# Imaging in Urolithiasis

William R. Masch, MD[a], Kevin C. Cronin, MD[b], Dushyant V. Sahani, MD[b],
Avinash Kambadakone, MD, FRCR[b,*]

**KEYWORDS**

• Imaging • Urolithiasis • Computed tomography • Ultrasound

**KEY POINTS**

- Imaging plays an important role in the diagnosis of urolithiasis as well as its pre-treatment planning and post-treatment follow-up.
- Proper imaging technique is essential to provide appropriate clinical care to affected patients.
- Minimizing radiation dose while maintaining acceptable diagnostic accuracy is important when imaging patients affected by urolithiasis as it is common for patients to undergo multiple imaging examinations.
- Knowledge of the various treatment options for urolithiasis and the clinically relevant imaging findings most likely to influence management decisions will assist in image interpretation and reporting.

## INTRODUCTION

Urolithiasis is common in both developing and industrialized nations.[1–7] It is estimated that urolithiasis will affect up to 12% of men and 5% of women in the United States during their lifetime.[2,5–7] Although the incidence of urolithiasis in the United States may have reached a plateau in recent years,[4] there is a general consensus that it continues to increase worldwide due to a variety of proposed factors, including obesity, dietary changes, and global warming.[1–3]

In addition to being a cause of significant patient morbidity, urolithiasis constitutes a significant burden on the health care system and accounts for approximately $2 billion in United States health care expenditures per year.[8] Consequently, accurate diagnosis and appropriate treatment are of paramount importance, such that complications of nephrolithiasis (eg, infection and chronic renal impairment) may be avoided. Imaging plays an important role in diagnosis, pretreatment planning, and post-treatment follow-up of patients with urinary tract calculi, and proper imaging technique and image interpretation will help clinicians render timely and effective care. This article discusses current imaging strategies and common radiologic findings of urolithiasis with an emphasis on issues that are relevant to clinical management.

### *Imaging Techniques*

Most urinary tract stones are thought to form in the distal nephron within or near the renal papilla,[9] the junction between the renal medulla and minor calyx where the collecting ducts empty into a common papillary duct. There are various stone types with calcium-based stones (eg, calcium oxalate monohydrate, calcium oxalate dehydrate, calcium phosphate), uric acid, and struvite being most common.[10] Less common stones include cysteine, brushite, protein matrix, and stones related to drug therapies (eg, indinavir-related calculi).[10] Stone type often influences management decisions (see later discussion) and computed tomography (CT), namely dual-energy CT (DECT), is the only imaging modality able to provide insight into stone composition.

---

[a] Division of Abdominal Radiology, Department of Radiology, University of Michigan Health System, 1500 East Medical Center Dr., Ann Arbor, MI 48109, USA; [b] Division of Abdominal Imaging, Department of Radiology, Massachusetts General Hospital, 55 Fruit Street, Boston, MA 02114, USA

[*] Corresponding author. Department of Radiology, Massachusetts General Hospital, Harvard Medical School, 55 Fruit Street, White 270, Boston, MA 02114.

*E-mail address:* akambadakone@mgh.harvard.edu

Radiol Clin N Am ■ (2016) ■–■
http://dx.doi.org/10.1016/j.rcl.2016.10.002

### Multidetector computed tomography

Noncontrast CT is without doubt the gold standard for imaging of urolithiasis[10–12] and long ago supplanted intravenous pyelography[13] due to its ability to near-instantaneously image all portions of the urinary tract with superior spatial and contrast resolution without need for administration of iodinated contrast media. Accurate stone size, stone location, and secondary signs of obstruction (eg, hydroureteronephrosis, perinephric edema, renal enlargement) are clearly depicted by CT. Technical advances in CT have enabled reliable determination of stone burden, stone density, stone fragility, and stone-to-skin distance (SSD); such data are important for both treatment planning and prognostication of treatment success. In the setting of acute flank pain, CT has the added benefit of providing an alternative diagnosis (eg, appendicitis, tubo-ovarian abscess) because it depicts many abdominal structures not well-evaluated with other modalities. Studies have reported an extraurinary cause of flank pain in 9% to 15% of CT scans being performed for suspicion of urolithiasis.[14,15] CT also confers superior ability to diagnose anatomic variations of the urinary tract, such as collecting system duplication, which have implications to urologists in planning intervention.

### Dual-energy computed tomography

The advent of DECT, allowing for simultaneous acquisition of CT images at 2 different energies has significantly advanced the ability of CT in determining stone composition. Conventionally, stone composition is evaluated using attenuation numbers. However, routine CT scanning at a single energy does not allow reliable differentiation of stone composition due to significant overlap in attenuation values for the different stone subtypes. This issue is somewhat mitigated by scanning a stone simultaneously at both high and low energy, typically 140 and 80 kilovolt (peak) (kV[p]). The degree to which a stone will attenuate x-ray photons is based on the atomic numbers of the elements making up that stone (ie, higher atomic number calcium-dominant calculi will attenuate incident photons more than lower atomic number non–calcium-dominant calculi). The difference in attenuation values at 2 energy levels for a given stone may then be compared with the attenuation profiles of stones of known composition, which aids stone type classification. This is particularly helpful for distinguishing uric acid stones from calcium-based stones (see later discussion).[16–18] Both dual-source DECT (dsDECT) and single-source DECT (ssDECT) with rapid kV(p) switching, each with different postprocessing techniques, are available commercially.

### Low-dose computed tomography

Patients affected by urolithiasis are often subject to multiple CT examinations during their lifetime, thus cumulative radiation dose is a crucial concern.[19] Low-dose CT protocols use low tube currents, which has been shown to maintain diagnostic accuracy despite increased noise in the diagnosis of stone disease.[17,18,20] Dose-reduction techniques include limited field scanning (ie, scanning only from the top of the kidneys to the bottom of the bladder for urolithiasis)[21]; use of automatic tube current modulation[22]; lower tube potential for thin, lightweight patients (eg, 80–100 kV[p])[23,24]; and use of iterative reconstruction algorithms.[24–30] Statistical iterative reconstruction algorithms, such as adaptive statistical iterative reconstruction (ASIR, GE Healthcare, Little Chalfont, UK), sinogram-affirmed iterative reconstruction (SAFIRE, Siemens, Erlangen, Germany), and iDose (Philips, Amsterdam, Netherlands), have been shown to maintain CT image quality and diagnostic accuracy at reduced doses compared with traditional filtered back projection[24,27,28,30] and are now being used routinely in many clinical practices. Further dose reductions have been attempted with model-based iterative reconstruction algorithms, and preliminary studies have shown maintained diagnostic accuracy for detection of calculi greater than 3 mm at below 1 mSv doses.[25,28–30]

### Computed tomography protocol

The multidetector CT (MDCT) protocol for evaluation of urolithiasis involves a noncontrast CT acquisition without administration of oral or intravenous contrast. The scan field of view for a stone protocol CT only extends from the top of both kidneys to the bladder base, which allows for radiation dose reduction as previously discussed. Some centers prefer to scan renal stone protocol CTs with the patient prone to assist in differentiating stones located at the ureterovesical junction from dependent bladder calculi in the region of the ureterovesical junction. Other centers prefer scanning with the patient supine to offer greater patient comfort. In rare circumstances, administration of intravenous contrast for acquisition of an excretory phase may add value in helping differentiate a distal ureteral calculus from a phlebolith.

Thinner transverse slices (1–3 mm) are preferable and improve sensitivity for stone detection; however, 5 mm axial slices with 3 mm coronal