Imaging for Nephrolithiasis and Radiation Safety

Overview: ideal imaging modality — determines presence or absence of ureteric obstruction, diagnoses clot, tumor, or stricture, and assesses severity of obstruction; if no obstruction present, determines other causes for renal colic; has high sensitivity and specificity, minimal or no radiation exposure, low cost, and can be completed quickly; helical computerized tomography (CT) — fulfills most of these criteria; in recent technology assessment of imaging modalities for ureteral stones by American Urological Association (AUA), found to have sensitivity and specificity approaching 100%; problems with CT for nephrolithiasis include ineffective use of imaging, incompletely defined risk for radiation exposure, and high cost

Radiation exposure: percentage of patients undergoing imaging for flank and abdominal pain has increased since 2001, with majority of increase in CT imaging; however, percentage of patients found to have nephrolithiasis has not increased proportionately; increased use of imaging studies represents growing concern in medicine; in 1980, average American received 3 mSv of radiation, with only 0.5 mSv from medical sources; in 2006, amount of radiation increased to ≈6 mSv, with half from medical sources (most from CT imaging); until use of low-dose CT, CT had highest dose of radiation of imaging modalities; one review of number of imaging studies performed on 100 patients with newly diagnosed renal stones found median amount of radiation received ≈30 mSv, with 20% of patients receiving >50 mSv

Reducing radiation exposure: key concept consists of “as low as reasonably achievable” or ALARA; involves using time, distance, shielding, and machine maintenance to minimize amount of radiation received by patient and physician; time — consider pulsed fluoroscopy or last-image hold (both techniques reduce amount of radiation exposure by 50%-80%); distance — step away from radiation source if not performing procedure (distance reduces dose); persons >12 ft away from source receive dose equivalent to background radiation only; shielding — all personnel in fluoroscopy suite needs lead shielding; consider lead glasses; consider use of lead shields around base of table; most radiation sources project upward from bottom of table (overhead sources have more scatter radiation); consider collimation when looking at certain portion of collecting system or ureter; air pyelography — does not obscure stone with percutaneous access; amount of radiation reduced by ≈50% (lower settings required to penetrate air compared with contrast); if extravasation occurs, not as obscuring as with contrast

Low-dose CT: recent cadaver study found standard-dose CT (19 mSv) achieved sensitivity and specificity of 99% and 83%, respectively, in imaging ureteral calculi; low-dose CT (≈1 mSv) had nearly identical sensitivity and specificity; however, low-dose CT less sensitive in larger patients (BMI >30); sensitivity also decreases (as low as 67%) for smaller stones; another study indicated distal ureteric stones perhaps more difficult to image with low-dose CT than more proximal stones; current research under way to evaluate further reduction of CT radiation dose or use of enhanced modalities (eg, as 3-D ultrasonography); cost of CT imaging for renal stones estimated at $416 million annually (total of $2.6 billion annually to manage patients with renal stones); consider x-ray or ultrasonography when feasible

Other modalities: intravenous pyelography (IVP) details anatomy well and evaluates for ureteral obstruction; however, rarely used outside United States; traditional tomography seldom used now; digital tomosynthesis — now available at most hospitals; produces series of x-ray projections acquired during single sweep of x-ray tube at limited angle; requires flat-paneled detector and image-reconstruction software; first popularized for breast imaging; can identify stones in collecting system and proximal ureter; has advantage of removing overlapping structures and provides depth information; also permits identification of hydronephrosis in some patients; study comparing sensitivity and specificity of digital

Educational Objectives

The goal of this program is to improve the management of nephrolithiasis. After hearing and assimilating this program, the clinician will be better able to:

1. Weigh benefits of imaging modalities in patients with nephrolithiasis against potential harms.
2. Choose imaging technologies with maximal effectiveness in the assessment of nephrolithiasis.
3. Appropriately manage patients with staghorn renal stones.
4. Select appropriate treatment options for lower pole stones.
5. Recommend a plan of action for patients with cystine stones.

Faculty Disclosure

In adherence to ACCME Standards for Commercial Support, Audio Digest requires all faculty and members of the planning committee to disclose relevant financial relationships within the past 12 months that might create any personal conflicts of interest. Any identified conflicts were resolved to ensure that this educational activity promotes quality in health care and not a proprietary business or commercial interest. For this program, the following has been disclosed: Dr. Preminger is a consultant for Boston Scientific and Mission Pharmacal. The planning committee reported nothing to disclose.
tomosynthesis to that of CT indicated tomosynthesis as sensitive as CT in kidney, less for ureteral stones; another study comparing radiation exposure showed patients undergoing standard radiography with tomosynthesis received ≈4 mSv; those undergoing low-dose CT received 3 mSv; and those undergoing digital tomosynthesis received 0.5 mSv; optimizing technique — reducing number of images obtained reduces amount of irradiation; standard CT urography obtains ≈428 images; removing contrasted images and performing only non-contrast CT (NCCT) reduces radiation exposure by 33%; for patients with known distal ureteral stone returning for follow-up, consider obtaining pelvic CT only (reduces irradiation by 40%)

**AUA guidelines:** NCCT recommended for initial diagnosis of stones; consider conventional x-ray of kidneys, ureters, and bladder (KUB), digital tomosynthesis, or ultrasonography for following patient; after treatment, ultrasonography with KUB or ultrasonography alone recommended for radiopaque stones (ultrasonography still useful in radiolucent stones); in past, speaker performed IVP or low-dose NCCT on patients after ureteroscopy or percutaneous stone removal, but now uses digital tomosynthesis and ultrasonography in most patients unless concerned about stricture or ureteral tract injury; study data show appropriate protocols and judicious use of imaging modalities significantly reduce cost of imaging ureteral stones (≈$150 million annually)

**Questions and answers:** imaging of distal ureteral stones — ultrasonography poor modality overall for distal stones; with small (<3 mm) stone, speaker uses ultrasonography to rule out hydronephrosis; if no hydronephrosis, small stone at ureterovesical junction most likely to pass spontaneously; speaker obtains KUB for larger radiopaque stones and, if not effective, obtains pelvic CT; danger of air embolism — remote possibility with air pyelography; unlikely because study uses only 15 mL of air under low pressure; dose equivalence and fluoroscopy time — dose increases quickly if operator continues stepping on pedal; options include having another person manage C-arm, or performing on-off fluoroscopy with single tap on pedal; speaker rarely steps on pedal for more than 1 to 2 sec unless trying to maneuver around impacted stone; recent study found 75% reduction in radiation exposure when fluoroscopy unit changed to pulsed fluoroscopy only; most radiologists familiar with this technique and with low-dose CT (now standard in most areas of United States)

### Controversies in Surgical Renal Stone Management

#### Evolution in management:

**Shock wave lithotripsy (SWL)** has changed significantly over past 20 yr; third-generation lithotripters now available, but not as effective as first generation (Dornier HM3); effectiveness of SWL depends on size, location, and stone composition; percutaneous nephrolithotomy (PNL) typically performed for patients with large stones, obstruction, stones of adverse composition, morbid obesity, or those who have previously failed SWL; as stone size increases, stone-free rate declines significantly; AUA guidelines indicate stone-free rate only ≈50% with SWL monotherapy, but closer to 80% with PNL; need for secondary intervention and ancillary treatment reduced significantly with endoscopy-based therapy for complex stones

**Staghorn stones:** previous guidelines advocated use of combination or “sandwich” therapy, consisting of percutaneous stone debulking, followed by SWL of residual stones, then second-look endoscopy to retrieve remaining fragments; however, SWL often leaves large residual stones that require second-look endoscopy; in such cases, SWL adds unnecessary procedure; recommended approach for these stones single procedure consisting of PNL with multiple nephrostomy tracts as needed and flexible nephroscopy

**Lower pole stones:** SWL or PNL can be used, but ureteroscopy now favored by many; candidates for ureteroscopy — patients with both ureteral and lower pole stones; with stones with ureteral issues (eg, stricture); those with stones resistant to SWL (eg, calcium oxalate monohydrate or cystine stone); patients with bleeding disorder in which PNL contraindicated; patients with renal anomalies or solitary kidneys; anyone with morbid obesity; techniques — new Nitinol baskets and graspers and flexible, deflectable ureteroscopes facilitate stone retrieval and minimize damage to working channel; at speaker’s institution, involves use of Nitinol basket to displace lower pole stone into upper pole calyx and fragmentation with ball-tip holmium laser fiber (TracTip); prospective randomized trial showed ≈20% increase in stone-free rates (from 71% to 94%) when stone routinely displaced from lower pole to upper pole calyx; study comparing SWL with ureteroscopy for small stones and ureteroscopy with PNL for lower pole stones found that ureteroscopy had better (20%) stone-free rates than SWL for smaller stones (<1 cm), whereas efficacy of PNL superior to that of ureteroscopy for larger stones; summary of algorithm — SWL reasonable choice for small stone with reasonable lower pole calyx anatomy; ureteroscopy good choice for stone size ≈1 cm and more acute angle; PNL probably better choice for stones 1.5 cm to 2.0 cm because of better stone-free rate and need for fewer adjunctive procedures

**Cystine stones:** stones of very hard composition (eg, cystine, calcium oxalate monohydrate) remain difficult to treat, either medically and surgically; stone-free rate only ≈40% for SWL, but approaches 100% with PNL; speaker suggests aggressive ureteroscopy in these patients; PNL most efficient way to remove large (≥2 cm) stone; patient should be followed closely with more frequent imaging than used for patients with calcium stones (to identify recurrent stone while still small, thereby allowing ureteroscopic removal); studies of patients with cystinuria who have undergone multiple PNL procedures show association between multiple stone removal procedures and impaired renal function; more frequent imaging with subsequent stone removal via flexible ureteroscopy and holmium laser reduces morbidity; review at speaker’s institution showed patients with cystinuria managed using this method had complete fragmentation, with 76% stone-free rate at 3 mo; good outcomes seen in remaining 24% of patients who had small residual fragments managed with potassium citrate, tiopronin (Thiola), and frequent imaging

**Summary:** current trend in management of nephrolithiasis favors endoscopy; SWL still has role for treatment of routine stones, but large, hard stones or stones in difficult location often managed better with endoscopy; overall
treatment philosophy suggests SWL for smaller stones; 2 to 3 cm stones considered “grey zone”; stones >3 cm generally require PNL; use SWL or ureteroscopy for small stones in lower pole and PNL for larger stones; manage cystine stones with endoscopy if possible; SWL contraindicated in—patients with previous SWL failure (avoid steinstrasse formation from multiple failed SWL procedures); patients with hard or large stones or obstruction; if SWL fails, proceed to endoscopic approach

Questions and answers: risks of moving stone from lower to upper pole—stone becoming stuck major risk; speaker avoids pulling out stones judged to be too large; ball-tip laser fiber useful for large stones; if stone judged too large for removal, break into pieces to avoid basket becoming stuck; ureteral access sheath—speaker almost always uses with flexible ureteroscope; prefers 12- to 14-Fr access sheath; ease of dilation—dilation required in ≈20% of cases; use inner stylet of access sheath as dilator; if ineffective, speaker uses balloon and then access sheath; review of data at speaker’s institution found balloon dilation safe; presenting another alternative, but poorly tolerated by patients and requires additional procedure; if patient needs stent at conclusion of stone removal, speaker uses stent with string so patient can remove stent at home 3 to 4 days later to reduce morbidity

Suggested Reading

1. A recent technology assessment by the American Urological Association indicated the sensitivity of helical computerized tomography (CT) for diagnosis of nephrolithiasis is approximately:
   (A) 50%  (B) 75%  (C) 90%  (D) 100%  **

2. Which of the following techniques reduce(s) radiation exposure during treatment of nephrolithiasis?
   (A) Pulsed fluoroscopy  (C) Last-image hold
   (B) Collimation  (D) All the above  **

3. Which of the following statements about low-dose CT is true?
   (A) Less sensitive than standard-dose CT
   (B) Less specific than standard-dose CT  (C) Less sensitive for detection of smaller stones
   (D) Effectively images distal stones

4. Which of the following imaging modalities delivers the lowest dose of radiation?
   (A) Conventional x-ray (KUB) with tomography  (C) Low-dose CT
   (B) Intravenous pyelography  (D) Digital tomosynthesis

5. Which of the following imaging modalities is recommended for initial presentation of nephrolithiasis?
   (A) Noncontrast CT  (C) Ultrasonography
   (B) Intravenous pyelography  (D) KUB

6. Which of the following statements about shock wave lithotripsy (SWL) is(are) correct?
   1. New lithotripters are more effective than first-generation lithotripters
   2. Effectiveness decreases as stone size increases
   3. Stone-free rates reduced in the morbidly obese
   4. Stone-free rates similar to percutaneous nephrolithotomy (PNL)
   (A) 4  (B) 2,3  ** (C) 1,2,3 (D) 1,2,3,4

7. Current guidelines recommend which of the following for the treatment of staghorn calculi?
   (A) SWL monotherapy  (C) Open surgery
   (B) PNL combination therapy  (D) Ureteroscopy

8. A study found that, in patients with lower pole stones, ureteroscopy was _______ to SWL for stones <1 cm, and _______ to PNL for larger stones.
   (A) Inferior; superior  (C) Superior; inferior
   (B) Equivalent; superior  (D) Inferior; equivalent

9. Which of the following is the most appropriate treatment for a patient with a 2-cm cystine stone?
   (A) PNL followed by frequent imaging  (C) Medical expulsive therapy
   (B) SWL  (D) Ureteroscopy

10. SWL is contraindicated in which of the following patients?
    1. A 51-yr-old man with a previous SWL failure
    2. A 44-yr-old man with a cystine stone
    3. A 65-yr-old man with a 2.5-cm lower pole stone
    4. A 49-yr-old woman with a 1.9-cm proximal stone and significant obstruction
    (A) 4  (B) 3  (C) 1,2,3 (D) 1,2,3,4

Answers to Audio Digest Urology Volume 38, Issue 01: 1-D, 2-B, 3-C, 4-A, 5-D, 6-A, 7-B, 8-C, 9-B, 10-B