

Management of kidney stones

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Urolithiasis affects 5-15% of the population worldwide.^{1 w1} Recurrence rates are close to 50%,^{2 w2} and the cost of urolithiasis to individuals and society is high. Acute renal colic is a common presentation in general practice, so a basic understanding of its evaluation and treatment would be useful. Most of the literature is retrospective, but we will try to provide an evidence based review of the management of urolithiasis and will cite prospective randomised controlled trials when available.

Sources and selection criteria

We performed a literature search to identify information on the management of urolithiasis. We searched databases including Medline and the Cochrane Library to assemble appropriate evidence based reference material

What is the clinical presentation and initial evaluation?

Initial evaluation of the patient with urolithiasis should include a complete medical history and physical examination. Typical symptoms of acute renal colic are intermittent colicky flank pain that may radiate to the lower abdomen or groin, often associated with nausea and vomiting.³ Lower urinary tract symptoms such as dysuria, urgency, and frequency may occur once a stone enters the ureter.

Comorbid diseases should be identified, particularly any systemic illnesses that might increase the risk of kidney stone formation or that might influence the clinical course of the disease (box 1). Other important features are a personal or family history of kidney stones with previous treatments and stone analysis, and any anatomical abnormalities or surgery of the urinary tract (box 1). A complete history of drugs use can help identify those that are known to increase the risk of kidney stones (box 1).^{w3}

Assessment should include measurement of vital signs because fever may be an indication for acute intervention (box 2). Physical examination often reveals costovertebral angle or lower abdominal tenderness. Urinalysis should be performed in all patients. Microscopic haematuria combined with the typical symptoms of renal colic is highly predictive of urolithiasis, but stones may occur in the absence of haematuria.³ Positivity for nitrites or bacteria and leucocytes on urine dipstick analysis may indicate urinary tract infection,

SUMMARY POINTS

Unenhanced helical computed tomography is the best radiographic technique for diagnosing urolithiasis

Shock wave lithotripsy, ureteroscopy, and percutaneous nephrolithotomy have replaced open surgery for treating urolithiasis

Most simple renal calculi (80-85%) can be treated with shock wave lithotripsy

Percutaneous nephrolithotomy is the treatment of choice for complex renal calculi

Staghorn calculi should be treated, and percutaneous nephrolithotomy is the preferred treatment in most patients

Ureteroscopy is the preferred treatment in pregnant, morbidly obese, or patients with coagulopathy

Most ureteral calculi <5 mm in diameter will pass spontaneously within four weeks of the onset of symptoms

in which case urine should be sent for culture. Finally, microscopic urinalysis may identify crystals, such as the classic hexagonal crystals seen in cystinuria. In the acute setting, laboratory evaluation includes complete blood count, serum electrolytes, and measurement of renal function. A more detailed metabolic evaluation is best performed after the acute stone event has resolved.⁴

How is the diagnosis made?

Unenhanced helical computed tomography is the best radiographical test for diagnosing urolithiasis in patients with acute flank pain.⁵ Intravenous urography was formerly the gold standard, but recent prospective trials have shown that computed tomography is the best method for diagnosing ureteral calculi.⁶ If the symptoms are not caused by urolithiasis, computed tomography can often identify the real cause.⁵ Most kidney stones (box 3) are visible on computed tomography, except for stones induced by certain drugs, such as indinavir.

A plain abdominal radiograph can determine whether stones are radio-opaque and can be used to monitor disease activity. Alternatively, some clinicians prefer to use computed tomography in the follow-up of kidney stones, particularly when the stone is radio-lucent. Ultrasound is rarely used because of its relatively low sensitivity, although it is often used as the initial imaging test in pregnant patients with flank pain.^{w4}

Box 1 | Important factors to identify in the patient's history**Presence of systemic illness**

- Primary hyperparathyroidism
- Renal tubular acidosis
- Cystinuria
- Gout
- Diabetes mellitus
- Inflammatory bowel disease
- Renal insufficiency
- Sarcoidosis
- Medullary sponge kidney

Anatomical features

- Presence of horseshoe kidney
- Previous urinary diversion
- Obstruction of the ureteropelvic junction
- Solitary kidney
- Previous renal or ureteral surgery

Previous kidney disease

- History of urinary tract infection or pyelonephritis, or both
- Family history of urolithiasis
- Detailed history of previous stone events
 - Treatment
 - Stone analysis

Drugs that affect stone disease

- Carbonic anhydrase inhibitors (topirimate)
- Ephedrine
- Guaifenesin
- Calcium with vitamin D
- Triamterene
- Indinavir or sulfadiazine

What are the indications for urgent intervention?

Urgent intervention is most often needed in acute obstruction. Once a stone passes into the ureter, obstruction may cause reduced glomerular filtration rate and renal blood flow. Box 2 lists the indications for acute intervention.^{w5} A randomised controlled trial found that ureteral catheters, ureteral stents, and percutaneous nephrostomy tubes are equally effective for decompressing the urinary tract.⁷ Bladder and renal pelvic urine should be sent for culture and antibiotic sensitivity testing. Broad spectrum antibiotics are best prescribed initially, and further antimicrobial treatment should be tailored to the results of urine culture.

While parenteral narcotics have traditionally been prescribed for acute renal colic,⁸ non-steroidal anti-inflammatory drugs such as ketorolac and diclofenac are effective in relieving pain by inhibiting prostaglandin mediated pain pathways and decreasing ureteral contractility.^{9 w6} However, non-steroidal anti-inflammatory drugs should be avoided in patients with compromised renal function or a history of gastrointestinal bleeding.^{w7}

What are common treatments for nephrolithiasis?

Open surgery was the mainstay of treatment for urolithiasis, but it has now been supplanted by less invasive treatments.

Shock wave lithotripsy

The introduction of shock wave lithotripsy in the early 1980s revolutionised the treatment of nephrolithiasis. A shock wave is generated by a source external to the patient that propagates through the body before being focused on a kidney stone. Shock waves cause stone fragmentation directly by producing mechanical stresses or indirectly by the collapse of cavitation bubbles.¹⁰

Although shock wave lithotripsy is the most common treatment for urolithiasis, it can have side effects. In human and animal models it can cause acute renal injury.^{11 w8 w9} Computed tomography and magnetic resonance imaging have demonstrated renal injury in 63-85% of patients treated with shock wave lithotripsy.^{12 w10-w12} A recent retrospective case-control study with 19 year follow-up noted an association between shock wave lithotripsy and the development of hypertension and diabetes mellitus.^{13 w13} In the lithotripsy group, diabetes developed in 16.8% of patients versus 6.6% of controls.¹³ The chronic effects of shock wave lithotripsy are an area of ongoing research.

Ureterscopy

Ureterscopy involves retrograde visualisation of the collecting system using a rigid, semi-rigid, or flexible endoscope. Improved fibreoptics and deflectability and the reduced size of ureteroscopes have expanded the use of ureterscopy for stones in the upper urinary tract. The ureterscope has a working channel that allows the introduction of a variety of instruments for stone fragmentation and removal.

A retrospective study showed that ureterscopy is useful when lithotripsy fails; when complex or lower pole renal calculi are present¹⁴; or when patient factors such as pregnancy, coagulopathy, or morbid obesity preclude lithotripsy.^{w14 w15} One disadvantage of ureterscopy is that a ureteral stent, which causes considerable discomfort in some patients, is often necessary to prevent obstruction from ureteral oedema or stone fragments.

Percutaneous nephrolithotomy

Percutaneous nephrolithotomy involves creating an access tract into the renal collecting system through which nephroscopy can be performed. The nephroscope has a working channel through which an intracorporeal lithotripsy device (lithotrite or laser) can be introduced. Stone fragments are removed using suction, graspers, or basket extraction. The technique enables stones to be retrieved for analysis, and all stone material can be removed so that the patient does not have to pass any fragments, as is common with shock wave lithotripsy and ureterscopy. Although percutaneous nephrolithotomy is thought to be more invasive than other treatments, a large meta-analysis has demonstrated its safety and efficacy, particularly when stones are large, multiple, or complex.¹⁵

What are the guidelines for treatment selection?

The fundamental principle guiding treatment selection is to maximise stone clearance while minimising patient

Box 2 | Indications for urgent intervention

- Presence of infection with urinary tract obstruction
- Urosepsis
- Intractable pain or vomiting, or both
- Impending acute renal failure
- Obstruction in a solitary or transplanted kidney
- Bilateral obstructing stones

Box 3 | Classification of kidney stones by composition (% of stones)

- Calcium oxalate, phosphate, or both (70-80%)
- Uric acid (5-10%)
- Cystine (1%)
- Struvite (magnesium ammonium phosphate) (5-15%)
- Other (such as xanthine, guaiifenesin) (1%)

morbidity. The decision making process can be simplified by stratifying stones into clinical categories based on location (renal or ureteral) and complexity (simple or complex).

Renal calculi

The characteristics of the stones (size, number, location, and composition), renal anatomy, and clinical factors are all considered when selecting a treatment approach for renal calculi.

Simple renal calculi

Simple renal calculi are those with a stone burden of <2 cm (aggregate diameter) and normal renal anatomy. Most simple renal calculi (80-85%) can be treated successfully with shock wave lithotripsy (fig 1).¹⁶ However, lithotripsy may fail or be less effective when stones are larger; stones are located in dependent or obstructed parts of the collecting system; stones are made up of calcium oxalate monohydrate, brushite, or cystine; the patient is obese or has a body build that inhibits proper imaging; or it is difficult to target the stone for shock wave delivery and subsequent fragmentation.^{14 w17} A retrospective comparison of percutaneous nephrolithotomy and shock wave lithotripsy found that as stone burden increased, the number of lithotripsy treatments and ancillary procedures increased, but stone-free rates decreased.^{16 w18}

Percutaneous nephrolithotomy results in higher stone-free rates and lower retreatment rates than shock wave lithotripsy.^{16 17} Because it is more invasive, however, percutaneous nephrolithotomy is usually reserved for patients in whom shock wave lithotripsy fails or those who are unsuitable for lithotripsy. Ureteroscopy is an increasingly used alternative for treating simple renal calculi because it has similar stone-free rates to shock wave lithotripsy and morbidity is lower than with percutaneous nephrolithotomy.¹⁸ Ureteroscopy is especially attractive in coagulopathic, pregnant, or morbidly obese patients where shock wave lithotripsy or percutaneous nephrolithotomy are less effective or contraindicated.

Complex renal calculi

Complex renal calculi include stones >2 cm, such as staghorn calculi; stones occurring in kidneys with abnormal anatomy; and stones resistant to fragmentation. Recently published guidelines of the American Urologic Association recommend that staghorn calculi should not be treated with lithotripsy because of relatively poor stone-free rates.¹⁵ Ureteroscopy has been used to treat upper tract stones >2 cm, but stone clearance rates are significantly lower than with percutaneous nephrolithotomy and stones recur rapidly (16% within six months).¹⁹ For this reason, percutaneous nephrolithotomy is the treatment of choice for most complex renal stones (fig 2).¹⁵ Combined percutaneous nephrolithotomy and shock wave lithotripsy (sandwich therapy) for complex stones was commonplace in the 1990s, but improvements in percutaneous nephrolithotomy techniques have led to a decline in the need for shock wave lithotripsy.^{15 20} Even the largest

staghorn calculi can be cleared percutaneously with the aid of secondary look nephroscopy and multiple access tracts.

The management of lower pole calyceal calculi remains controversial. A prospective randomised multi-centre trial showed that percutaneous nephrolithotomy was better than shock wave lithotripsy in the clearance of lower pole calculi >1 cm (stone-free rates of 91% v 21%).²¹ However, for lower pole calculi <1 cm, a recent prospective randomised trial failed to show a statistically significant difference in stone-free rates between the two techniques.²² Urolithiasis associated with aberrant renal anatomy can present a treatment challenge. All three techniques described above and even laparoscopy have been used to treat calculi in these situations.

Ureteral calculi

Ureteral calculi most commonly present with symptoms of acute renal colic. If urgent intervention is not needed (see box 2), the patient and clinician must decide whether to intervene or proceed with expectant management. The likelihood of spontaneous passage decreases as stone size increases.^{w19}

An extensive meta-analysis is found that most ureteral calculi <5 mm in diameter will pass through the urinary tract spontaneously.²³ Spontaneous passage usually occurs within four weeks after the onset of symptoms.²³ If a stone has not been passed within four weeks, intervention is indicated, as the risk of complications such as ureteral stricture and renal deterioration increase. Therefore, observation is adequate for stones <5 mm if symptoms can be controlled and follow-up is ensured.



Fig 1 | Simple right renal calculus (5 mm). The patient was successfully treated with shock wave lithotripsy



Fig 2 | Complex left renal calculus. The patient was successfully treated with percutaneous nephrolithotomy

For the purposes of selecting treatment, ureteral calculi can be divided into categories on the basis of location—proximal or distal—with the point of division being the narrow part of the ureter over the iliac vessels.

Proximal ureteral calculi

Several endourological options are available for the treatment of proximal ureteral stones: shock wave lithotripsy with or without stone manipulation, ureteroscopy, and percutaneous nephrolithotomy. In 1997, the ureteral stones guidelines panel of the American Urologic Association recommended shock wave lithotripsy as the treatment of choice for stones ≤ 1 cm in the proximal ureter, with stone-free rates up to 85%.²³ A retrospective series noted that proximal ureteral stones > 1 cm have poor stone-free rates with this treatment.^{23 24} However, flexible ureteroscopy is increasingly popular as primary treatment for proximal ureteral stones as

a result of the availability of small diameter flexible ureteroscopes, ureteral access sheaths, holmium laser lithotripsy, and stone baskets.^{19 w20} Percutaneous nephrolithotomy is reserved for large (≥ 2 cm) or impacted proximal ureteral stones.^{w21}

Distal ureteral calculi

Although the likelihood of spontaneous passage of stones is highest in the distal ureter, intervention with ureteroscopy or shock wave lithotripsy is often necessary. Both techniques are excellent options for symptomatic ureteral calculi < 1 cm. Randomised controlled trials comparing the two techniques have reached conflicting conclusions.^{21 25} Unlike shock wave lithotripsy, ureteroscopy is not influenced by stone size and can be used to treat distal ureteral calculi > 1 cm.^{w22} Semirigid ureteroscopy has a success rate of 90-99% for treating distal ureteral stones.^{w23} Ureteroscopy may also be the simplest solution in institutions with limited access to a lithotripter.

Which patients should have a metabolic evaluation?

Although a comprehensive metabolic evaluation may not be cost effective in patients with their first occurrence of stones,^{4 26} patients with risk factors for stone recurrence should be evaluated (box 4). Box 5 outlines the components of a standard metabolic evaluation.⁴ First time stone formers will benefit from recommendations to prevent stone recurrence, such as increasing fluid intake to maintain a urine output of at least two litres a day, decreasing animal protein intake to less than 12 ounces a day, and restricting dietary sodium and oxalate intake.^{1 27 28} Dietary restrictions of calcium are not recommended as they may increase urinary oxalate excretion and result in negative calcium balance.²⁸ Medical management of the recurrent or high risk stone former can be individually tailored using the results of the metabolic evaluation.

What's new? Medical expulsive therapy

This treatment comprises the use of drugs to help the spontaneous passage of ureteral calculi. Several drugs including calcium channel blockers (nifedipine),

Box 4 | Indications for comprehensive metabolic evaluation

- Family history of urolithiasis
- Presence of bilateral stone disease
- Presence of inflammatory bowel disease, chronic diarrhoea, or malabsorption
- History of bariatric surgery
- Concurrent medical conditions associated with urolithiasis (primary hyperparathyroidism, gout, renal tubular acidosis)
- Presence of nephrocalcinosis
- Presence of osteoporosis or pathological skeletal fractures
- Stones are formed from cystine, uric acid, or calcium phosphate
- The patient is a child

Box 5 | Components of a comprehensive metabolic evaluation

- Analysis of stone composition
- Two 24 hour urine collections for:
 - Volume, pH, calcium, oxalate, citrate, uric acid, phosphate, sodium, potassium, magnesium, ammonium, chloride, sulfate, and creatinine
 - Cystine screen
- Measurement of serum calcium, bicarbonate, creatinine, chloride, potassium, magnesium, phosphate, and uric acid
- Measurement of blood urea nitrogen
- In cystinuric patients, evaluation as above and 24 hour measurement of cystine
- In hypercalcaemic patients, intact parathyroid hormone and 1,25 dihydroxyvitamin D

ADDITIONAL EDUCATIONAL RESOURCES

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Information resources for patients

- International Kidney Stone Institute (www.iksi.org)—Website of a charitable organisation dedicated to supporting research into clinical and basic science and education to help detect, manage, and prevent kidney stone disease. It contains educational material for patients as well as a description of the ongoing research projects in the area of kidney stone disease
- National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) Information Clearinghouse (www.kidney.niddk.nih.gov/kudiseases/pubs/stonesadults/)—Contains clear concise explanations of diseases affecting the kidneys, including kidney stones
- American Urological Association-Urology Health (www.urologyhealth.org)—Also contains user friendly information on the diagnosis and treatment of kidney stones
- Patient UK (www.patient.co.uk)—This website contains comprehensive and free up to date information on various medical conditions, including kidney stones
- Royal Infirmary of Edinburgh Renal Unit (<http://renux.dmed.ed.ac.uk/EdREN/EdRenINFObits/KidStonesLong.html>)—A source of information about kidney diseases for patients and non-specialist doctors
- National Kidney Foundation (www.kidney.org/atoz/atozTopic.cfm?topic=13)—An excellent source of information for patients with various kidney problems such as chronic kidney disease, kidney stones, and those who need dialysis

steroids, and α adrenergic blockers have recently been investigated.^{w24 w25} The rationale for using α blockers is based on the presence of large numbers of $\alpha 1$ adrenoceptors in the distal ureter. These blockers inhibit basal ureteral tone and peristaltic frequency and decrease the intensity of ureteral contractions.

A recent prospective randomised study compared three drugs as medical expulsive therapy for distal ureteral calculi.²⁹ Two hundred and ten patients with symptomatic distal ureteral stones >4 mm were randomly assigned to three treatment groups: phloroglucinol and corticosteroid, tamsulosin and corticosteroid, or nifedipine and corticosteroid. Tamsulosin and corticosteroid was the most efficacious combination—stones were passed more quickly and the need for analgesics was reduced. A randomised controlled prospective study has also shown tamsulosin to be a useful addition to shock wave lithotripsy.^{30 w26 w27}

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