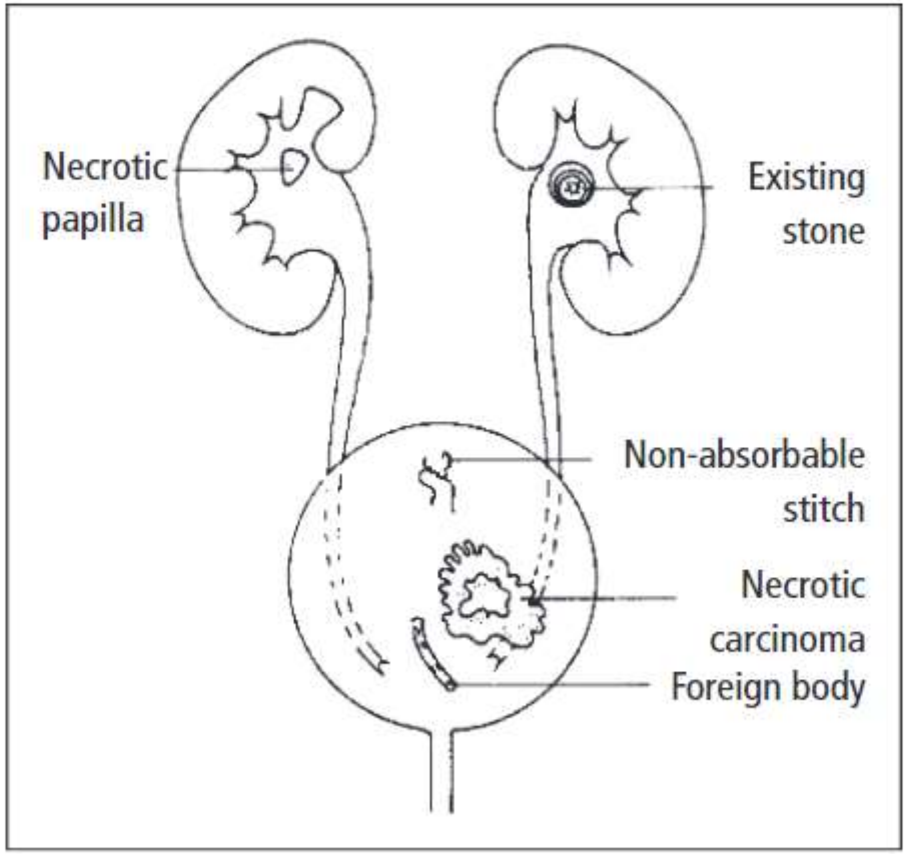


Figure 7.3 Many things can act as a nucleus for stone formation.

- The pH of the urine may be important in the formation of calculi.

  *Magnesium ammonium phosphate is insoluble in alkaline urine.

  *Uric acid is insoluble in acid urine but may dissolve if the urine is made alkaline.

- All crystals prefer to be undisturbed if they are to grow, so calculi tend to form wherever there is stagnant urine, as in a ureterocele, a diverticulum, a hydronephrosis or a chronically obstructed bladder.

To summarize:

- There are three theories that can explain formation of stones:
  1. Nucleation and Stone Matrix theories:
     - A small crystal or foreign body promotes the crystallization and growth of a crystal lattice in urine. And a matrix of organic urinary proteins that provides a framework for the deposition of crystals.
  2. Inhibition of crystallization theory:
     - There are several urinary substances(magnesium, citrate etc.) which have been demonstrated to inhibit crystallization of salts in urine. If these are in low concentration or absent in urine, then there will be an increased tendency towards stone formation.
  3. Obstruction:
     - Stones tend to form at sites of obstruction. Examples would include a renal calyceal diverticulum, a ureterocele, an obstructed bladder or an obstructed prostatic duct.

Now let's talk about each stone, how it's formed, its causes and its risk factors.

Calcium stones:

- There are two types of calcium stones:
    - [calcium oxalate]
    - [calcium phosphate].

Calcium oxalate:

- Most common; 70-80% of stones.
- Very hard stone.
- It's composed of both [calcium] and [oxalate], thus an increase in one of these components or both may cause stones to form.
- Also, a decrease in [magnesium] and [citrate] (both inhibit crystallization) is another cause.
- Does hyperuricosuria promote calcium stones? We'll talk about that. [Spoiler: It does.]

Causes are:

- *Hypercalciuria*
- *Hypercalcemia*
- *Hyperoxaluria*
- *Hyperuricosuria*
- *Hypocitraturia*
- *Hypomagnesuria*
- *Low fluid intake, low urinary volume, dehydration.*
- *Vitamin D toxicity*

Hypercalciuria

- An excess of calcium in the urine (i.e.>350 mg/24 h in males,>300 mg/24 h in females) may be a cause of stones in some males.
- 3 types:
  1. Renal, where there is decreased renal tubular reabsorption of calcium.
  2. Absorptive, where too much calcium is absorbed from the bowel.
  3. Resorptive hypercalciuria, where an excess of calcium is absorbed from the bones, depends on the function of the parathyroid glands.

Absorptive:

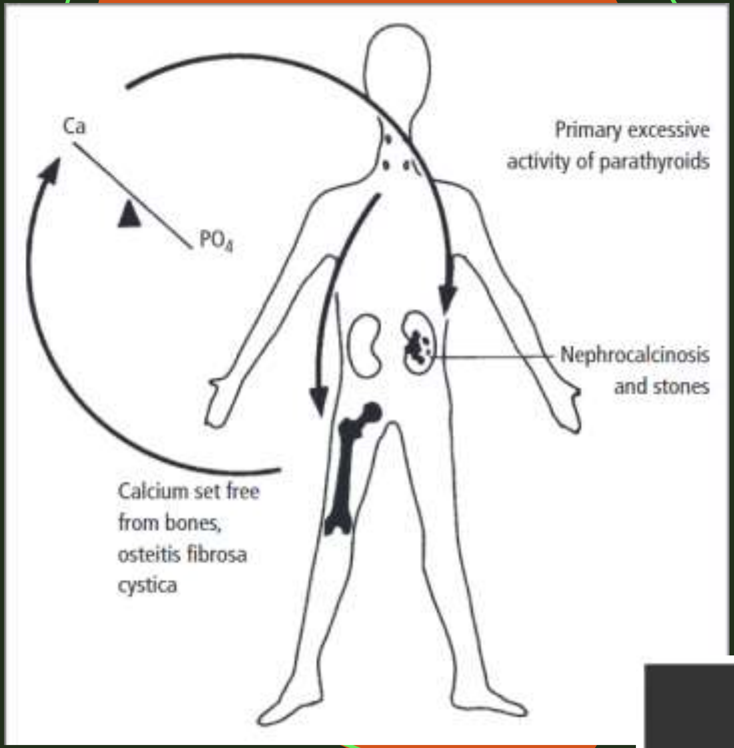
- The most common (about 60% of patients).
- Increased absorption of calcium, hypercalcemia and decreased parathyroid secretion.
- The basis of treatment is to limit calcium and sodium intake in the diet.
- Cellulose phosphate may be administered which exchanges sodium for calcium within the gastrointestinal tract and thus reduces calcium absorption, and orthophosphates reduce urinary calcium excretion and increase urinary pyrophosphate and citrate excretion.
- It is far more important to keep the urine dilute by drinking plenty of water.

Resorptive hypercalciuria

- 3 types of hyperparathyroidism:
    1. Primary hyperparathyroidism.
    2. Secondary hyperparathyroidism.
    3. Tertiary hyperparathyroidism.

Primary hyperparathyroidism.

- The parathyroid glands start to secrete more parathyroid hormone than is needed with the result that calcium is reabsorbed from the skeleton and added to the blood.
- *The plasma [Ca] rises* and the plasma [PO4] falls.
- The excess calcium enters the urine where it precipitates in the renal tubules as one form of nephrocalcinosis or forms a stone in the renal tract.



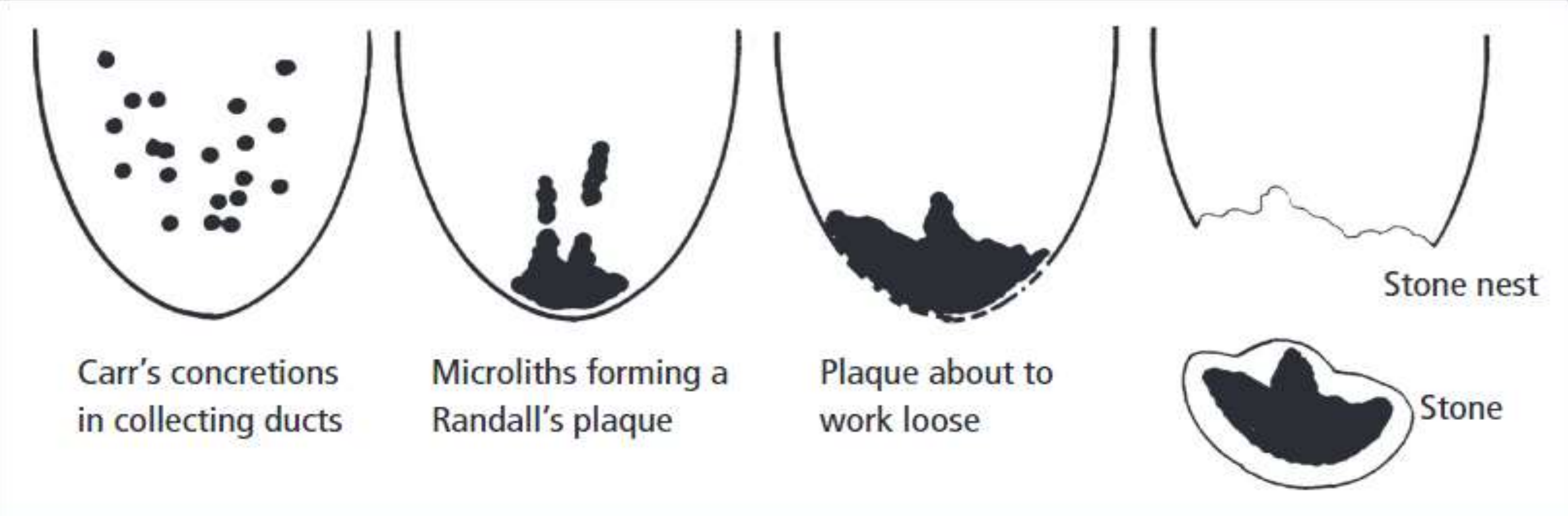
- It is very rare to find the classical changes of [osteitis fibrosa cystica], where massive collections of osteo-clasts cause cystic cavities in bones and sometimes a pathological fracture.
- (Subperiosteal bone resorption)

Secondary and tertiary hyperparathyroidism:

- Secondary: In chronic renal failure, phosphate is one of the metabolic products that is not adequately excreted; so, the plasma [PO4] rises, and the *[Ca] has to fall*. The [Ca] is precipitated in soft tissues as heterotopic calcification where it may cause joint stiffness and deafness. The parathyroids respond to the lowered [Ca] by secreting more parathyroid hormone, and all four glands become hyperplastic. Can be prevented by giving large doses of vitamin D.

- Tertiary: Here the overactive parathyroid glands seem not to know when to stop and in spite of extra vitamin D, keep on putting out far more parathyroid hormone than is needed to maintain a constant [Ca] (progression from 4-gland hyperplasia to autonomous PTH production). When this occurs, they must be removed.

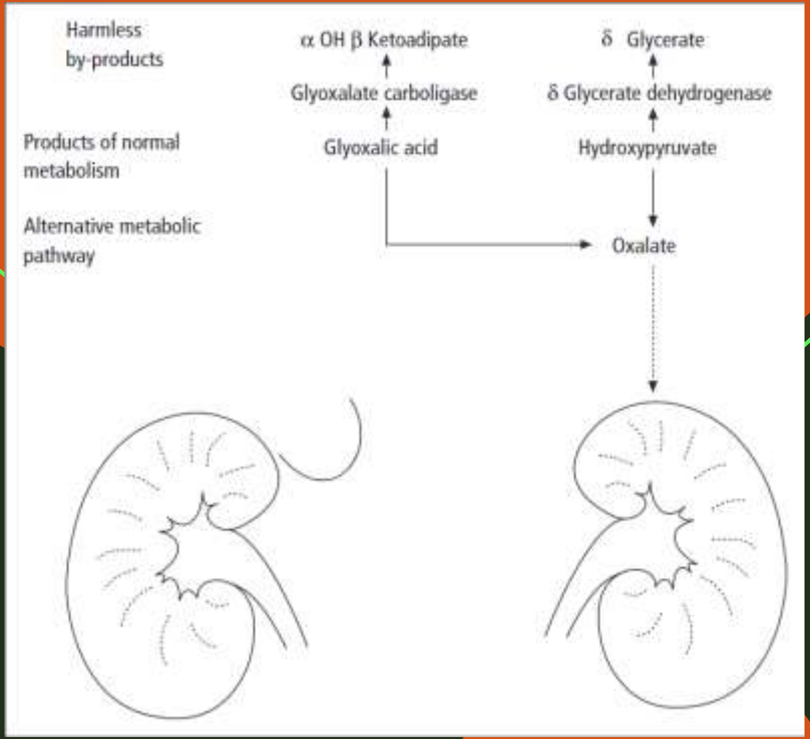
- Tiny spheres of calcium phosphate are often found in normal collecting ducts – Carr's concretions. Collections of these concretions gather near the tip of a papilla to form shining plaques easily seen with a nephroscope – Randall's plaques. When these become detached, they may act as a nucleus for further stone formation.
- A similar nucleus is formed by a necrotic renal papilla.
- From then on, the stone continues to grow as layer after layer of calcium salts, together with a protein matrix, is laid down.

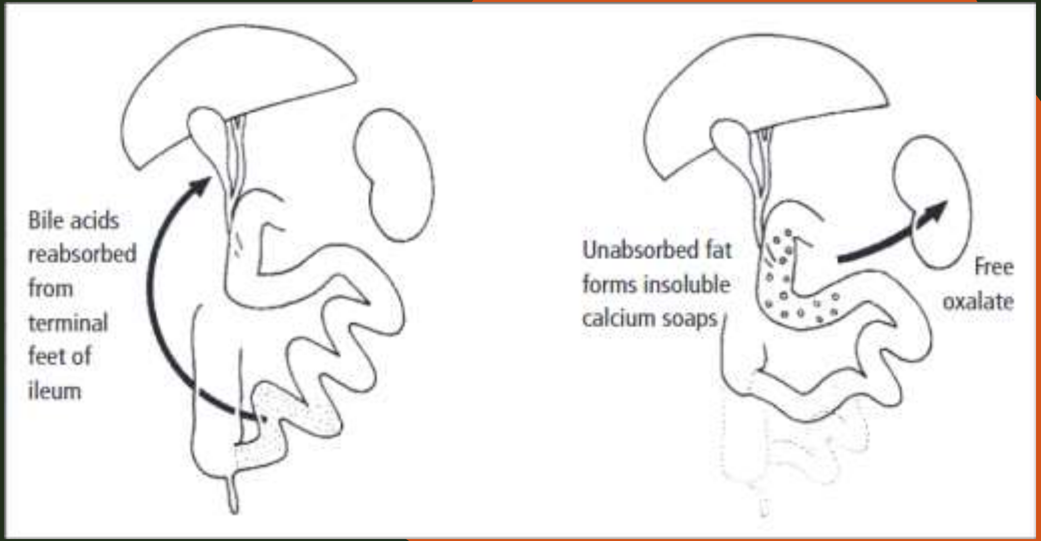


Carr's concretions in collecting ducts
Microliths forming a Randall's plaque
Plaque about to work loose

Hyperoxaluria

- Primary (hepatic): Inherited liver enzyme deficiency (either of glyoxalate carboligase, or gamma-glycerate dehydrogenase) leading to an excess of oxalate in the urine (Fig. 1), which precipitates in the collecting tubules and eventually leads to renal failure. A combined liver and kidney transplant can be successful as treatment.
- Secondary (ileal): A diseases of the terminal ileum where bile acids are normally absorbed. If bile acids are not reabsorbed and recycled in the liver to be added to bile, then dietary fat cannot be emulsified, and remains in the bowel where it forms an insoluble soap with dietary calcium (Fig. 2). This in turn leaves an excess of dietary oxalate which is absorbed, excreted in the urine, and forms a stone. This type of hyperoxaluria may be prevented by giving cholestyramine and by avoiding food rich in oxalate such as tea, chocolate, coffee, spinach and rhubarb(الراوند).





What about *Hyperuricosuria?*

- Several theories have been proposed to explain the possible mechanism of calcium stone formation in hyperuricosuric patients.

1. Epitaxy, the formation of one crystal on top of another, related to heterogeneous nucleation.
2. Addition of crystalline sodium urate (but not uric acid) accelerated crystallization of calcium oxalate from a metastable solution

Further explanation on point 2:

- Salting out is a decrease in solubility of a non-electrolyte with increasing concentrations of electrolyte, causing the former to precipitate from solution. In the current example, calcium oxalate is poorly soluble and uncharged and is considered the non-electrolyte, while uric acid is the more soluble, charged electrolyte that causes precipitation of calcium oxalate.
- For more on this subject: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4514566/#S2title

Calcium phosphate:

- These stones occur in patients with renal tubular acidosis (RTA) Type 1 (distal).
- RTA 1 is characterized by metabolic acidosis ,hypokalemia, low urinary citrate, hypercalciuria with high urine pH (alkaline urine).

Uric acid stones:

- Account for about 10% of urinary calculi.
- Uric acid is an end product of purine metabolism and is very insoluble in acidic water. As urine becomes more acidic, more uric acid will become insoluble and thus lead to stone formation.
- Uric acid stones arise in patients with an either idiopathic form of the disease with normal levels of serum and urinary uric acid.
- In other patients hyperuricemia is associated, an excess of uric acid occurs when there is a primary defect of metabolism of uric acid (as in gout) or rapid catabolism of protein, e.g., after cancer chemotherapy. Hyperuricemia also occurs in patients with myeloproliferative disorders (as a consequence of an abnormally rapid metabolism of nucleoprotein **or cytotoxic drugs not sure**). It is also seen in dehydration, chronic diarrhea, in patients with ulcerative colitis and ileostomies.

Struvite stones (infection or triple phosphate stones):

- These stones are twice as common in women as in men and account for 15% of all urinary calculi.
- They are often large and fill the pelvicalyceal system, giving the characteristic ‘staghorn’ appearances.
- Chemically, they comprise of a mixture of magnesium ammonium phosphate and calcium apatite.
- The stones usually arise in the presence of ‘urea-splitting’ organisms within the urine, typically *Proteus* species. (*Proteus mirabilis*)
- These organisms alkalinize the urine above pH 7.0, causing precipitation of urinary calcium and other ions.

Cystine stones:

- In cystinuria, there is a congenital (Mendelian recessive) defect in the enzymes necessary for the transport of cystine, ornithine, arginine and lysine in the proximal tubule. So reduced absorption results in supersaturation with cystine crystal formation.
- Cystine is more soluble in alkaline urine.

Calcium stones are formed due to an excess of a mineral called oxalate – commonly found in some fruit, vegetables, nuts and chocolate.

A struvite stone is less common and caused by infection in the urinary tract. It can grow quickly and become quite large.

Uric acid stones form due to chronic dehydration. The risk increases in those with gout, a genetic tendency or a diet too high in protein.

Cystine stones form in people with an inherited disorder that causes the kidneys to excrete an excess of certain amino acids.

Xanthine stones are caused by an enzyme deficiency that causes the build-up of xanthine deposits.

Silica stones are rare and caused by certain medications or herbal supplements.

History and examination

{symptoms & signs}

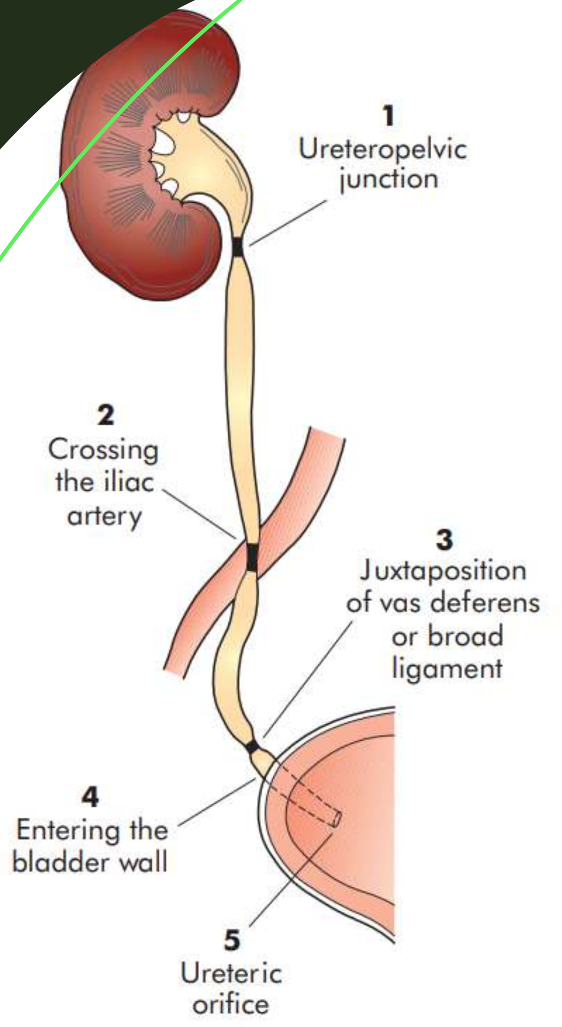
Symptoms

- The symptoms caused by these stones depend upon their size, position and the presence of complicating factors such as infection.
- Many renal stones are asymptomatic and identified when investigations are performed as a result of other clinical conditions.
- Non-specific symptoms may be associated with the presence of urinary stones in patients with chronic urolithiasis.

- Pain.
- Hematuria.
- Urinary tract infection with fever.
- Urinary urgency or frequency.
- Nausea and vomiting.

Pain

- Most patients will present with isolated symptoms of loin pain, with or without hematuria.
- Typical 'ureteric colic'.
- The pain originates in the loin, comes in waves of severity often lasting several minutes and radiates into the scrotum and testis in the male, and labia in the female.
- The pain frequently is abrupt in onset, severe and may awaken a patient from sleep.
- Severity of pain is related to the degree of obstruction, presence of ureteral spasm, and presence of any associated infection.
- More severe and consistent pain with or without hematuria may occur if the stone becomes 'stuck' at any of these sites.



re 75.28 Normal anatomical narrowings (1–5) of the urete

- Small ureteral stones frequently present with severe pain, while large staghorn calculi may present with a dull ache or flank discomfort.
- Stones may be found in renal calyx, renal pelvis, upper, middle and distal ureter as mentioned before. The severity of symptoms increase as a stone moves down the urinary tract.

- Stones situated in renal calyces may be small and asymptomatic but occasionally present after a single episode of relatively painless hematuria. When they become big enough to obstruct the flow of urine from a calyx, they may cause flank pain, hematuria and recurrent infection.
- Stones that become lodged at the pelviureteric junction [PUJ] may cause severe loin pain associated with nausea and vomiting. This can also cause severe pain in the costovertebral angle.

- Stones in the upper or midureter often cause severe, sharp back (costovertebral angle) or flank pain.
- Pain from upper ureteral stones tends to radiate to the flank and lumbar areas.
- Midureteral calculi cause pain that radiates anteriorly and caudally.
- Distal ureteral stones cause pain that tends to radiate into the groin or testicle in the male or labia majora in the female because the pain is referred from the ilioinguinal or genitofemoral nerves.

HEMATURIA

- Most people with kidney stones will have blood in the urine.
- The urine may appear pink or reddish, or the blood may not be visible until a urine sample is examined under a microscope.
- The lack of microscopic hematuria does not eliminate renal colic as a potential diagnosis.
- Degree of hematuria is not predictive of stone size or likelihood of passage. No literature exists to support the theory that ureterolithiasis without hematuria is indicative of complete ureteral obstruction. (Medscape, 2020)

UTI

- Symptoms related to urinary tract infection such as dysuria, urinary frequency and fever may occur.
- This is either as the primary cause of the stone itself (struvite), or due to infection secondary to obstruction and stasis of urine.
- Stones should be suspected if a patient is suffering recurrent UTIs.
- And as mentioned before, the presence of complicating factors such as infections can contribute to the symptoms as pain for example.

Fever

- The presence of pyrexia should be established at an early stage as a sign of sepsis.
- Signs of clinical sepsis are variable and include fever, tachycardia, hypotension, and cutaneous vasodilation.

- Non-specific symptoms may be associated with the presence of urinary stones in patients with chronic urolithiasis.
- Failure to thrive in a child may indicate the presence of chronic urinary tract infection.

Bladder stones

- Bladder stones will present with increasing filling lower urinary tract symptoms and recurrent urinary tract infection.
- Voiding may be interrupted in a variable manner as the stone falls into the bladder outlet causing intermittent obstruction and severe ‘strangury’ may be associated with the presence of a large bladder stone.
- Rarely, a patient who has passed a sizeable stone into the urethra may present in painful retention of urine and positional urinary retention (obstruction precipitated by standing, relieved by recumbency, which is due to the ball-valve effect of a large stone located at the bladder outlet.)

Other questions to ask in taking history:

- Ask the patient about their diet; decrease amount of fluid intake, increase consumption of animal meats and fatty acids, and decrease in dietary fiber increase risk of stone formation.
- What medications they use. Drugs that induce metabolic calculi include loop diuretics; carbonic anhydrase inhibitors; and laxatives, when abused. Drugs that induce calculi via urinary supersaturation of the agent and become the primary component of the stones include ciprofloxacin; sulfa medications and triamterene. (further reading https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1508366/)
- Family history, as those with a family history of stones have an increased incidence of multiple and early recurrences. And of course, for genetic causes as cystinuria.

Signs and physical examination

- Physical examination often reveals a pale patient in severe distress with considerable pain.
- The patient may well be vomiting with tachypnoea and a tachycardia.
- In comparison to a patient with peritonitis who will invariably remain still, the patient with renal or ureteric colic is often restless, moving around excessively in an effort to find a more comfortable position and this clinical observation is a useful diagnostic sign in cases where symptoms are not clear cut.
- The abdomen should be carefully palpated for signs of localized tenderness and to rule out other causes of acute abdominal pain.

- When assessing a patient clinically with a suspected diagnosis of urinary tract stones always bear in mind that a potentially more serious gastrointestinal, gynecological or vascular diagnosis may be present, and these possibilities must be excluded especially where conservative treatment is likely to be initiated for presumed stone disease.

DIFFERENTIAL DIAGNOSIS

- For pain of upper ureter: On right side, this can be confused with cholecystitis or cholelithiasis. On the left side, acute pancreatitis, peptic ulcer disease, and gastritis.
- Miduretral pain: This midureteral pain in particular can easily mimic appendicitis on the right or acute diverticulitis on the left.
- If a stone is lodged in the intramural ureter, symptoms may appear similar to cystitis or urethritis
- Symptoms can be confused with pelvic inflammatory disease, ovarian cyst rupture, or torsion and menstrual pain in women.
- The presence of a pulsatile mass should raise the suspicion of an abdominal aortic aneurysm.

Other differential diagnosis

- Ectopic and unrecognized pregnancies.
- Acute renal artery embolism.

Investigations

- To confirm the diagnosis.
- Is there evidence of urinary tract infection?
- Where is the stone?
- How big is the stone?
- Is the kidney partially/fully obstructed?
- Are there multiple stones present?
- What is the relative function of each kidney?
- To identify aetiological factors associated with the formation of urinary stones e.g., metabolic disorders, anatomical abnormalities.

Urinalysis

- Urinalysis is mandatory for all patients suspected of having urinary stones.
- The presence of microscopic or macroscopic hematuria will suggest urinary tract pathology, but not always diagnostic of urinary stone disease.
- The presence of pyuria and infection in the urine may suggest an increased risk of sepsis and can alter the approach to management.
- In none acute situations, pH of the urine may give clues as to the aetiology of urinary stone disease and the presence of crystals.

Radiological imaging

- Plain X-ray of the kidneys, ureters and bladder (KUB).
- Ultrasound scan (USS).

  Most (90%) urinary stones are radiopaque and are easily identified on a KUB X-ray, but radiolucent stones such as uric acid stones will usually be seen with USS.
- Intravenous urography (IVU) {or intravenous pyelogram (IVP)}.
- Computerized tomography urography (CTU).

KUB

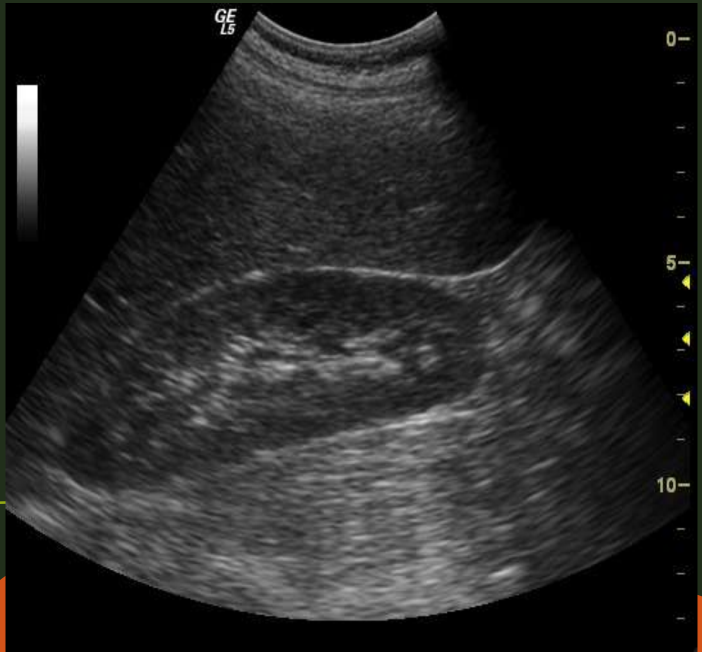
- Remember:

Radiopaque	Poor radiopacity	Radiolucent
Calcium oxalate dehydrate	Magnesium ammonium phosphate	Uric acid
Calcium oxalate monohydrate	Apatite	Ammonium urate
Calcium phosphates	Cystine	Xanthine
		2,8-Dihydroxyadenine
		Drug-stones (Section 4.11)

- Examples:

Ultrasound scan

- Its sensitivity for detecting renal calculi is ~95%.
- Can detect stones, hydronephrosis, hydroureter and scan the bladder (UVJ).
- Normal scans:



Stones:


SAMSUNG
Clinic Otradnoe
dr. Molov M.R.
FR 41Hz
V4-8
15.0см
Общ
MI 0.56
ТИм 0.2
24-01-2018
09:46:24
[2D] У50/125дБ/УК11/Дав.90/ИПС 1
Расст1 0.97 cm
Расст2 0.60 cm

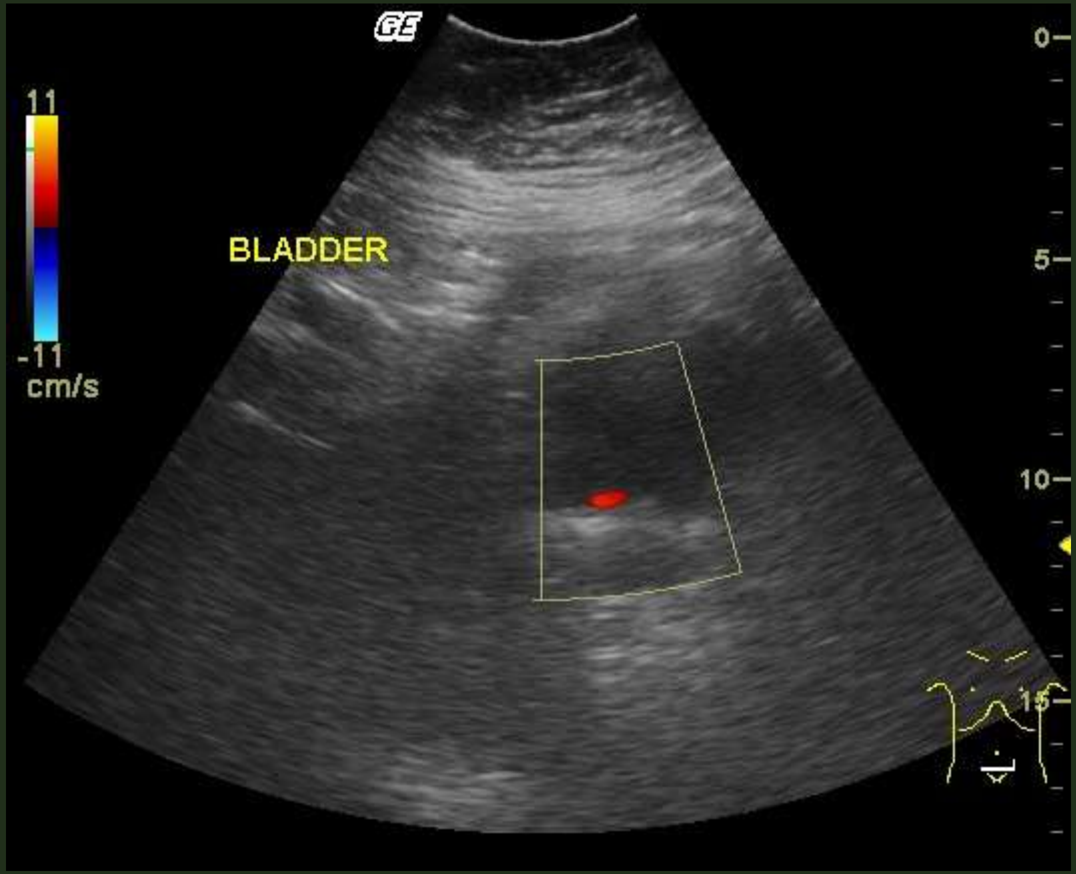

RT-
fineart
america


STONE
3.75 → G 82
IP 5

- Ureteric jets (or ureteral jets) are the visualization of the normal physiological periodic efflux of urine from the distal end of each ureter into the bladder.

Limitations of US:

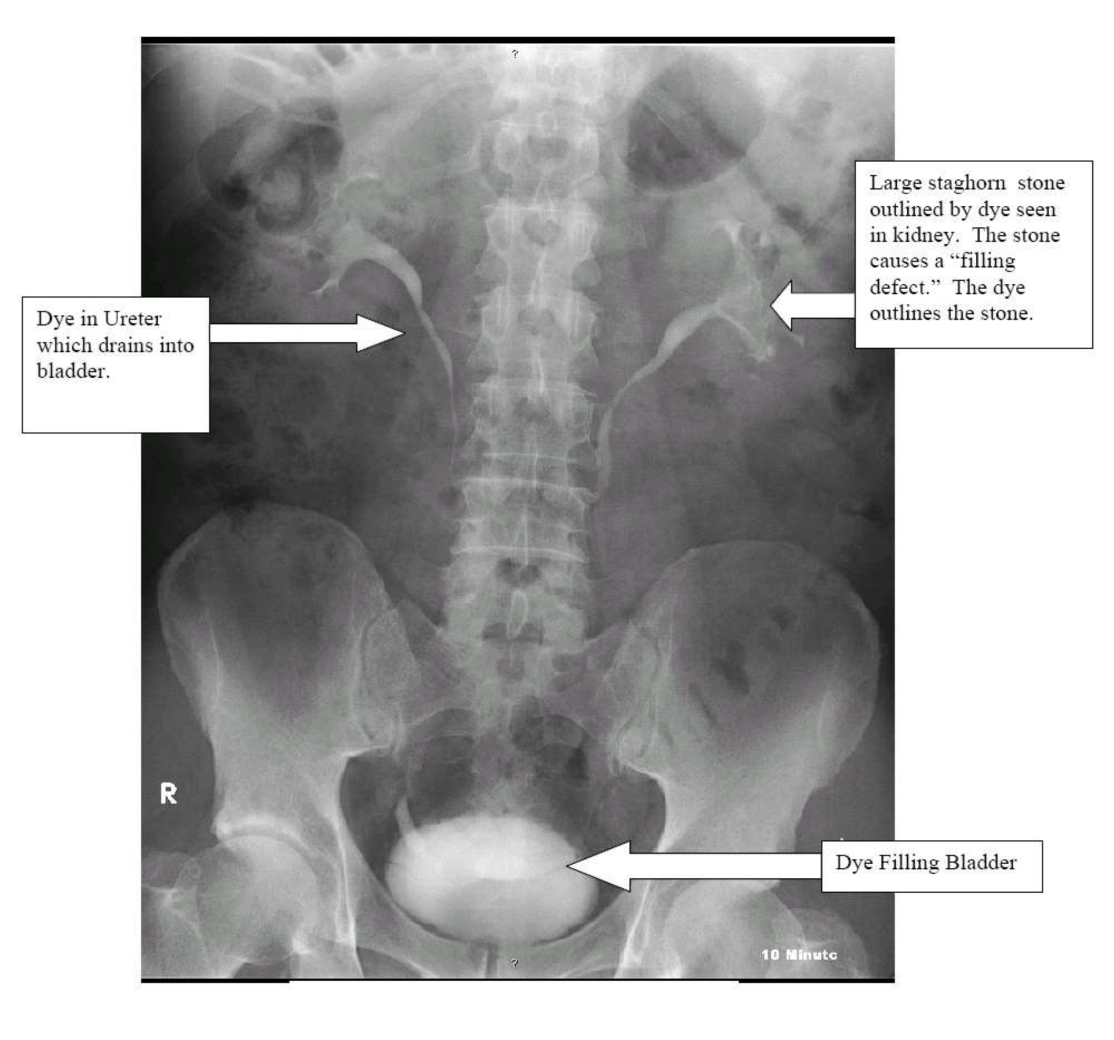
1. Acoustic shadow may not be present if stone is small.
2. Stones in ureter may not be visualized due to overlying bowel gas.
3. Detection of urinary stones on ultrasound (US) may be problematic when the stones are obscured by ultrasonic beam-attenuating tissue, such as renal sinus fat, mesenteric fat, and bowel.



Right Ureteral Jet, absent Left Ureteral Jet

Intravenous urography (IVU)

- It is now rarely used as a first line investigation in urinary stone disease, excluding the emergency investigation of ureteric colic. IVU may be performed if the diagnosis is not clear from KUB X-ray and USS. In recent years, computerized tomography urography (CTU) has superseded IVU in the investigation of urinary stones in some centers.
- Disadvantages: reaction to contrast, and long time of the procedure.



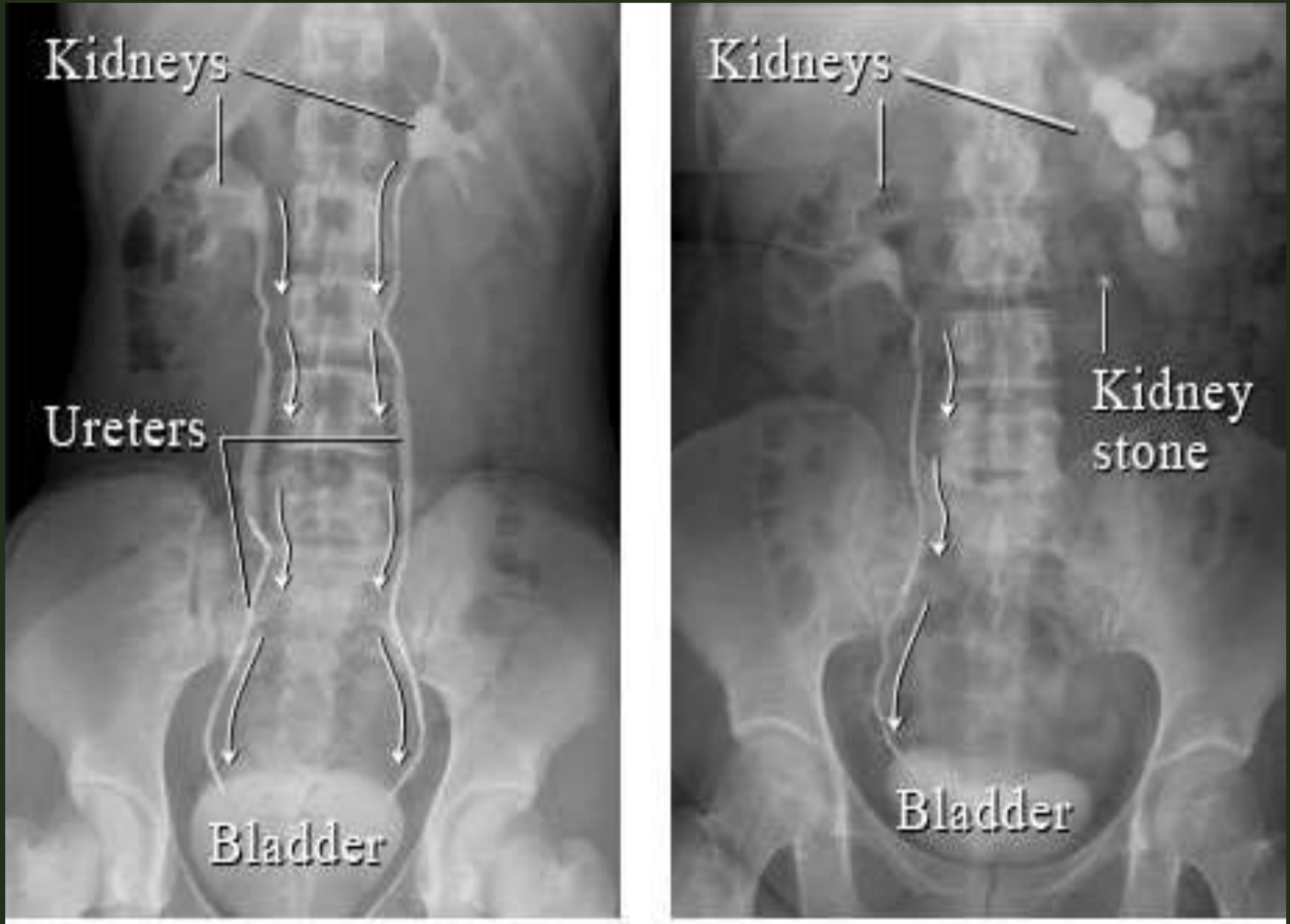
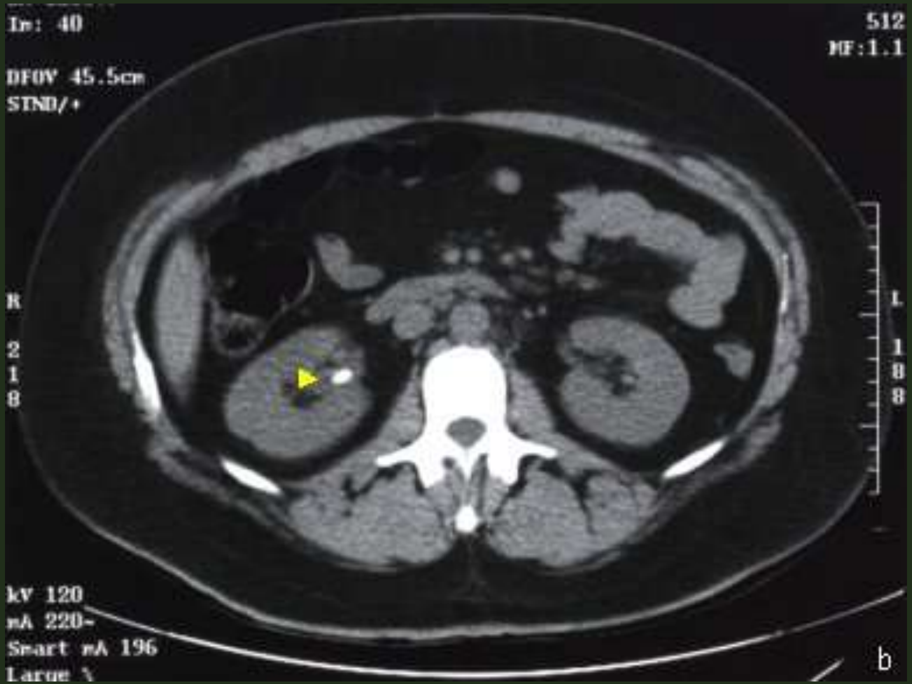


Figure 1

Figure 2

Computerized tomography urography (CTU)

- **Noncontrast spiral CT** scans are now the imaging modality of choice in patients presenting with acute renal colic.
- There is no need for intravenous contrast.
- These images do not give anatomic details as seen on an IVP.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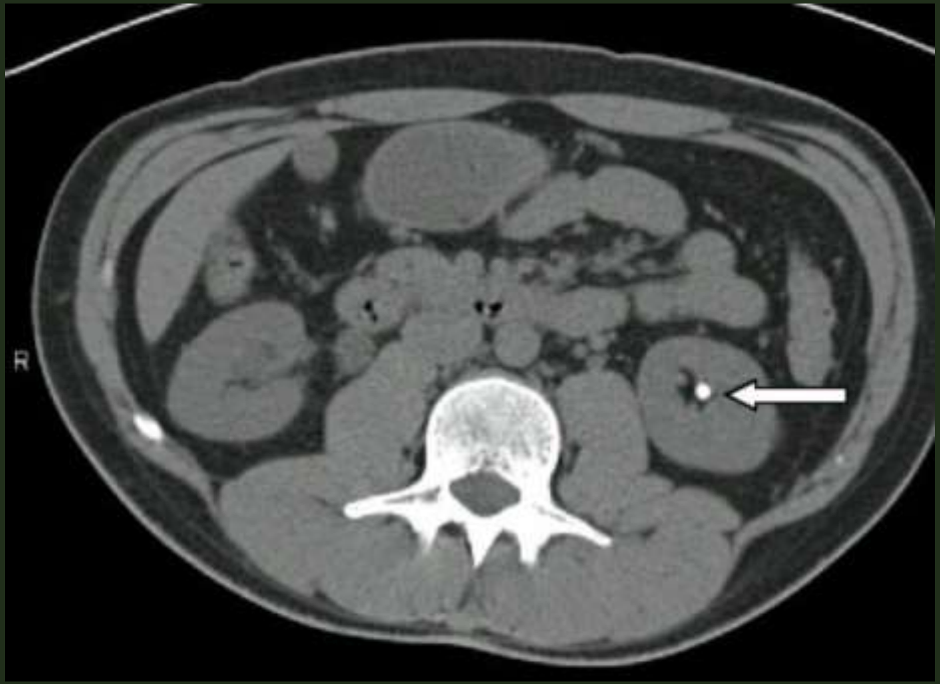
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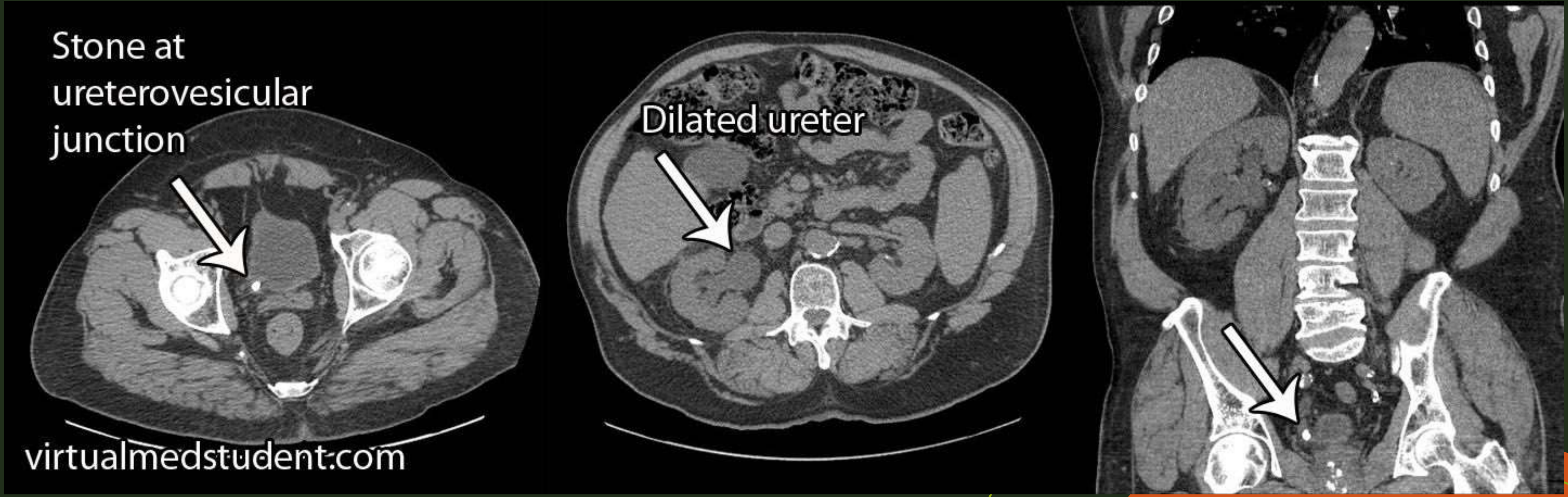
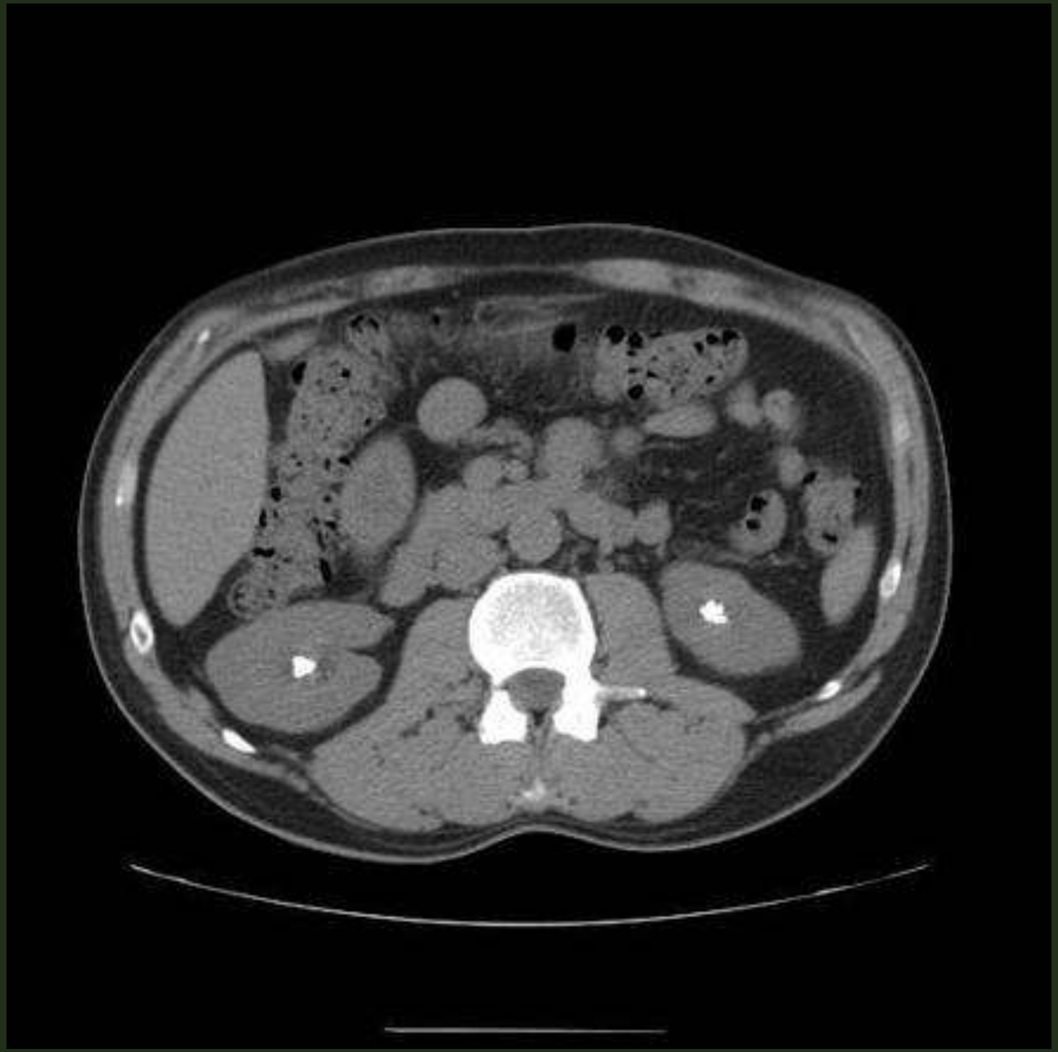

Stone at ureterovesicular junction
Dilated ureter
virtualmedstudent.com



Bilateral

Static renography using DMSA scan

- A DMSA scan is a radionuclide scan that uses dimercaptosuccinic acid (DMSA) in assessing renal morphology, structure and function.
- A DMSA scan is usually static imaging, other radiotracers like DTPA & MAG3 are usually used for dynamic imaging to assess renal excretion.
- Static renography can be utilized where knowledge of the relative function of an individual kidney is important. In a patient with a unilateral stag-horn renal calculus, attempted removal of the stone is not indicated where there is little or no function left in the kidney. In this scenario, a simple nephrectomy would be a better option.

Other imaging studies:

- MRI

  Poor for stones but good for hydronephrosis

- Retrograde pyelogram

  occasionally is required to delineate upper-tract anatomy and localize small or radiolucent offending calculi

- Nuclear scintigraphy.

  Bisphosphonate markers can identify even small calculi that are difficult to appreciate on a conventional KUB film.

Management

- There are 8 ways to manage stones (in kidney, ureter and bladder).

1. Conservative
2. Extracorporeal shock wave lithotripsy (ESWL)
3. Intracorporeal lithotripsy.
4. Percutaneous nephrolithotomy (PCNL).
5. Ureteroscopy (retrograde and antegrade, RIRS).
6. Surgery (Open nephrolithotomy, partial nephrectomy and simple nephrectomy).
7. Dissolution therapy.
8. Medical expulsive therapy.

Conservative

- Many patients with acute renal colic can be managed conservatively with pain medication and hydration until the stone passes.
- Most stones that are 5 mm or less in diameter have a very good chance of spontaneous passage without the need to intervene: 50% will pass if situated in the upper ureter at presentation and 90% will pass if situated in the distal ureter.
- Larger stones are less likely to pass spontaneously.
- During this time, the patient should be given adequate analgesia.
- It is not uncommon for patients to suffer continuing pain for several hours after the stone has passed, probably due to oedema within the ureter.
- Some small stones may not pass spontaneously, either due to irregular morphology or excessive ureteric oedema.
- Adequate time should be left to allow the stone to pass before resorting to invasive measures to remove the stone, provided that the patient's pain can be controlled with simple analgesics.

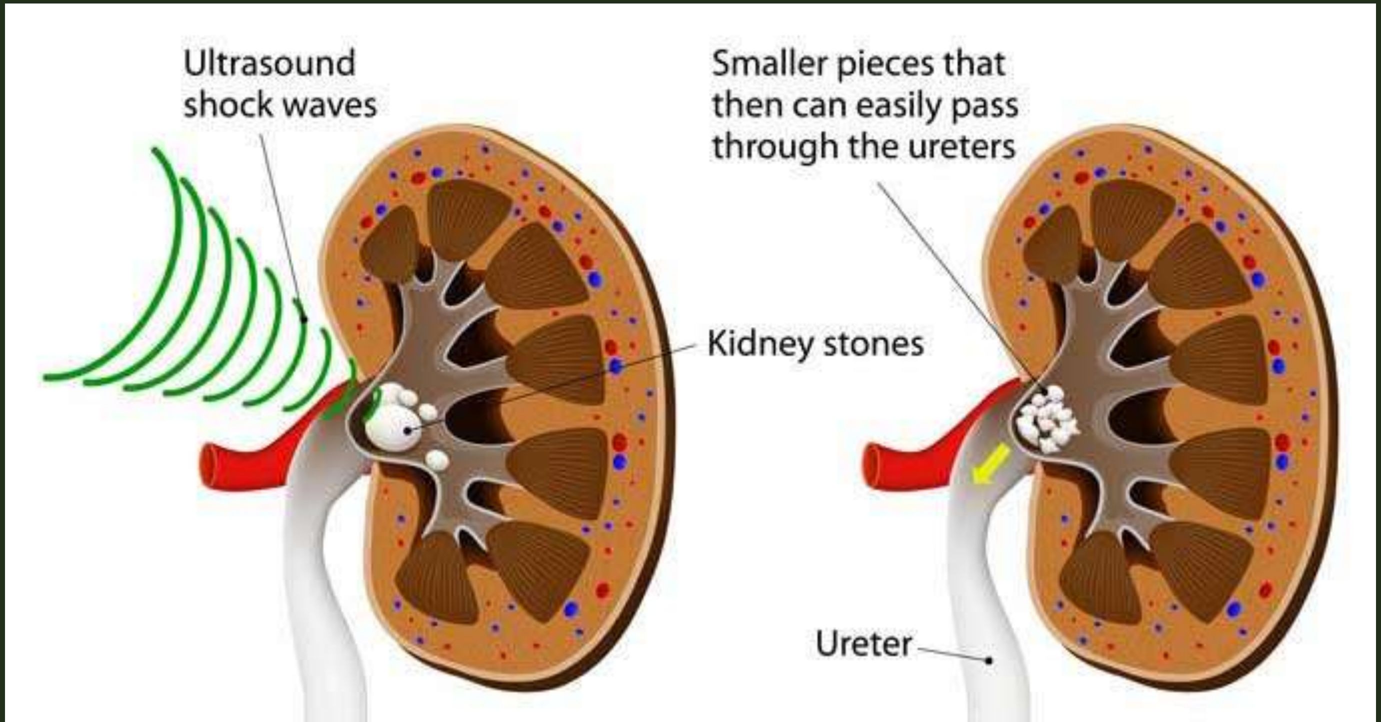
- It is estimated that 95% of stones up to 4 mm pass within 40 days.
- There are several indications for active stone removal in both ureteral stones and renal stones.
- Indications for active removal of ureteral stones are :
    - stones with a low likelihood of spontaneous passage
    - persistent pain despite adequate analgesic medication
    - persistent obstruction
    - renal insufficiency (renal failure, bilateral obstruction, or single kidney)

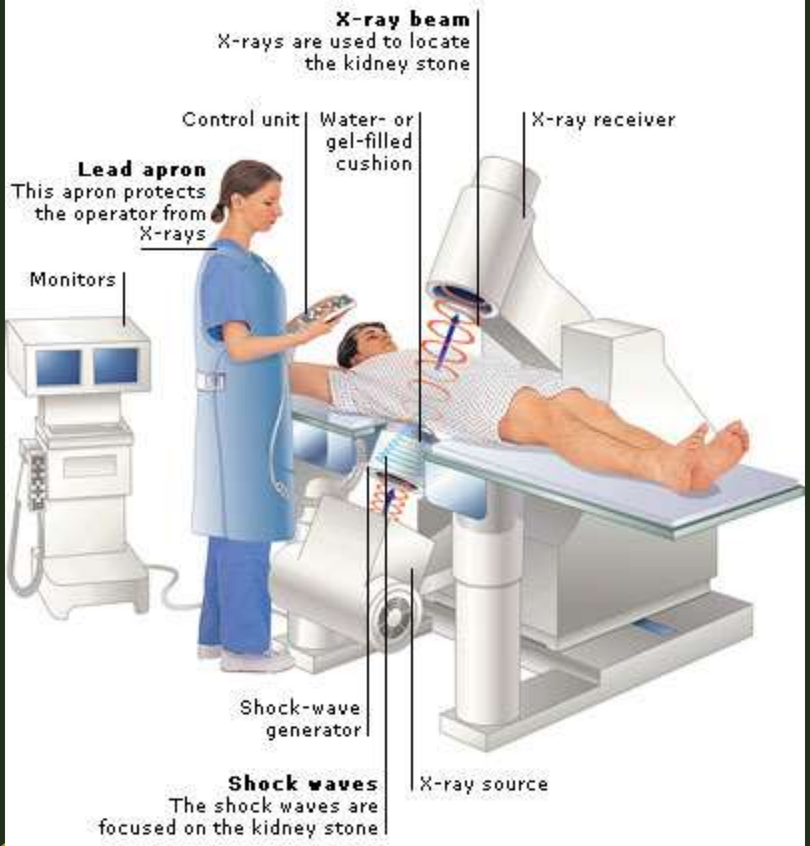
- Indications for active removal of renal stones are:
    - stone growth;
    - stones in high-risk patients for stone formation;
    - obstruction caused by stones;
    - infection;
    - symptomatic stones (e.g., pain or haematuria);
    - stones >15 mm;
    - stones <15 mm if observation is not the option of choice;
    - patient preference;
    - comorbidity;
    - social situation of the patient (e.g., profession or travelling);
    - choice of treatment.

Extracorporeal shock wave lithotripsy (ESWL)

- Shock waves travel through water. Different types of lithotriptors generate shock waves and focus them on the stone by means of X-rays or ultrasonic scanners. The shock waves break the stone up into fragments small enough to pass down the ureter.
- Many different types of lithotriptors are available, differing in the method by which the shockwave is generated, and the stone is localized.

- Some localize the stone with ultra-sound, others use X-rays.
- Most modern lithotripters patients can tolerate treatment on an out-patient basis with minimal analgesia (diclofenac).






Cystine Stone
Calcium-Oxalate Stone
Struvite Stone
0
1
2
3
4

- The success of SWL depends on the efficacy of the lithotripter and the following factors:
  - size, location (ureteral, pelvic or calyceal), and composition (hardness) of the stones;
  - patient's habitus (patients with deformed spines, etc);
  - performance of SWL.

- This method is effective for treating kidney stones 2 cm in maximum diameter, as long as no obstruction to the passage of stone fragments is present.
- Ninety-nine per cent of patients can tolerate the procedure after no more than a non-steroidal anti-inflammatory drug.
- More than one treatment session may be needed in patients with large or hard stones.
- The larger the stone, the greater the risk that fragments will cause a blockage in the ureter that has to be relieved endoscopically.
- This approach is less successful for ureteric stones than renal stones and is possible only at urological centers that have a static rather than mobile lithotripter.

- There are several contraindications to the use of extracorporeal SWL, including:
    - pregnancy, due to the potential effects on the foetus;
    - bleeding diatheses, which should be compensated for at least 24 hours before and 48 hours after treatment;
    - uncontrolled UTIs;
    - severe skeletal malformations and severe obesity, which prevent targeting of the stone;
    - arterial aneurysm in the vicinity of the stone;
    - anatomical obstruction distal to the stone.

Other limitations:

1. Very large stag-horn calculi (which often require a combination of ESWL and percutaneous renal surgery).
2. Abnormal drainage from the kidney (pelviureteric junction obstruction, horseshoe kidney) or ureter (ureterocele, stricture).

- Compared to percutaneous nephrolithotomy (PNL) and ureteroscopy (URS), there are fewer overall complications with SWL:

Complications			%
Related to stone fragments	Steinstrasse		4 – 7
	Regrowth of residual fragments		21 – 59
	Renal colic		2 – 4
Infectious	Bacteriuria in non-infection stones		7.7 – 23
	Sepsis		1 – 2.7
Tissue effect	Renal	Haematoma, symptomatic	< 1
		Haematoma, asymptomatic	4 – 19
	Cardiovascular	Dysrhythmia	11 – 59
		Morbid cardiac events	Case reports
	Gastrointestinal	Bowel perforation	Case reports
		Liver, spleen haematoma	Case reports

- "Steinstrasse" is the German word for "stone street".
- Occasionally a 'cloud' of minute stone fragments pass down the ureter collectively causing upper tract obstruction.
- Steinstrasse occurs in 4-7% cases of SWL.
- When steinstrasse is asymptomatic, conservative treatment is an initial option.
- Alpha-blockers (medical expulsion therapy) help these little particles of stone to pass spontaneously.
- It may require the temporary insertion of a double J stent to relieve obstruction and subsequent ureteroscopy to remove the fragments in some cases. (cont.)

- Ureteroscopy and SWL are effective in treatment of steinstrasse.
- In the event of UTI or fever, the urinary system should be decompressed, preferably by percutaneous nephrostomy.

Recommendations	Strength rating
Treat steinstrasse associated with urinary tract infection (UTI)/fever preferably with percutaneous nephrostomy.	Weak
Treat steinstrasse when large stone fragments are present with shock wave lithotripsy or ureteroscopy (in absence of signs of UTI).	Weak

Double J stents

- To help the ureter to dilate and encourage the passage of the fragments of stone after ESWL, a double-J stent is often passed up the ureter over a guidewire introduced through a flexible or rigid cystoscope.

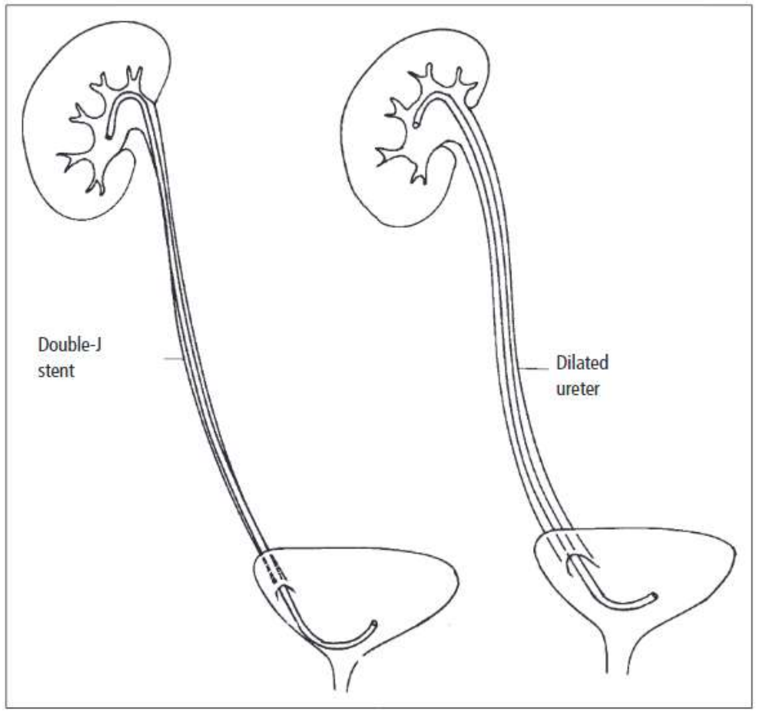
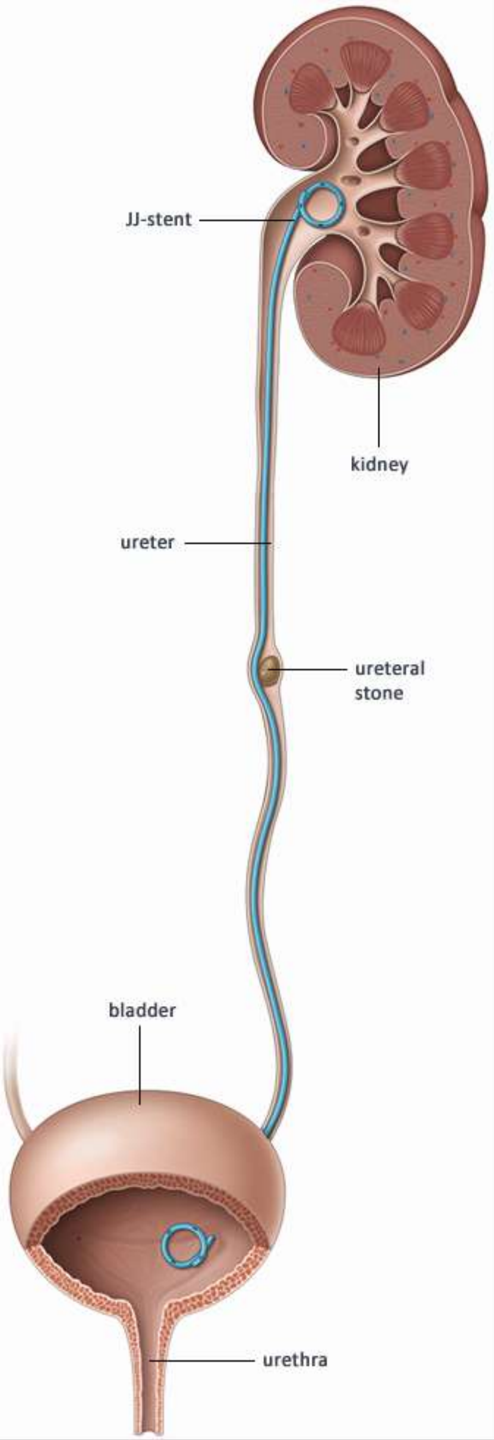
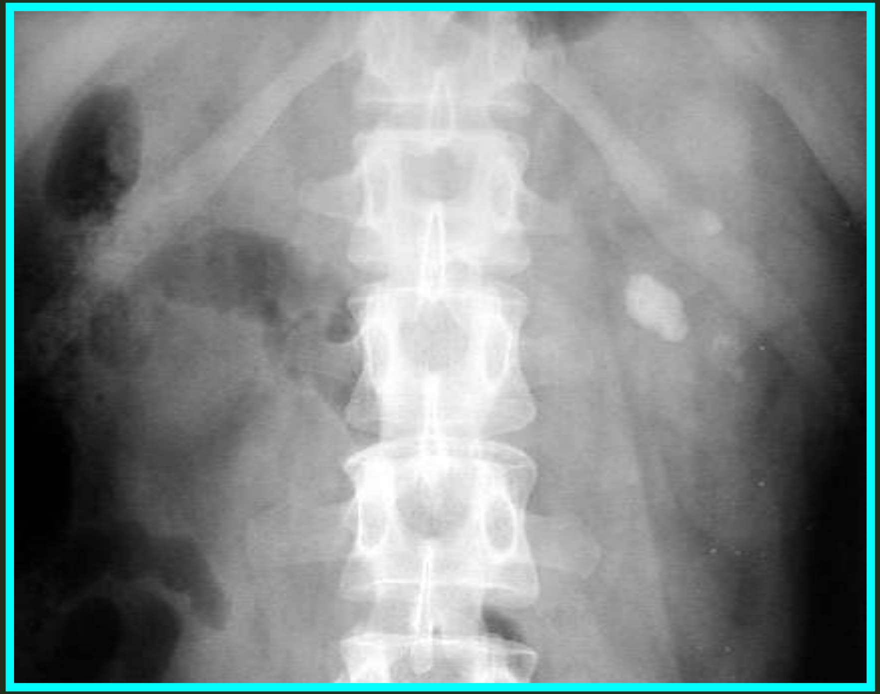


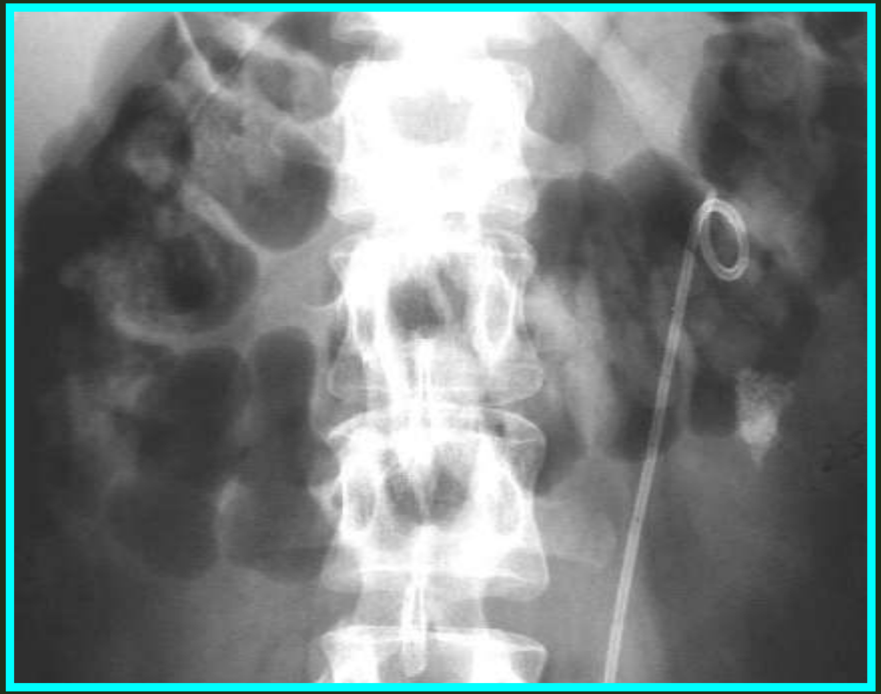
Figure 7.14 A double-J stent helps the ureter to dilate.



- Stone-free rates depends on :
    - Stone size.
    - Location.
    - Composition.
- Stone-free was defined as no residual stones remaining after surgery.(?)
- [further explanation need to be kindly provided/explained by the doctor]



Pre ESWL KUB



Post ESWL KUB

Intracorporeal techniques of stone fragmentation

- **Electrohydraulic lithotripsy (EHL):**

  - Principal uses are for bladder stones.

- **Pneumatic (ballistic) lithotripsy:**

  - Its principal use is for ureteric stones.

- **Ultrasonic lithotripsy:**

  - Principal uses include fragmentation of renal calculi during PCNL.

- **Laser lithotripsy:**

  - Principal uses are for ureteric stones and small intrarenal stones.

Ureteroscopy

- Rigid and flexible.
- Anterograde and retrograde (retrograde intrarenal surgery, RIRS).
- It is intracorporeal, endoscopic treatment of kidney stones.
- Stones that cannot be extracted directly must be disintegrated.

Figure 7.15 Storz ureteroscope

- Most interventions are performed under general anaesthesia, although local or spinal anaesthesia is possible.
- Antegrade URS is an option for large, impacted, proximal ureteral calculi.
- Hydrophilic-coated ureteral access sheaths, which are available in different calibres (inner diameter from 9 F upwards), can be inserted (via a guide wire) with the tip placed in the proximal ureter.
- The aim of URS is complete stone removal.
- Stones can be extracted by endoscopic forceps or baskets
- The most effective lithotripsy system is the holmium:yttrium-aluminium-garnet (Ho:YAG) laser, which is currently the optimum standard for URS and flexible nephroscopy because it is effective in all stone types. Pneumatic and US systems can be used with high disintegration efficacy in rigid URS. However, stone migration into the kidney is a common problem, which can be prevented by placement of special anti-migration tools proximal of the stone.
- The overall complication rate after URS is 9-25%. Most complications are minor and do not require intervention. Ureteral avulsion and strictures are rare (< 1%). Previous perforations are the most important risk factor for complications.

- It can allow access to areas of the kidney where ESWL is less efficient or where PCNL cannot reach.
- It is most suited to stones <2 cm in diameter.

Indications for flexible ureteroscopic:

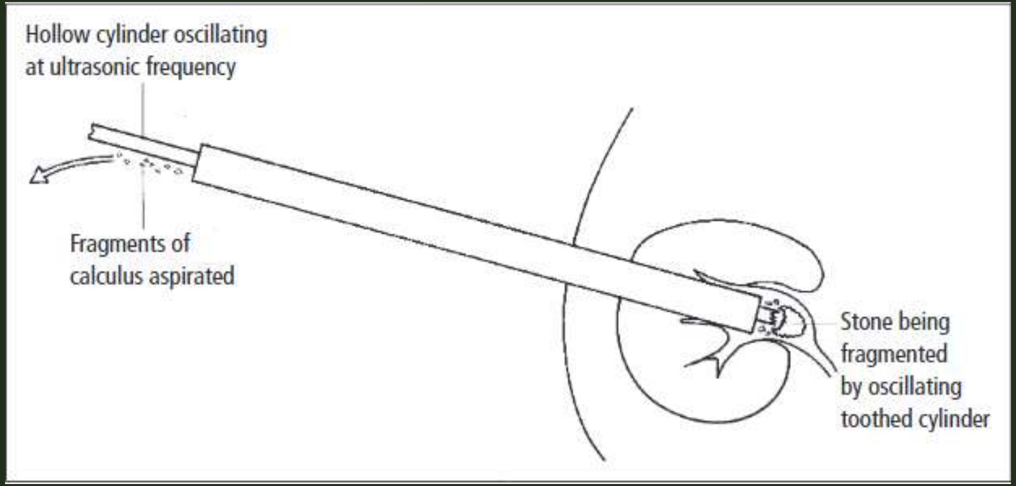
- ESWL failure.
- Lower pole stone.
- Obesity (BMI > 28).
- Musculoskeletal deformities (e.g., kyphoscoliosis).
- Horseshoe or pelvic kidney.
- Bleeding diathesis where reversal of this diathesis is potentially dangerous or difficult.

Percutaneous nephrolithotomy (PCNL).

- Percutaneous nephrolithotomy remains the standard procedure for large renal calculi, and it is the first-line option for staghorn calculi.
- Several methods for intracorporeal lithotripsy during PNL are available. Ultrasonic and pneumatic systems are most commonly used for rigid nephroscopy, whilst laser is increasingly used for miniaturized instruments. Flexible endoscopes also require laser lithotripsy to maintain tip deflection, with the Ho:YAG laser having become the standard.

How?

- After placing a needle under X-ray or ultrasound control into the renal pelvis, a guidewire is passed, and the needle withdrawn.
- A series of dilators of increasing size are then passed over the guidewire until a track has been made into the kidney big enough to admit a working sheath, through which instruments can be passed (Fig. 1).
- The stone is now examined with a nephroscope and broken up with one of several ingenious gadgets: one emits a stream of sparks which cracks the stone; another does the same thing with a Q-switched laser; a third grinds the stone to powder with a toothed cylinder oscillated at ultrasonic frequency; and a fourth uses a miniature jackhammer to break up the stone.
- Some probes are hollowed so that the fragments can be sucked out while the stone is being broken up. A variety of forceps are available to pick out the bits



Contraindications:

- Patients receiving anti-coagulant therapy must be monitored carefully pre- and post-operatively. Anti-coagulant therapy must be discontinued before PNL.
- Untreated UTI;
- Tumor in the presumptive access tract area;
- Potential malignant kidney tumor;
- Pregnancy.

Complications: [European Association of Urology 2020]

- A systematic review of almost 12,000 patients shows the incidence of complications associated with PNL;

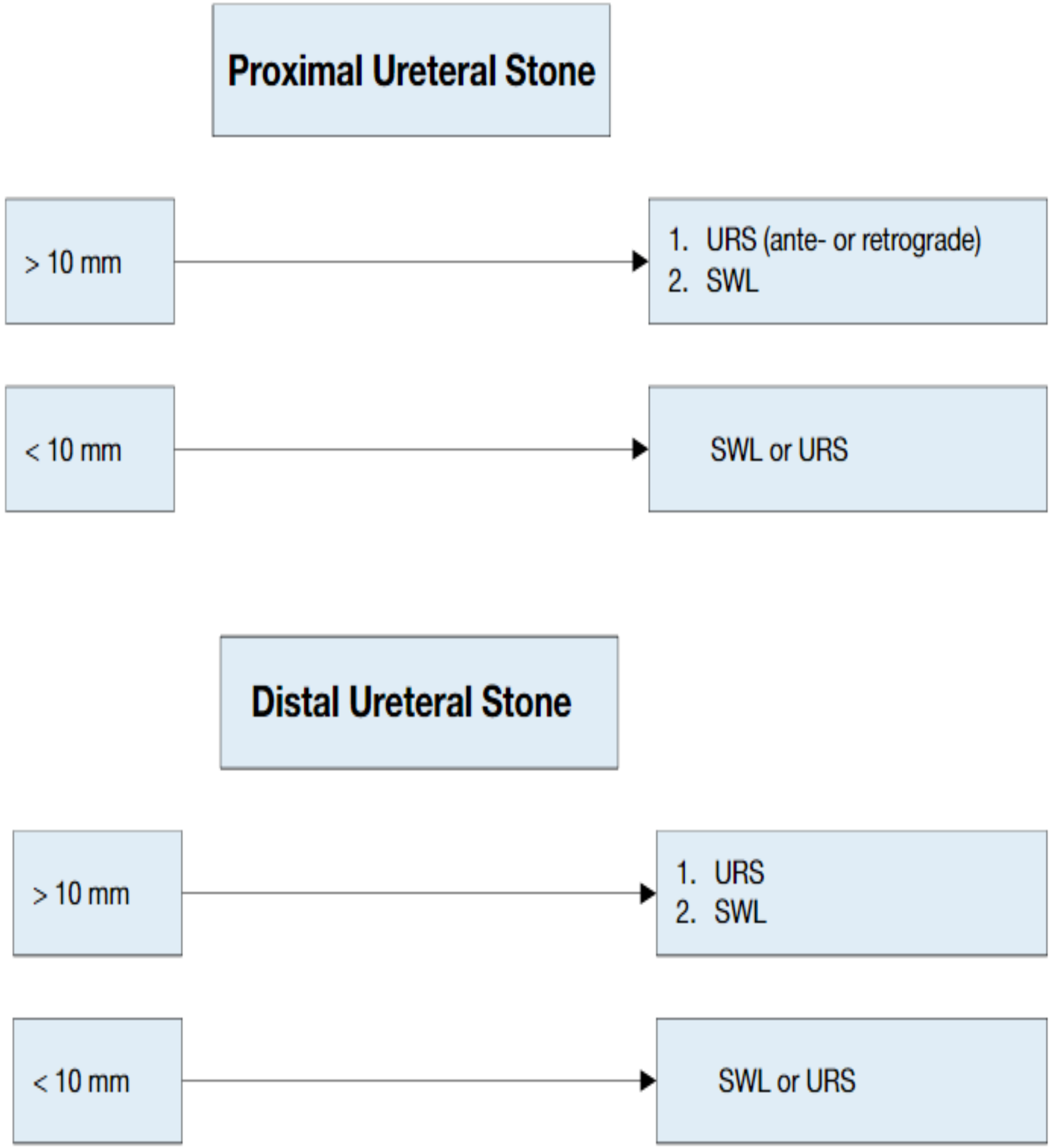
  fever 10.8%,
  transfusion 7%,
  thoracic complication 1.5%,
  sepsis 0.5%,
  organ injury 0.4%,
  embolisation 0.4%,
  urinoma 0.2%, (extravasation of urine from a disruption of the urinary collecting system at any level from the calix to the urethra)
  and death 0.05%

- Bleeding after PNL may be treated by briefly clamping of the nephrostomy tube.

Pre-op IVP

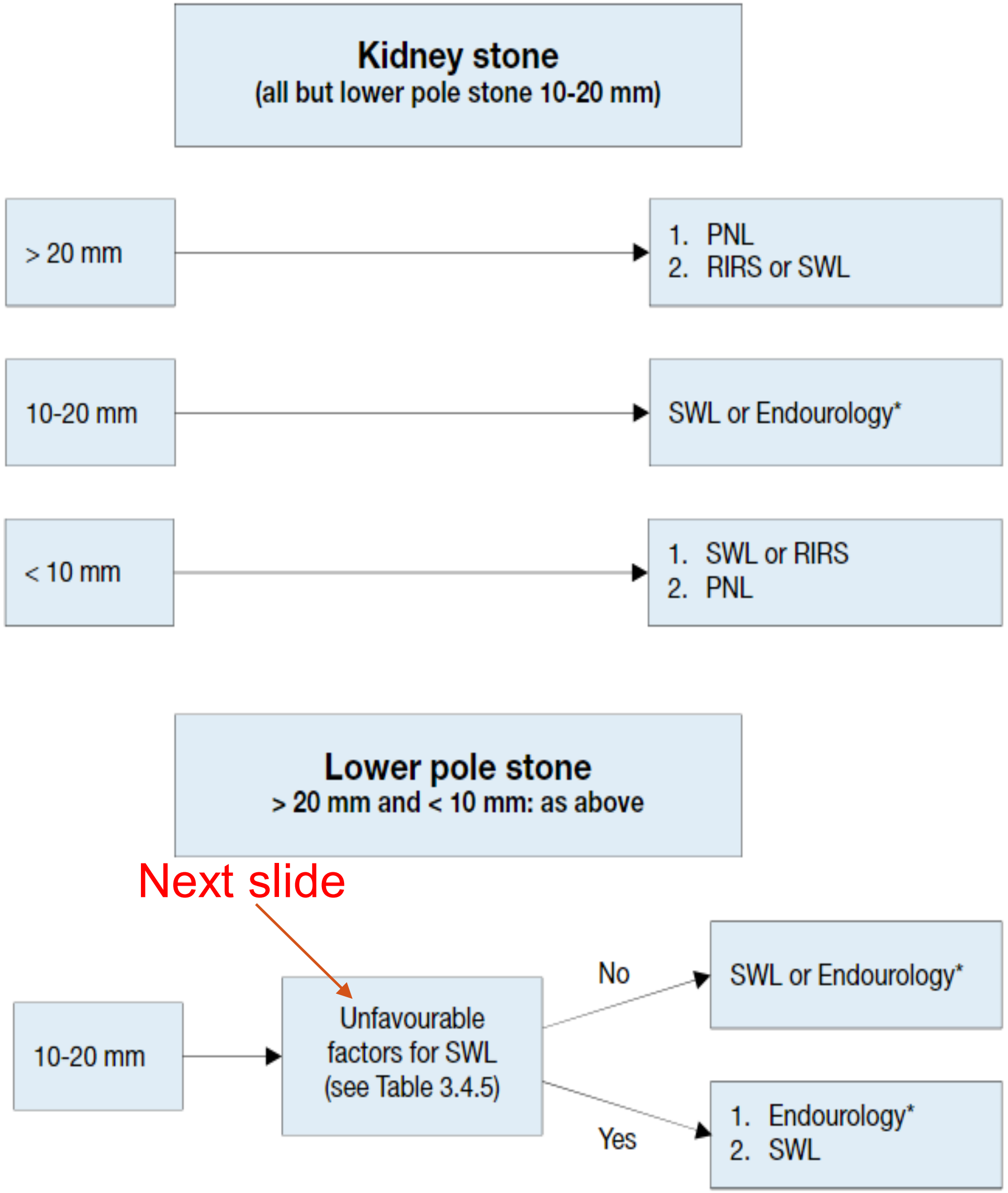

Post-op IVP

Figure 3.1: Treatment algorithm for ureteral stones (if active stone removal is indicated)



SWL = shock wave lithotripsy; URS = Ureteroscopy.

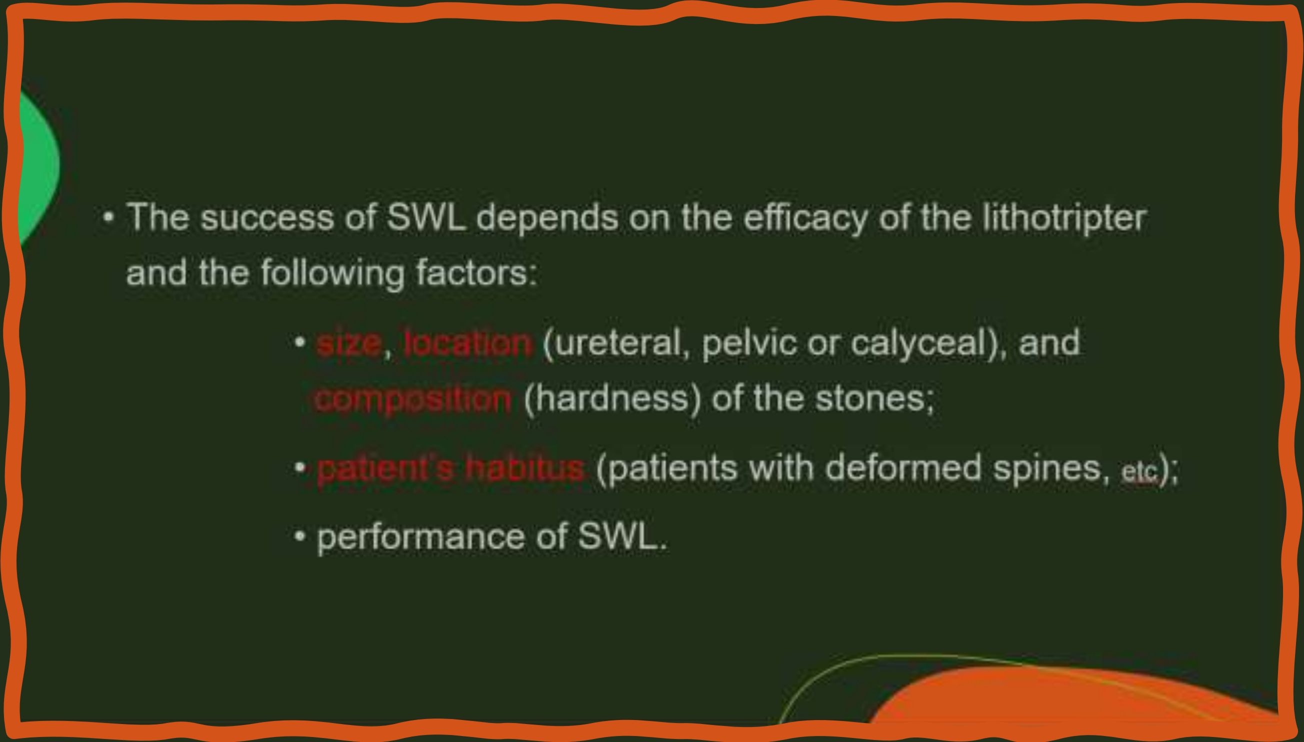
Figure 3.2: Treatment algorithm for renal stones (if/when active treatment is indicated)



**The term 'Endourology' encompasses all PNL and URS interventions.*

PNL = percutaneous nephrolithotomy; RIRS = retrograde renal surgery; SWL = shock wave lithotripsy; URS = ureteroscopy.

- Remember this slide:



- The success of SWL depends on the efficacy of the lithotripter and the following factors:
  - size, location (ureteral, pelvic or calyceal), and composition (hardness) of the stones;
  - patient's habitus (patients with deformed spines, etc);
  - performance of SWL.

- The following can impair successful stone treatment by SWL
  - Steep infundibular-pelvic angle;
  - Long calyx;
  - Long skin-to-stone distance;
  - Narrow infundibulum;
  - Shock wave-resistant stones (calcium oxalate monohydrate, brushite, or cystine)

Laparoscopy and open surgery

- Advances in SWL and endourological surgery (URS and PNL) have significantly decreased the indications for open or laparoscopic stone surgery.
- There is a consensus that most complex stones, including partial and complete staghorn stones, should be approached primarily with PNL.
- However, if percutaneous approaches are not likely to be successful, or if multiple endourological approaches have been performed unsuccessfully; open or laparoscopic surgery may be a valid treatment option.

Recommendation	Strength rating
Offer laparoscopic or open surgical stone removal in rare cases in which shock wave lithotripsy, retrograde or antegrade ureteroscopy and percutaneous nephrolithotomy fail, or are unlikely to be successful.	Strong

Complications

- Wound infection.
- Flank hernia.
- Wound pain.
- The scar tissue that develops around the kidney will make subsequent open stone surgery technically more difficult.

Medical Therapy

- Agents used:
  - **Alkalinizing pH agents:** Potassium citrate,
  - **Gastrointestinal absorption inhibitor:** Cellulose phosphate
  - **Phosphate supplementation**
  - **Diuretics-Thiazides**
  - **Calcium supplementation (**hyperoxaluric calcium)
  - **Uric acid-lowering medications**
  - **Urease inhibitor** Acetohydroxamic acid
- Uric acid and cystine stones are potentially suitable for dissolution therapy.
- Uric acid stones :

Dissolution therapy is based on:

- Hydration (urine output 2–3 L/day).

- Urine alkalinization to pH 6.5–7 by (sodium bicarbonate or potassium citrate).

- Allopurinol (inhibits conversion of hypoxanthine and xanthine to uric acid).

- Dietary manipulation.

- Cystine stones:
- Reduce cystine excretion (dietary restriction of the cystine precursor amino acid methionine and also of sodium intake to <100 mg/day).
- Increase solubility of cystine by alkalinization of the urine to >pH 7.5
- Maintenance of a high fluid intake
- And use of drugs (D-penicillamine) that convert cystine to more soluble compounds.

Medical expulsive therapy

- Medical expulsive therapy should only be used in informed patients if active stone removal is not indicated.
- Treatment should be discontinued if complications develop (infection, refractory pain, deterioration of renal function).
- Several drug classes are used for MET; α-blockers, calcium-channel inhibitors (nifedipine) and phosphodiesterase type 5 inhibitors (PDEI-5) (tadalafil) are more likely to pass stones with fewer colic episodes.

[European Association of Urology 2020]

- The Panel concludes that MET seems efficacious in the treatment of patients with ureteral stones who are amenable (open and responsive to suggestion) to conservative management. The greatest benefit might be among those with > 5 mm distal stones.

Recommendation	**Strength rating**
Offer α-blockers as medical expulsive therapy as one of the treatment options for (distal) ureteral stones > 5 mm.	Strong

Management of sepsis and/or anuria in obstructed kidney

- The obstructed kidney with all signs of urinary tract infection (UTI) and/or anuria is a ***urological emergency***.
- Urgent decompression is often necessary to prevent further complications in infected hydronephrosis secondary to stone-induced, unilateral or bilateral, renal obstruction.
- Decompression:
  Currently, there are two options for urgent decompression of obstructed collecting systems:
    - placement of an indwelling ureteral stent;
    - percutaneous placement of a nephrostomy tube.

- Definitive stone removal should be delayed until the infection is cleared following a complete course of antimicrobial therapy.
- Following urgent decompression of the obstructed and infected urinary collecting system, both urine- and blood samples should be sent for culture-antibiogram sensitivity testing and antibiotics should be initiated immediately thereafter or continued, if initiated prior to testing.
- Intensive care might become necessary

To summarize

Recommendations	Strength rating
Urgently decompress the collecting system in case of sepsis with obstructing stones, using percutaneous drainage or ureteral stenting.	Strong
Delay definitive treatment of the stone until sepsis is resolved.	Strong
Collect (again) urine for antibiogram test following decompression.	Strong
Start antibiotics immediately (+ intensive care, if necessary).	Strong
Re-evaluate antibiotic regimen following antibiogram findings.	Strong

Prevention

- Other than the mentioned previously for each stone:
- Patient Education
  - Hydration
    - Drink 2-3 liters of fluid per day.
    - Lemonade (citrate decrease stone formation).
  - Diet
    - Low sodium.
    - Watch amounts of oxalate.
    - Low protein.
  - Exercise/Increase Activity