Urolithiasis: the role of imaging

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The incidence of urinary calculi is increasing, as is the diagnostic ability of medical imaging. The authors review imaging modalities for the diagnosis and treatment of urinary stone disease, and explain how imaging has a key role in management of patients with nephrolithiasis.

Urinary tract calculus exerts a significant impact upon healthcare, with an incidence of eight in 1000 in the general population. There is a 10 per cent lifetime risk of developing a renal stone, and urinary stone disease has been estimated to be responsible for 1.8–2 per 10 000 hospital admissions. The extent of the problem is increasing, with 7–20 per 1000 hospital admissions in the USA attributed to urinary stone disease. The recurrence rate is reported at 15 per cent at one year, 35 per cent at five years, 50 per cent at ten years and 75 per cent at 20 years.

Increasing use of medical imaging is undoubtedly linked to a rise in the reported incidence of urinary calculi. More patients are undergoing abdominal ultrasound, computed tomography (CT) and magnetic resonance imaging scans than ever before, and often the diagnosis is an incidental finding.

TYPES OF STONE
Calcium-containing stones are the most common type encountered in UK practice. The stones may be pure calcium oxalate or contain a mixture of calcium oxalate and calcium phosphate. Matrix or struvite stones are the next most common presenting stone type. These are composed of magnesium ammonium phosphate. These stones may branch and cause large staghorn calculi. Pure matrix stones are non-opaque as a result of lack of calcium.

Patients with hyperuricaemia may develop uric acid stones, and cysteine stones can be found in patients with homocystinuria. Increasingly, calculi are being diagnosed in patients treated for HIV with protease inhibitors such as indinavir. These calculi pose a particular challenge for clinicians because of their relative lucency on radiographs and CT.
CLINICAL PRESENTATION
The classic acute presentation of urinary tract stones is with typical severe renal colic ‘loin to groin’ pain, accompanied by microscopic haematuria in most cases. Nausea and vomiting may also be presenting features. More insidious presentation may occur with mild aching in the flanks, and micro- or macroscopic haematuria. Patients may also present with the symptoms and signs of renal failure caused by bilateral obstructing calculi or in those patients with an obstructed single kidney. Perhaps the most dramatic and emergent presentation is in patients who have developed acute sepsis as a result of an obstructing calculus. Prompt drainage and appropriate antibiotic therapy is of vital importance in such cases.

IMAGING MODALITIES
Imaging enables not only the diagnosis of urinary tract calculi, but also the characterisation of stones, planning and stratification of further treatment and prediction of response to such treatment. The choice of imaging modality and subsequent management is influenced by patient parameters such as patient preference, clinical status and symptom load, as well as stone volume and location.

Plain radiograph/intravenous urography
The kidneys/ureters/bladder (KUB) radiograph can visualise calcium-containing calculi because of their radio-opaque nature. However, it may be rendered relatively insensitive by overlying bowel gas, adjacent bony structures and patient body habitus, with sensitivity in the order of 50 per cent.4,5 The KUB radiograph is considered most useful in the follow-up of previously detected radio-opaque calculi and in planning and assessing the effects of therapeutic interventions such as extracorporeal shockwave lithotripsy (ESWL) or percutaneous nephrolithotomy (PCNL). It also serves to screen those patients whose symptom load is relatively light, or in whom the presentation has been non-acute.

Intravenous urography (IVU) has largely been superseded by CT-KUB in recent years, as the latter has a higher sensitivity. However, it is of use in situations where CT is not readily available and is most useful in excluding obstruction in the acute setting. Tomography can be used to further increase the sensitivity and definition obtained from an IVU series. Such definition can be useful in planning intervention such as PCNL, where intrarenal anatomy and precise calyceal localisation is often better on IVU compared to CT-KUB (see Figure 1).

Ultrasound
Ultrasound plays an important role in diagnosing urinary tract calculi. It is a safe and readily available imaging technique, but its sensitivity is modest and hugely dependent on the operator and the body habitus of the patient. Sensitivities range from 40 to 65 per cent for detection of stones and from 74 to 85 per cent for detection of acute obstruction.6,7 Detection relies upon visualisation of hyperechoic calculi and any possible shadowing that they may cause (Figure 2). The visualisation of such foci can be challenging against background renal tissue; in practice, only larger stones (>5mm) tend to cast acoustic shadows. Ureteric calculi are poorly demonstrated in most cases unless situated within the proximal ureter or close to the vesicoureteric junction.

The advantage of ultrasound relates to its relative portability and lack of non-ionising radiation. It can be used in the community or in a urological outpatient clinic and it is suitable for investigating children or pregnant women. It is also of use in the surveillance of those patients who are managed conservatively, although difficulties in reproducibility arise. Its ease and portability also allow for its utilisation in an intraoperative setting, such as during a PCNL procedure.

Computed tomography
CT-KUB is now the accepted gold standard imaging modality for urinary tract calculi as a result of its high diagnostic accuracy. Most stones will be visible on unenhanced CT with a sensitivity of 95 per cent in the diagnosis of acute ureteric colic.8 A landmark study in 1995 established the superiority of CT over IVU in the diagnosis of calculi, with a sensitivity of 91.6 per cent for CT compared with 41.6 per cent for IVU.9
CT-KUB allows for rapid diagnosis of the presence of calculi and has been adopted in many acute centres as a first-line imaging strategy for renal stones because of its unparalleled ability in diagnosis of ureteric calculi. It is a rapid investigation to perform, does not involve intravenous contrast administration and can aid in the diagnosis of pathologies other than urinary tract calculi that may share similar presenting characteristics, such as appendicitis.

The presence of hydronephrosis and other signs of urinary tract obstruction can also be elucidated from CT-KUB, and accurate measurements of stone size can be undertaken (Figure 3). In addition, measurements of the internal composition of the stone can be obtained in terms of stone density, measured in Hounsfield units (HU). This measure of density assists in treatment stratification. For example, stones are less likely to respond to ESWL if they are >1000 HU in density.

CT-KUB allows for three-dimensional reconstructions of data and is especially useful in planning PCNL procedures. In our institution, unenhanced CT is combined with a post-contrast CT pyelogram to facilitate accurate representation of the calyceal anatomy and planning of percutaneous tracks (Figure 4).

Further CT advances include the use of dual source imaging, a relatively new technique that utilises two X-ray tubes and two detector units, which can be used to extract virtual ‘non-contrast’ images from post-contrast enhanced data and allows for determination of the chemical content of stones. In particular, this method is useful for distinguishing uric acid stones from calcium stones, as the former can be treated non-invasively with urine alkalinisation (Figure 5).

The disadvantage of CT stems from the use of ionising radiation. The effective dose from a multidetector CT-KUB is dependent upon many factors such as patient habitus, the type of CT scanner and scanning protocol utilised. However it is estimated at approximately 2–9mSv, compared to 0.5mSv for an abdominal radiograph. To put these figures into context, the dose from a standard anteroposterior chest X-ray is 0.1mSv.

Dose-saving techniques are in place on most new CT scanners and these can reduce the effective dose. It can be reduced to as low as 1mSv, but at some cost to image quality.

Nuclear medicine
Mercaptuacetyltriglycine (MAG-III) scanning involves the use of the radioactive tracer technetium-99m MAG3 and can be of use in determining the secondary effects of calculi, namely obstruction and subsequent relative loss of function between the two kidneys. It is especially useful in the determination of ongoing obstruction in those patients with long-standing ureteric/pelvicalyceal dilation. However, it is not helpful as an acute imaging modality because of its limited availability and its insensitivity at diagnosing calculi.

Magnetic resonance imaging
Magnetic resonance urography can be utilised in those patients in whom other investigations are contraindicated, such as...
Urinary tract calculus is a common condition that places a significant burden on both community and hospital resources. Accurate imaging is of vital importance in allowing diagnosis of stones and in planning treatment.

Computed tomography–kidneys/ureters/bladder (CT-KUB) is the accepted gold standard for detection of urinary tract calculi, with sensitivities of >95 per cent.

KUB radiography and ultrasound still play an important role in diagnosing calculi in those patients with a low pretest probability and in the surveillance of patients with known stones.

be undertaken only very rarely without the assistance of preceding imaging and it usually requires general anaesthesia. However, retrograde ureterorenography may be utilised if other investigations have proven inconclusive. Such a technique also allows for placement of a ureteric stent and/or extraction of stone particles.

CONCLUSION

Accurate imaging is of the utmost importance in the diagnosis of urinary tract calculi. Each modality has its differing strengths and weaknesses, and the choice of imaging technique should always relate back to the strength of clinical suspicion. In those non-emergent patients with vague symptoms, investigation with plain film KUB and ultrasound may be sufficient. However, it is now well established that CT-KUB is the gold standard investigation for the diagnosis of urinary tract stones and its use in the acute setting is the optimal means of investigating urinary calculi.

Declaration of interests: none declared.

REFERENCES