1. Management of renal calculus disease is multifactorial, but one key component is the mineral composition of the stone(s). Pure attenuation-based methods are unreliable, but dual-energy CT has shown promise as a method of noninvasively characterizing renal stone composition. On what principle is this technique based?
   A. The likelihood of Compton scatter in unique elements imaged at differing kVp settings
   B. The difference in K-edge of unique elements imaged at differing kVp settings
   C. The change in noise levels within a particular structure imaged at differing kVp settings
   D. The change in apparent size of a particular structure imaged at differing kVp settings

2. What are the common radiographic manifestations of medullary sponge kidney?
   A. Cortical nephrocalcinosis alone
   B. Cortical nephrocalcinosis and renal tubular ectasia
   C. Medullary nephrocalcinosis alone
   D. Medullary nephrocalcinosis and renal tubular ectasia

3. Which of the following correctly describes the normal temporal progression of radiographic contrast material uptake and excretion from the kidneys?
   A. Corticomedullary, nephrographic, pyelographic
   B. Corticomedullary, pyelographic, nephrographic
   C. Nephrographic, corticomedullary, pyelographic
   D. Nephrographic, pyelographic, corticomedullary
   E. Pyelographic, corticomedullary, nephrographic
   F. Pyelographic, nephrographic, corticomedullary
A 65-year-old male with bladder cancer undergoes a loopogram for upper tract surveillance. Which of the following diseases is a common cause of the imaging findings in the lower pole of the left kidney?

A. Tuberous sclerosis
B. Diabetes mellitus
C. Hypertension
D. Urothelial carcinoma

A 3-year-old boy with a congenital left ureteropelvic junction (UPJ) obstruction related to a crossing vessel undergoes MR urography. The image on the left was acquired with a repetition time (TR) of 2,000 msec and an echo time (TE) of 200 msec. The image on the right was obtained at the same level with a TR of 3.6 msec and a TE of 1.8 msec. What is the most likely cause of the hypointense material in the left renal pelvis on the right-hand image?

A. Hemorrhage
B. Malignancy
C. Contrast material
D. Parasitic infection
E. The etiology cannot be determined with the provided images.
6. A 25-year-old male with vesicoureteric reflux presents with right flank discomfort, and an ultrasound is obtained. The arcuate arteries are sampled within each kidney and compared to assess for symmetry. What is the formula for calculating the resistive index?

A. (Peak systolic velocity – End-diastolic velocity)/Peak systolic velocity
B. (End-diastolic velocity – Peak systolic velocity)/Peak diastolic velocity
C. (Peak systolic velocity – End-diastolic velocity)/End-systolic velocity
D. (End-diastolic velocity – Peak systolic velocity)/End-diastolic velocity
E. End-diastolic velocity/Peak systolic velocity
F. End-systolic velocity/Peak diastolic velocity
G. End-diastolic velocity/Peak diastolic velocity
H. End systolic velocity/Peak systolic velocity

7. A 62-year-old male with a 40-pack-year smoking history, chronic obstructive pulmonary disease, and hematuria presents for a CT urogram and subsequent right retrograde pyelogram. What are the two most common causes of this imaging finding?

A. Urothelial cancer and Mycobacterium tuberculosis
B. Urothelial cancer and renal calculus disease
C. Schistosoma haematobium and Proteus mirabilis
D. Escherichia coli and Proteus mirabilis
A 22-year-old pregnant female in the third trimester with suspected stone disease undergoes an ultrasound examination that demonstrates moderate dilation of the proximal right collecting system and asymmetric resistive indices. The referring service requests a low-dose unenhanced renal stone protocol CT of the abdomen and pelvis. If the effective dose to the fetus is 10 mSv, what is the approximate risk of radiation-induced cancer conferred to the fetus?

A. The exact risk is speculative, but it is estimated to be roughly 1 in 250 (0.4%).
B. The exact risk is speculative, but it is estimated to be roughly 1 in 25 (4%).
C. The exact risk is speculative, but it is estimated to be roughly 1 in 5 (20%).
D. The exact risk is speculative, but it is estimated to be roughly 1 in 2 (50%).

A 42-year-old female with microhematuria undergoes an intravenous urogram. The only identifiable abnormality is a completely duplicated right collecting system (shown below). With respect to this finding, what does the Weigert-Meyer rule predict?

A. The upper pole moiety will insert superior and medial to the lower pole moiety.
B. The upper pole moiety will insert inferior and medial to the lower pole moiety.
C. The upper pole moiety will insert superior and lateral to the lower pole moiety.
D. The upper pole moiety will insert inferior and lateral to the lower pole moiety.
A 22-year-old nonsmoking female with no past medical history presents with asymptomatic microhematuria (≥3 red blood cells per high-powered field) detected during a preemployment urinalysis. A triphasic CT urogram is ordered. What is the best next step?
A. Perform the CT urogram as ordered.
B. Recommend a limited CT urogram (two of three phases).
C. Recommend an unenhanced CT.
D. Consider cancelling the test.

A 40-year-old male with recurrent urolithiasis undergoes an unenhanced CT of the abdomen and pelvis. The following exam card is reported by the scanner at the end of the study. What does the number 15.42 represent?

<table>
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<tr>
<th>Series</th>
<th>Type</th>
<th>Scan Range (mm)</th>
<th>CTDvol (mGy)</th>
<th>DLP (mGy-cm)</th>
<th>Phantom cm</th>
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</thead>
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<td>Scout</td>
<td>-</td>
<td>-</td>
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<tr>
<td>2</td>
<td>Helical</td>
<td>14.000–149.1500</td>
<td>15.42</td>
<td>850.84</td>
<td>Body 32</td>
</tr>
</tbody>
</table>

A. It is the radiation dose delivered to the patient.
B. It is the scanner-specific radiation output.
C. It is the radiation dose delivered to a hypothetical patient.
D. It is the radiation output delivered by a hypothetical scanner.

A 32-year-old pregnant female in her second trimester presents with right flank pain. A retroperitoneal ultrasound is performed, demonstrating bilateral ureteral jets. Which of the following best explains the principle of color Doppler imaging?

A. The reflected ultrasound frequency always increases when the ultrasound beam interacts with a structure moving toward it.
B. The reflected ultrasound wavelength always increases when the ultrasound beam interacts with a structure moving toward it.
C. Red pixels are always assigned when the ultrasound beam interacts with a structure moving toward it.
D. Blue pixels are always assigned when the ultrasound beam interacts with a structure moving toward it.
A 55-year-old male with gross hematuria undergoes a CT urogram consisting of unenhanced, nephrographic, and excretory phase images of the abdomen and pelvis. The following exam card is reported by the scanner at the end of the study. What is the effective dose to the patient?

A. 8.24 mGy  
B. 21.05 mGy  
C. 978.89 mGy-cm  
D. The effective dose cannot be determined with these data.

A 5-year-old boy with congenital orthotopic megaureter undergoes MR urography to assess anatomy and function. Three-dimensional reconstructions were performed of the coronal source data. The image on the left was obtained with a repetition time (TR) of 4,000 msec and an echo time (TE) of 200 msec. The image on the right was obtained with a TR of 3.6 msec and a TE of 1.8 msec. What is the approximate relative function of the two kidneys?

A. The right kidney is substantially less functional than is the left kidney.  
B. The left kidney is substantially less functional than is the right kidney.  
C. The two kidneys have grossly similar function.  
D. The relative function of the kidneys cannot be estimated with these images.
15 A 52-year-old male with diabetes mellitus, fever, and leukocytosis presents with left flank pain. Vital signs are as follows: pulse 115, blood pressure 89/65, respiratory rate 22, SpO₂ 98% on room air. The following ultrasound is obtained. What is the most likely diagnosis?

- A. Pyelonephritis
- B. Pyelitis
- C. Pyonephrosis
- D. Emphysematous pyelitis
- E. Emphysematous pyelonephritis

16 A 7-year-old girl with recurrent pyelonephritis undergoes a voiding cystourethrogram (VCUG). What is the diagnosis?

- A. Normal study
- B. Bilateral grade I vesicoureteric reflux
- C. Bilateral grade II vesicoureteric reflux
- D. Bilateral grade IV vesicoureteric reflux
17 A 70-year-old male undergoes bilateral percutaneous nephrostomy catheter placement. Which of the following best characterizes the imaging findings in the midportions of the ureters?

A. Malignant condition associated with urothelial carcinoma
B. Benign condition associated with urothelial carcinoma
C. Benign vascular impressions
D. Benign ureteral “kinks”

18 An 8-year-old girl with recurrent abdominal pain undergoes a retroperitoneal ultrasound. Which of the following is the best explanation for the imaging finding(s) in the left kidney?

A. Multicystic dysplastic kidney
B. Autosomal dominant polycystic kidney disease
C. Acquired renal cyst
D. Obstructed ectopic ureter
E. Autosomal recessive polycystic kidney disease
19 A 55-year-old male with asymptomatic microscopic hematuria undergoes a CT urogram. Representative images below depict an abnormality in the left kidney. What is the most appropriate management for this entity?

A. Ignore (benign finding)
B. Prophylactic antibiotics
C. Percutaneous aspiration
D. Embolization
E. Operative resection

20 A 50-year-old male with recurrent urolithiasis undergoes an unenhanced CT of the abdomen and pelvis with a CTDI$_{vol}$ of 14 mGy based on a 32-cm-diameter body dosimetry phantom. His effective diameter \( \sqrt{\text{AP diameter} \times \text{transverse diameter}} \) is 17 cm, which translates to a 1.98 \( f_{\text{size}} \) conversion factor, and the DLP is 700 mGy-cm (scan length: 50 cm). What is this patient’s size-specific dose estimate (SSDE)?

A. 7.1 mGy
B. 27.7 mGy
C. 553.5 mGy-cm
D. 1,386 mGy-cm
E. The SSDE cannot be determined with these data.
21 A 60-year-old male with gross hematuria and a negative cystoscopy undergoes a CT urogram that demonstrates an abnormality in the left proximal collecting system. Which of the following is a correct comparison between upper tract urothelial cancer and bladder cancer?

A. Upper tract urothelial cancer is more common than is bladder cancer.
B. Upper tract urothelial cancer is less likely to be invasive than is bladder cancer.
C. Smoking is a risk factor for bladder cancer but not for upper tract urothelial cancer.
D. Aromatic hydrocarbons cause both bladder cancer and upper tract urothelial cancer.

22 A 63-year-old male with a history of urothelial carcinoma of the right renal pelvis and bladder, and who is status post right nephroureterectomy, cystoprostatectomy, and ileal loop creation with an end-to-end anastomosis, undergoes a loopogram to assess for leak. How should the contrast material in the left collecting system be characterized?

A. Abnormal spontaneous reflux, grade I
B. Abnormal spontaneous reflux, grade III
C. Abnormal spontaneous reflux, grade V
D. Expected finding
A 62-year-old male with hydronephrosis undergoes a right retrograde pyelogram. What is the name of this finding, and what does it imply?

A. Goblet sign, which supports the diagnosis of a urothelial malignancy
B. Goblet sign, which supports the diagnosis of a ureteral calculus
C. Comet tail sign, which supports the diagnosis of a urothelial malignancy
D. Comet tail sign, which supports the diagnosis of a ureteral calculus

A 2-year-old girl with an abnormal abdominal ultrasound undergoes a voiding cystourethrogram (VCUG). What is the most likely diagnosis?

A. Grade III reflux
B. Grade III reflux and congenital duplication
C. Opacification of an obstructed collecting system
D. Opacification of a normal collecting system
Unnecessary renal stone CT examinations are commonly cited as a major source of radiation exposure in young patients, and efforts are underway to minimize the radiation dose from these examinations. What is the principal effect of statistical iterative reconstruction?

A. Improve image signal  
B. Improve image contrast  
C. Decrease radiation dose  
D. Decrease image noise

A 25-year-old male with right lower quadrant pain and suspected appendicitis presents for a contrast-enhanced CT of the abdomen and pelvis. The effective dose is estimated to be 10 mSv. How does this compare to the typical annual natural background radiation dose for United States citizens living at sea level?

A. It is approximately five times the annual background dose of 2 mSv.  
B. It is approximately 50 times the annual background dose of 0.2 mSv.  
C. It is approximately 500 times the annual background dose of 0.02 mSv.  
D. It is approximately 5,000 times the annual background dose of 0.002 mSv.

A 32-year-old female with left flank pain and hematuria undergoes an unenhanced renal stone protocol CT of the abdomen and pelvis. Which imaging sign best characterizes the more anterior calcification in the left hemipelvis, and what does it imply?

A. Comet tail sign, which supports the diagnosis of a ureteral calculus  
B. Comet tail sign, which supports the diagnosis of a phlebolith  
C. Soft-tissue “rim” sign, which supports the diagnosis of a ureteral calculus  
D. Soft-tissue “rim” sign, which supports the diagnosis of a phlebolith
A 50-year-old male with recurrent urinary tract infections undergoes an abdominal radiograph demonstrating a large calcification in the right upper quadrant. This calcification is likely comprised of what dominant material?

A. Calcium oxalate  
B. Calcium phosphate  
C. Struvite  
D. Cystine  
E. Uric acid

A radiology practice is interested in updating their abdominal CT scan protocols to reduce the radiation dose to their patients. What effect would a lower kVp setting (e.g., 80 kVp instead of 120 kVp) have on the resultant images?

A. Decreased image noise  
B. Increased radiation dose  
C. Increased attenuation of iodine  
D. Decreased pseudoenhancement

A new imaging modality is developed for the detection of upper tract urothelial carcinoma. Its feasibility is tested in a small patient population. The test identifies cancer in three patients with the disease and two patients without the disease. The test is “negative” in one patient with the disease and eight patients without the disease. What are the sensitivity and specificity of this test based on these data?

A. Sensitivity: 75%, specificity: 20%  
B. Sensitivity: 25%, specificity: 80%  
C. Sensitivity: 75%, specificity: 80%  
D. Sensitivity: 25%, specificity: 20%
ANSWERS AND EXPLANATIONS

1. **Answer B.** Dual-energy CT is based on the principle of distinguishing elements that have sufficiently unique K-edges by imaging them with two different kVp settings. When an atom is struck by a photon of sufficient energy to dislodge an electron from the K-shell of that atom, the electron can be discharged and replaced by an electron from a neighboring ring. When this occurs, an x-ray photon is discharged. This phenomenon is known as the photoelectric effect.

   Just above the K-shell binding energy is the K-edge, which is characterized by a sudden increase in attenuation at that energy level caused by a sudden increase in the probability of the photoelectric effect occurring. The K-edge is element specific and increases with increasing atomic number. When two elements with sufficiently unique K-edges are imaged with two different kVp settings (most commonly 80 and 140 kVp on clinical scanners), it is possible to determine the composition of those elements by the way they behave in the radiation environment. The attenuation of those elements at varying kVp settings gives information about their K-edge, and allows one to determine indirectly what they are.

   Most elements that constitute the human body (e.g., carbon, hydrogen, oxygen, nitrogen) have very similar K-edges (range: 0.01 to 0.53 keV), making them unlikely candidates for dual-energy separation. However, minerals (e.g., calcium [K-edge: 4.0 keV]) and iodine (e.g., iodinated contrast material [K-edge: 33.2 keV]) are different enough from background tissue that separation is possible. Once separation is achieved, those elements can be characterized, quantified, and/or removed from the image. This forms the foundation of dual-energy characterization of renal calculi and permits the creation of "virtual unenhanced" CT.


2. **Answer D.** Medullary sponge kidney is characterized by medullary nephrocalcinosis and renal tubular ectasia. Renal tubular ectasia is characterized by radiating parallel linear contrast arrays at the medullary tips (two examples shown below); it should be distinguished from the normal "papillary blush," which is homogeneous, vague, and nonlinear. The underlying abnormality in renal tubular ectasia is a defect in the renal tubules that results in tiny sac-like cysts that impair urine transit and predispose to stone formation. Many patients with renal tubular ectasia do not have calculi or systemic signs of renal disease; in these patients, the ectatic ducts are often thought to be an incidental finding.
The differential diagnosis for medullary nephrocalcinosis is:

- Medullary sponge kidney [common cause]
- Type I (distal) renal tubular acidosis [common cause]
- Hyperparathyroidism [common cause]
- Other causes of hypercalcinosis (e.g., hypervitaminosis D, milk–alkali syndrome)
- Sarcoidosis
- Oxaluria
- Furosemide use

The differential diagnosis for cortical nephrocalcinosis is:

- Renal cortical necrosis (secondary to severe systemic hypotension) [common cause]
- Chronic glomerulonephritis [common cause]
- Chronic pyelonephritis
- Alport syndrome
- Oxaluria

Medullary nephrocalcinosis is much more common than is cortical nephrocalcinosis.

References:

**Answer A.** The normal progression of contrast material uptake and excretion from the kidneys is as follows: unenhanced (prior to contrast material uptake), arterial (20 to 25 seconds postcontrast), corticomedullary (25 to 80 seconds postcontrast), nephrographic (90 to 110 seconds postcontrast), pyelographic (starting ~3 minutes postcontrast and continuing for many minutes). The pyelographic phase is sometimes also referred to as the excretory phase.
The corticomedullary phase is most commonly imaged during routine “portal venous” phase acquisitions that are timed to optimize liver imaging. The nephrographic phase is targeted for renal mass evaluation because the homogeneous appearance of the kidneys in this phase renders it more sensitive for the detection of renal masses than the corticomedullary phase. The pyelographic phase is obtained to evaluate for abnormalities of the collecting system. Although the pyelographic phase begins earlier, most pyelographic phase images are obtained 10 to 15 minutes after contrast material administration to maximize distention of the collecting systems and minimize residual renal parenchymal uptake.

The normal pattern of uptake is important to remember because when the pattern is delayed (at an earlier stage than would be predicted based on the postcontrast timing), it indicates that a functionally significant abnormality is occurring on the affected side(s). In cases where one side is delayed and the other is not, the delayed side is the abnormal side. The generic differential diagnosis for a delayed nephrogram is as follows:

- “Blood in”: renal artery stenosis/thrombosis/injury
- “Blood out”: renal vein thrombosis
- “Urine in”: acute tubular necrosis, pyelonephritis, glomerulonephritis
- “Urine out”: collecting system obstruction


Answer B. The imaging findings are compatible with papillary necrosis, which manifests in a variety of ways: (a) elongated fornix, (b) “lobster claw” deformity, (c) “clubbed” calyx filled with contrast material, (d) “clubbed calyx” filled with nonenhancing debris, (e) “golf-ball-on-a-tee” deformity, and (f) a combination of the above. All of these deformities result from ischemic necrosis of the medullary papilla, often from a microangiopathic process (e.g., diabetes mellitus).

Common causes of papillary necrosis can be remembered with the mnemonic “NSAID,” which includes

- Nonsteroidal anti-inflammatory drugs (NSAIDs)
- Sickle cell disease
- Analgesic abuse
- Infection (Tuberculosis, fungal)
- Diabetes mellitus


Answer C. The hypointense material within the left renal pelvis on the right-hand T1-weighted postcontrast image from the question is concentrated gadolinium-based contrast material (GBCM). Note the homogeneous fluid-signal intensity appearance shown within the same location on the left-hand T2-weighted image. If the material was caused by a fixed filling defect, such as hemorrhage, a mass, or a parasitic infection, the filling defect(s) would likely be visible on the T2-weighted image as well.
The principal diagnostic effect of GBCM is to indirectly shorten the T1 time of adjacent protons, but it also shortens T2 relaxation times. This effect is not noticeable on most T1-weighted images because the T1-shortening effects dominate. However, when gadolinium becomes highly concentrated (e.g., within a dilated renal pelvis, or in the dependent urinary bladder), the T2-shortening effects take over and produce a signal void. Remember that no image reflects purely T1 information or purely T2 information. MR images are a combination of both, with “weighting” toward one or the other based on the desired image contrast.


Answer A. The formula for calculating the renal arterial resistive index is

\[
\text{Resistive Index} = \frac{\text{Peak systolic velocity} - \text{End diastolic velocity}}{\text{Peak systolic velocity}}
\]

The resistive index (RI) is unit-less, and the normal value in a native kidney is 0.60 to 0.70. In elderly patients, and in patients with chronic kidney disease, it is common to have values \( \geq 0.70 \). The utility of the resistive index is debated because it is not a sensitive marker for partial or incomplete obstruction. In a patient with a dilated system, a difference in RIs between the ipsilateral (greater RI) and contralateral (lower RI) side \( \geq 0.08 \) to \( 0.10 \) is strongly suggestive of an acute obstruction. These changes are most commonly observed 6 to 48 hours after the inciting event.

It is important to remember that grayscale sonography only reveals anatomic information; in particular, dilation or no dilation. Collecting system dilation is not always due to obstruction. It also can be seen in patients with previous obstruction (now relieved), vesicoureteric reflux, and postsurgical change.


Answer A. The images demonstrate an “amputated calyx,” which is an infundibular stricture that results in dilation of the upstream calyces and nonvisualization of the infundibulum. It is most commonly seen in the setting of upper tract urothelial cancer and, in endemic areas, genitourinary tuberculosis.

Renal calculi (Answer B) do not typically cause this appearance. *Schistosoma haematobium* (Answer C) produces an ascending infection of the urinary tract associated with hemorrhagic cystitis, bladder wall calcifications, and squamous cell carcinoma of the bladder. Urinary strictures associated with *Schistosoma haematobium* usually concentrate in the distal ureters. *Proteus mirabilis* (Answers C and D) is a urease-producing organism that infects the urinary tract and is associated with staghorn calculi. *Escherichia coli* (Answer D) is one of the most common causes of urinary tract infection in the United States. Neither *Proteus mirabilis* nor *Escherichia coli* are common causes of urinary tract strictures.

Answer A. Stochastic effects at doses <100 mSv are speculative and based on the “linear-no-threshold” model, but the risk of cancer induction is estimated to be roughly 0.01% (1 in 1,000) for an adult patient who receives an effective dose of 10 mSv. The risk likely is higher for young adults, children, infants, and fetuses. The risk to a newborn infant is estimated to be roughly 0.4% (1 in 250) per 10 mSv dose; the risk to a fetus in the second or third trimester is likely similar, but also difficult to predict.


Answer B. The Weigert-Meyer rule predicts that in a completely duplicated system, the upper pole moiety will insert inferior and medial to the lower pole moiety. Only rare exceptions to this rule exist. This rule is useful because duplicated systems have ectopic insertions; localizing these insertion sites is important for management. Ectopic ureters can insert into the bladder (most common), infrasphincteric urethra, seminal vesicles, vagina, fallopian tubes, ejaculatory ducts, and perineum. When an ectopic ureter inserts into the bladder, it often forms a ureterocele, which manifests as a so-called cobra-head deformity. “Cobra-head” describes the shape of the filling defect within the bladder caused by the distally dilated ectopic ureter.


Answer D. The best answer is to consider cancelling the test. In a young asymptomatic female with no risk factors, the yield of a triphasic CT urogram to detect significant pathology is low. The American Urological Association recommends first completing a history and physical to assess for other potential causes of microscopic hematuria (e.g., menstruation, urinary tract infection), and then, if one or more is present, repeating the urinalysis before proceeding with other diagnostic testing. If the finding persists, a targeted assessment should be considered (e.g., unenhanced renal stone CT with or without cystoscopy, renal function testing). The benefits of performing multiphasic imaging in this patient population, which is not at risk for urothelial carcinoma, are extremely low. In patients with risk factors for urothelial malignancy (e.g., age > 35 years, male sex, smoking history, gross hematuria, etc.) workup usually consists of cystoscopy, triphasic CT urography, and renal function testing, with or without urine cytology.


11 Answer B. The CTDI_{vol} (volume CT dose index, expressed in mGy) is a measure of the scanner-specific radiation output. Because CTDI_{vol} is scanner specific, it is an excellent way to compare the radiation output between scanners and scan protocols. However, it is not the dose delivered to the patient. Dose (expressed in Sv) and exposure (expressed in Gy) are related but not the same thing.

CTDI_{vol} is independent of patient body size and scan length. To give a better indication of the radiation exposure to a patient, CTDI_{vol} can be converted into the dose–length product, or DLP (mGy-cm), by multiplying the CTDI_{vol} by the scan length. Despite the name, DLP is not an indication of patient-specific dose either; it is merely a representation of the scanner output multiplied by the scan coverage. CTDI_{vol} and DLP are tools for comparison that can be used to optimize protocols and to compare scanner outputs across sites and studies (and within institutions).

References: Bankier AA, Kressel HY. Through the Looking Glass revisited: the need for more meaning and less drama in the reporting of dose and dose reduction in CT. Radiology 2012;265:4–8.

12 Answer A. The reflected ultrasound frequency always increases when the ultrasound beam interacts with a structure moving toward it. Likewise, the reflected ultrasound frequency always decreases when the ultrasound beam interacts with a structure moving away from it. This is known as the Doppler shift, and is the fundamental physical principal behind Doppler imaging. As the frequency increases, the wavelength decreases (i.e., becomes more compressed), and as the frequency decreases, the wavelength increases (i.e., becomes more elongated). Interestingly, although these properties are fixed, there must be an impedance difference between the moving structure(s) and the background fluid/tissue for a Doppler shift to be detected by the transducer (e.g., red blood cells in blood; dilute urine from the ureters entering concentrated urine in the bladder).

By convention, red pixels signify interaction with an object moving toward the transducer and blue pixels signify interaction with an object moving away from the transducer, but this is actually not a fixed property and can be altered by the ultrasound operator (Answers C and D).


13 Answer D. The scanner exam card does not provide sufficient information to allow calculation of the patient’s effective dose. Neither the volume CT dose index (CTDI_{vol}) nor the dose–length product (DLP) is a measure of patient dose; rather, each is a measure of scanner and protocol-specific radiation output. To calculate an estimate of patient dose requires not only a measure of the scanner output (e.g., CTDI_{vol}) but also the patient’s size (e.g., effective diameter), and the body area imaged (e.g., abdomen and pelvis). CTDI_{vol} and DLP should not be considered as, nor reported to be, the radiation dose delivered to the patient.

Bankier AA, Kressel HY. Through the Looking Glass revisited: the need for more meaning and less drama in the reporting of dose and dose reduction in CT. Radiology 2012;265:4–8.
14 **Answer C.** Although there is a congenital megaureter and left renal scarring, the overall function of the two kidneys is grossly similar. This is evidenced by similar nephrograms and similar patterns of excretion on the excretory-phase T1-weighted right-hand image. Intravenously administered contrast media with renal-dominant excretion patterns are good indicators of glomerular filtration. Most iodinated contrast media and most gadolinium-based contrast media fit this profile.

The left-hand image is heavily T2 weighted (long TR, long TE, fast spin echo-based sequence), and the right-hand image is T1 weighted (short TR, short TE, gradient recalled echo-based sequence). Heavily T2-weighted sequences are referred to as "static-fluid" sequences because they take a long time to acquire and best depict dilated, fluid-filled structures (e.g., a congenital megaureter). Fluid has a very long T2; therefore, on a heavily T2-weighted sequence, the signal from all other structures is suppressed while the signal from fluid is preserved. This is the same principle used for MRCP imaging in the liver and pancreas.

The collecting systems are only well seen on the right-hand image because contrast material has been administered. Gadolinium-based contrast material indirectly shortens the T1 times of adjacent protons, rendering them hyperintense on T1-weighted images. On MR urography, heavily T2-weighted images are used for anatomic depiction of the collecting systems (in particular, when dilated), and postcontrast T1-weighted images are used to assess function and to detect pathologic enhancement.


15 **Answer C.** The constellation of findings (echogenic material within a dilated collecting system in the setting of sepsis) is compatible with pyonephrosis, which should be managed with intravenous antibiotic therapy and emergent decompression of the collecting system. Often this is achieved with an antegrade percutaneous nephrostomy. Delay in or failure to decompress the collecting system can result in severe sepsis and loss of the renal unit. Pyelonephritis (Answer A) is a renal parenchymal infection without collecting system dilation, pyelitis (Answer B) is infection or inflammation of a nondilated collecting system, emphysematous pyelitis (Answer D) is infection of the collecting system by one or more gas-producing organism(s), and emphysematous pyelonephritis (Answer E) is infection of the renal parenchyma by one or more gas-producing organism(s).


16 **Answer C.** The images demonstrate reflux into the pelvicalyceal systems without dilation. Therefore, this is grade II reflux. This study cannot be normal because the contrast material was instilled retrograde. In a native system, it is not normal for fluid to enter the upper tracts in a retrograde fashion. Vesicoureteric reflux grading has high interrater agreement (weighted kappa: 0.93 to 0.94) and is performed using the following scale:

- Grade I: Reflux into the ureter(s) only
- Grade II: Reflux into the pelvicalyceal system(s) without dilation
- Grade III: Reflux into the pelvicalyceal system(s) with mild dilation
• Grade IV: Reflux into the pelvicalyceal system(s) with moderate dilation
• Grade V: Reflux into the pelvicalyceal system(s) with severe dilation


Answer B. The images demonstrate numerous contrast-filled pseudodiverticula arising from the ureteral walls consistent with ureteral pseudodiverticulosis. This uncommon condition is associated with chronic urinary tract infection, and it has a strong association with urothelial malignancy (up to 45% of affected patients will develop a urothelial malignancy). Routine surveillance of the upper and lower urinary tracts is recommended in these patients. Despite the location of the pseudodiverticula, urothelial carcinoma of the bladder remains more common than urothelial carcinoma of the upper tracts (as it is in the general population). When urothelial carcinoma does develop, it usually does so 2 to 10 years after the pseudodiverticula are initially identified. Benign vascular impressions (Answer C) and benign ureteral “kinks” (Answer D) can distort the ureter, but they do not cause outpouchings to extend beyond the normal luminal contour. Only the left ureter from the question has extrinsic impressions that might reflect “kinks” or vascular impressions; therefore Answer C and Answer D are not the best choices.


Answer D. The imaging findings are compatible with an obstructed upper pole moiety in a complete congenital duplication. A single dominant upper pole “cyst” with no or minimal surrounding cortex in a young patient is strongly suggestive of this diagnosis. In a complete duplication, the upper pole moiety tends to obstruct because of the ectopic insertion of the upper pole ureter upon the bladder or a nearby structure, often with associated ureterocele formation. The lower pole moiety, which is prone to vesicoureteric reflux and recurrent infection, typically inserts at or near the normal location at the bladder trigone.

Multicystic dysplastic kidney (Answer A) is characterized by a congenitally nonfunctional kidney replaced by noncommunicating cysts and minimal parenchymal volume. Autosomal dominant polycystic kidney disease (Answer B, ADPKD) usually does not present this early in life. ADPKD can be diagnosed in young patients 15 to 39 years of age if there are three or more unilateral or bilateral cysts with a confirmed family history. This is in contradistinction to autosomal recessive polycystic kidney disease (Answer E, ARPCKD), which typically presents in young children with innumerable tiny cysts replacing both kidneys. The cysts in this condition (ARPCKD) are so small that they can actually appear echogenic on ultrasound. Acquired renal cysts (Answer C) of this size are rare in young children and should not affect the cortical volume.

Answer A. The images demonstrate a well-demarcated fluid-filled peripherally based structure that accumulates contrast material on excretory-phase imaging compatible with a calyceal diverticulum. Calyceal diverticula require no management unless they become complicated. Because they predispose to local urinary stasis, they carry a risk of recurrent infection and stone disease. Recurrent infection and stone disease are complications associated with all causes of urinary stasis (e.g., urethral diverticula, bladder outlet obstruction).


Answer B. The correct answer is 27.7 mGy (14 × 1.98 = 27.7). The size-specific dose estimate (SSDE, expressed in mGy) takes into account the patient’s size (i.e., diameter or effective diameter), as well as the radiation output of the scanner (CTDINV), to provide an estimate of the patient-specific radiation dose. The units are mGy (not mSv) because this is an estimate based on exposure; it is not a true dose. The formula for calculating SSDE is as follows:

\[ f_{\text{size}} \times \text{CTDINV} = \text{SSDE} \]

\( f_{\text{size}} \) is a conversion factor based on the patient’s body diameter that is determined using a look-up table produced by the American Association of Physicists in Medicine Task Group 204 (2011). The \( f_{\text{size}} \) is contingent on the phantom size that was used in the CTDINV determination (32 cm or 16 cm), and can be determined with a variety of diameter measurements (lateral + AP diameter, lateral diameter, AP diameter, or effective diameter). Effective diameter is calculated with the following equation:

\[ \sqrt{\text{AP diameter} \times \text{transverse diameter}} = \text{Effective diameter} \]

Bankier AA, Kressel HY. Through the Looking Glass revisited: the need for more meaning and less drama in the reporting of dose and dose reduction in CT. Radiology 2012;265:4–8.

Answer D. Industrial aromatic hydrocarbons, such as those associated with aniline dyes, textiles, petrochemicals, and coal increase the risk of both bladder cancer and upper tract urothelial cancer by approximately eight times. Smoking is a leading cause of both upper tract and lower tract malignancy. Upper tract urothelial cancer is much less common than is bladder cancer, with approximately 90% to 95% of urothelial cancers arising in the bladder. When diagnosed, upper tract urothelial cancers are more likely to be muscle invasive (60% vs. 15% to 25%). Patients with urothelial carcinoma of either the upper tract or lower tract are considered to have “at-risk” urothelium, and typically undergo annual surveillance for local recurrence, metastatic disease, and/or metachronous malignancies.

Answer D. It is often normal to see spontaneous ureteric reflux after an ileal loop creation. This is because the submucosal tunnel of the ureter through the bladder wall, which helps prevent reflux from occurring in the native system, is no longer present. In some cases, antirefluxing surgical techniques are applied to the ureteroenteric anastomoses to minimize the risk of high-volume reflux. In this case, a refluxing end-to-end anastomosis was created. Absence of reflux in this setting is actually an indirect sign of pathology (e.g., benign stricture [most common], obstructing mass) at the level of the anastomosis. The normal pattern of reflux seen after ileal loop creation can be exploited during a loopogram to monitor the upper tract(s) for metachronous urothelial carcinoma recurrence.


Answer A. The images demonstrate a “goblet sign,” which is associated with urothelial carcinoma of the ureter. It is caused by slow expansion of a mass within the lumen of the ureter that grows slowly enough to allow the segment to distend and accommodate its growth pattern. It can also be seen with other slowly growing processes (e.g., ureteral metastasis, ureteral endometriosis). The combined features of a central ureteral filling defect with a tapered lumen caudal to it produce the shape of a goblet (i.e., wine glass). Interestingly, there is a second sign on the images that favors urothelial carcinoma of the ureter: the “stipple sign.” This sign, described in 1979, is characterized by entrapment of contrast material within the lucent papillary projections of a urothelial malignancy.

The “comet tail” sign (Answers C and D) is a finding on CT in which a calcification (the “comet”) is at the tip of a linear soft tissue attenuation structure (a vein) without a surrounding rim. When seen, it favors that the calcification is a phlebolith (i.e., a benign venous calcification) and not a calcification in the ureter.


Answer B. The images demonstrate grade III vesicoureteric reflux (reflux associated with mild collecting system dilation) and a “drooping lily” sign, indicative of reflux into the lower pole moiety of a duplicated collecting system. The “drooping lily” sign refers to the morphology of the lower pole calyces and lower pole infundibula, and their appearance in the setting of a nonvisualized upper pole. The upper pole moiety is not identified on this study and cannot be evaluated. In the setting of a completely duplicated collecting system, the upper pole moiety is associated with obstruction, and the lower pole moiety is associated with reflux and infection. The upper pole moiety typically inserts ectopically inferior and medial to the lower pole moiety (Weigert-Meyer rule). A VCUG is a retrograde study; therefore, an obstructed system (Answer C) would not be visible with this technique.
Answer D. The primary function of statistical iterative reconstruction methods (ASIR, IRIS, SAFIRE, iDose) is to reduce image noise. This is accomplished by matching a simulated CT projection to the acquired CT projection in an iterative (repeated) fashion to better model the image noise. Reduced image noise can translate into radiation dose savings, but the effect is indirect: one can obtain noisier images with less radiation exposure, and then “clean up” the noisy images with statistical iterative reconstruction after they are acquired. Most statistical iterative reconstruction algorithms allow a blend of filtered back projection and iterative reconstruction data. Greater iterative reconstruction equates to less noise and greater image smoothing. Images reconstructed with 100% statistical iterative reconstruction can have a waxy, surreal appearance. The ideal blend varies based on the desired appearance, imaging protocol, and intended spatial resolution.


Answer A. The average annual natural background radiation dose is 2 to 3 mSv. A CT examination with an effective dose of 10 mSv is roughly four to five times this. No deterministic effects of radiation exposure (e.g., erythema, CNS abnormalities) occur at this dose level. Stochastic effects below 100 mSv are speculative and based on the “linear-no-threshold” model, but the risk of fatal cancer induction is estimated to be roughly 0.01% (1 in 1,000) for an adult patient who receives an effective dose of 10 mSv. Because a large fraction of people (about 1 in 5, or 20%) will be diagnosed with some form of cancer in their lifetime, the incremental risk is quite small (i.e., increasing from 20% to 20.01%). Decisions about imaging should include a consideration of the risks of imaging (e.g., the risk of a contrast reaction, the risk of radiation exposure), the benefits of imaging (e.g., diagnosis, prognosis), and the risks of not imaging (e.g., failure to diagnose).


Answer C. The images demonstrate a soft-tissue “rim” sign, which supports the diagnosis of a ureteral calculus. This sign is caused by mural edema surrounding a ureteral calculus. It is useful for differentiating a suspected ureteral calculus from a phlebolith (i.e., a benign venous calcification) because phleboliths are chronic and generally do not cause thickening of the vein wall. When a soft-tissue “rim” sign is detected, the positive predictive value for a ureteral calculus is high. Not all ureteral calculi demonstrate the soft-tissue “rim” sign. It is more frequently absent with larger calculi and those lodged at the ureterovesical junction (UVJ).
The comet tail sign is less reliable; its presence somewhat supports the diagnosis of a phlebolith over a ureteral calculus. With the comet tail sign, the calcification (the “comet”) is at the tip of a linear soft tissue attenuation structure (a vein, the “tail”) without a surrounding rim. An example of the comet tail sign is on the same image (the more posterior calcification in the left hemipelvis).


28 **Answer C.** Staghorn calculi usually are composed of struvite, a mineral (magnesium ammonium phosphate) that forms in alkaline urine, though they may often be admixed with variable amounts of calcium or other minerals. Staghorn calculi are strongly associated with urease-producing bacteria such as *Proteus mirabilis*. Urease splits uric acid and alkalinizes the urine. The following table details the basic characteristics of common minerals found in renal calculi. Note that many stones are formed from a combination of these minerals, and that the raw attenuation of many stones overlap (prohibiting classification by simple CT attenuation measurements alone).

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Visible on Radiography</th>
<th>Visible on CT</th>
<th>HU Range</th>
<th>Associations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium oxalate</td>
<td>Often</td>
<td>Yes</td>
<td>800–1,000</td>
<td>Most common (~80%)</td>
</tr>
<tr>
<td>Calcium phosphate</td>
<td>Often</td>
<td>Yes</td>
<td>800–1,000</td>
<td></td>
</tr>
<tr>
<td>Struvite</td>
<td>Often</td>
<td>Yes</td>
<td>330–900</td>
<td>Staghorn calculi</td>
</tr>
<tr>
<td>Cystine</td>
<td>Often</td>
<td>Yes</td>
<td>200–880</td>
<td>Congenital cystinuria</td>
</tr>
<tr>
<td>Uric acid</td>
<td>No</td>
<td>Yes</td>
<td>150–500</td>
<td>Invisible on plain x-ray</td>
</tr>
<tr>
<td>“Indinavir stones”</td>
<td>No</td>
<td>No</td>
<td>&lt;100</td>
<td>HIV therapy, invisible on CT</td>
</tr>
</tbody>
</table>


29 **Answer C.** Decreasing kVp decreases the average and peak energy of the x-ray beam, which increases image noise, decreases radiation dose, increases the attenuation of iodine, and decreases pseudoenhancement effects. kVp has a quadratic relationship with radiation dose, while mA has a linear relationship.
with radiation dose. Therefore, lowering kVp will have a greater effect on radiation dose than does lowering mA. However, changes in kVp have a greater effect on the resulting image (kVp affects noise as well as attenuation, while mA only affects noise).

Pseudoenhancement is common with multidetector CT scanners and is primarily related to a computational error that fails to appropriately correct for beam hardening. As the beam energy approaches the K-edge of iodine (33.2 keV), the likelihood of the photoelectric effect will increase with respect to Compton interactions, thereby reducing non-linearity errors due to scattered radiation. Additionally, use of a lower kVp will permit a reduction in the necessary volume of iodinated contrast material while maintaining the same degree of attenuation. This reduction will decrease the beam hardening effects of iodine, which will decrease the incidence and magnitude of pseudoenhancement.


30 Answer C. The sensitivity is 75%, and the specificity is 80%. Unlike positive (PPV) and negative (NPV) predictive values, which vary with the disease prevalence, sensitivity and specificity are fixed characteristics of the test. Sensitivity indicates the probability that the test will be positive in a patient with the disease (true positive rate), while specificity indicates the probability that the test will be negative in a patient without the disease (true negative rate). Most clinical decisions do not rely on sensitivity and specificity because usually it is unknown whether the patient has the disease; most clinical decisions instead rely on positive and negative predictive value, which are the probabilities that the patient has (PPV) or does not have (NPV) the disease given that the test is positive (PPV) or negative (NPV). To calculate these parameters, it is helpful to organize the data into a 2 × 2 table, as follows:

<table>
<thead>
<tr>
<th></th>
<th>Disease Present</th>
<th>Disease Absent</th>
<th>Predictive Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test Positive</strong></td>
<td>3</td>
<td>2</td>
<td>PPV = 3/(3+2) = 0.60</td>
</tr>
<tr>
<td><strong>Test Negative</strong></td>
<td>1</td>
<td>8</td>
<td>NPV = 8/(8+1) = 0.89</td>
</tr>
<tr>
<td><strong>Sens./Spec.</strong></td>
<td>Sens. = 3/(1+3) = 0.75</td>
<td>Spec.: 8/(2+8) = 0.80</td>
<td></td>
</tr>
</tbody>
</table>

*As mentioned, the positive and negative predictive values depend on the prevalence of disease in the population; therefore, the PPV and NPV will be different if the test is applied to a population with different disease prevalence.