Intravenous urography has long been the cornerstone of the imaging evaluation of urinary tract disease. However, other imaging modalities such as ultrasonography, computed tomography, and magnetic resonance imaging are being used with increasing frequency. The declining use of urography in clinical practice presents a challenge for instruction in urographic technique and interpretation. In addition, alternative modalities also have their limitations, and despite their increasing use, the ideal “global” urinary tract examination remains controversial. Nevertheless, urography may still be important in the diagnosis of some urinary tract disease processes. It is frequently performed in the evaluation of hematuria. Urography may also be performed in the pre- or posttherapeutic evaluation of stone disease that has been discovered with other imaging modalities. The urographic imaging sequence is designed to optimize depiction of specific portions of the urinary tract during maximal contrast material opacification, and a tailored urographic study may provide diagnostic detail beyond the current capabilities of other imaging modalities. However, this can be accomplished only with good technique, an understanding of the limitations of the procedure, and adherence to basic rules of interpretation. The ability to relate urographic findings of disease processes to other imaging modalities will remain an important skill until the ideal urinary tract imaging technique emerges.

Introduction

For decades, intravenous urography has been the primary imaging modality for evaluation of the urinary tract. In recent years, however, other imaging modalities including ultrasonography (US), computed tomography (CT), and magnetic resonance (MR) imaging have been used with increasing frequency to compensate for the limitations of intravenous urography in the evaluation of urinary tract disease (1). Like intravenous urography, however, these examinations have their limitations.

Abbreviation: KUB = kidney, ureter, bladder

Index terms: Genitourinary system, diseases, 80.20, 80.30, 80.81, 80.84 • Ureter, stenosis or obstruction, 82.843, 82.844 • Urography, 80.11, 80.12


1From the Department of Radiology, Wake Forest University School of Medicine, Medical Center Blvd, Winston-Salem, NC 27157-1088. Recipient of a Certificate of Merit award for an education exhibit at the 2000 RSNA scientific assembly. Received January 9, 2001; revision requested January 23 and received February 20; accepted February 28. Address correspondence to R.B.D. (e-mail: rdyer@wfubmc.edu).

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See the commentary by Hattery and King.
Large portions of the urinary tract are not visual-
ized at US; CT requires contrast material admin-
istration and excretory images (at times with a
prolonged delay), often with image reformatting
for evaluation of the urothelium; and MR imaging
may not demonstrate calcifications or show the
urothelium with sufficient resolution for evalua-
tion of subtle abnormalities. Thus, despite in-
creasing use of these alternative modalities, the
ideal “global” urinary tract examination remains
controversial (1,2). Axial imaging with contrast
material opacification of the urinary tract will
likely evolve as the most efficient imaging evalua-
tion. However, the declining use of intravenous
urography in clinical practice reduces the oppor-
tunity to learn important interpretive skills. For-
amal urography (or the urographic equivalent of
conventional radiography of the urinary tract fol-
lowing administration of contrast material for
CT) is frequently performed in the evaluation of
hematuria. Urography may also be performed in
the pre- or posttherapeutic evaluation of stone
disease that has been discovered with other mo-
dalities. In our opinion, CT with digital and re-
formatted images does not provide sufficient an-
atomical detail for evaluation of subtle uroepithelial
neoplasms or other collecting system disease (3).

In this article, we discuss and illustrate basic
urographic technique, review the rules of uro-
graphic interpretation, and discuss the impor-
tance of applying these rules to the interpretation
of findings seen at other imaging modalities.

<table>
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<th>Standard Procedure for Intravenous Urography</th>
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Figure 1. Urethral calculus in a patient with a recent history of severe right flank pain. Collimated radiograph demonstrates a calcification centered over the anatomic pelvis, behind the symphysis (arrow). This was the only calcification that was identified. CT helped confirm the presence of the urethral calculus. This case demonstrates the importance of full coverage of anatomic structures at KUB radiography.
appropriate technique (65–75 kVp, high milliamperage, short exposure time) to maximize inherent soft-tissue contrast and optimize visualization of calcium-containing lesions that are potentially of urinary tract origin (8). “Proper” KUB radiography may require additional images for evaluating portions of the urinary tract not seen on the standard 14 × 17-inch image. Imaging should encompass the area from the suprarenal region to a level below the symphysis pubis (Fig 1) (8). The patient should void immediately prior to undergoing this examination.

An assessment of the probable location of calcifications in the abdomen with respect to the urinary tract should be made prior to the injection of contrast material, which can obscure a calcification (Fig 2). Oblique conventional radiographs may be extremely helpful in ascertaining the position and nature of calcifications. This is especially important when a patient has flank pain but no obvious urinary tract calculus is seen on the KUB radiograph (the complex anatomy of the sacrum may obscure even sizable calculi) (Fig 3).

Figures 2, 3. (2) Calculus. (a) Urogram demonstrates no significant dilatation of the collecting system, with subtle changes in the opacified ureter. (b) Preliminary radiograph shows an 8-mm calculus in the ureter (arrow). This case demonstrates how a calculus can be obscured by contrast material. (3) Calculus in a patient with right flank pain. (a) Collimated preliminary radiograph of the pelvis shows no obvious stones. (b) Right posterior oblique radiograph of the pelvis shows a 6-mm ureteral calculus now projected onto the iliac bone (arrow). A urogram (not shown) helped confirm right ureteral obstruction secondary to the stone. This case shows how a calculus can be obscured by the complex sacral anatomy.
Although the evaluation of flank pain with unenhanced CT has lessened the need for this study, these techniques may be important when conventional radiography is used for follow-up.

In patients who are to undergo nephrotomography after contrast material administration, a preliminary nephrotomogram is obtained. We use the following formula to determine our preliminary tomographic level (11–13): 

\[
\frac{\text{anteroposterior abdominal diameter [cm]}}{1100}^{1/2} - 2 \text{ cm}
\]

On the basis of the appearance of the kidney on this image, adjustment of the levels to be obtained following contrast material administration can be made. Additional conventional tomograms may be obtained prior to the injection of contrast material in patients being evaluated for urinary tract stone disease. The preliminary images should always be reviewed for findings that may indicate urinary tract disease and with the intention of detecting other abdominal processes that might be mistaken for findings having a urinary tract origin (Fig 4).

A review of contrast materials and of the physiology of urinary excretion is not within the scope of this article, but excellent references are available (6,14–18). Contrast materials currently in use are excreted almost exclusively by glomerular filtration, with subsequent concentration in the postglomerular nephron and progressive opacification of the urinary tract. The urographic imaging sequence is designed to optimize depiction of

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**Figure 4.** Emphysematous pyelonephritis in a patient who was referred for urography for left flank pain. Preliminary radiograph reveals striated gas within the renal parenchyma as well as a large perirenal gas collection that extends into the retroperitoneum surrounding the adrenal gland. A finding of emphysematous pyelonephritis does not require further imaging, but urgent intervention.

**Figure 5.** Value of compression. (a) On a radiograph obtained 5 minutes after administration of low-osmolar urographic contrast material, the collecting system is bilaterally underfilled and poorly demonstrated. (b) On a radiograph obtained 5 minutes after compression was applied, distention of the collecting system is significantly improved (arrows).
specific portions of the urinary tract during maximal contrast material opacification.

In virtually all new patients, we perform nephrotomography following the bolus administration of contrast material for optimal renal parenchymal visualization. Urographic nephrograms are produced primarily by filtered contrast material within the nephron, with optimal visualization of the renal parenchyma 1–3 minutes after bolus injection (19). The tomographic levels are determined on the basis of the scout tomographic findings as described earlier. Linear tomography performed with a 20° arc allows coverage of most kidneys in three images separated by 1 or 2 cm. It is imperative that the entire renal outline be visualized for optimal mass detection. Nephrotomography is always performed after contrast material administration in patients with hematuria when a mass is a consideration, in patients who are poorly prepared, and for optimal assessment of the renal parenchyma. A standard radiograph collimated to the kidneys may be sufficient in young patients when obstruction is the specific issue, when repeat urography is performed shortly after a study that included tomography, or when the kidneys have been evaluated with other cross-sectional modalities and are without known parenchymal abnormality. If a kidney is not evident within the renal fossa at initial tomography, a KUB radiograph obtained during the nephrographic phase may demonstrate a nephrogram in an ectopic location. Masses that project from the anterior or posterior aspect of the kidney but do not produce distortion of the renal outline at linear tomography may be overlooked. In such cases, oblique radiographs or oblique nephrotomograms may be of added benefit if findings allow lateralization.

A KUB radiograph is obtained 5 minutes after the administration of contrast material to assess temporal symmetry and progress of opacification. Compression, an essential part of optimal urographic technique (especially when low-osmolar contrast material is used), is then applied unless there is a specific contraindication (20,21). We prefer using a device that can be placed around the patient rather than one that is attached to the imaging table. The ureters are compressed against the sacrum as the ureter traverses the sacral ala (Fig 5). Contraindications for the use of abdominal compression include evidence of obstruction on the 5-minute image, abdominal aortic aneurysm or some other abdominal mass, recent abdominal surgery or severe abdominal pain, suspected urinary tract trauma, and presence of urinary diversion or a renal transplant (22).

An image collimated to the kidneys for evaluation of the renal calices and collecting systems is obtained 5 minutes after the compression device is applied (23). This is especially important when low-osmolar contrast material is used because the osmotic diuresis and ultimate distention of the collecting system may not be as great as with high-osmolar materials. For optimal evaluation of the ureters and pelvocalyceal systems, oblique images or repeat tomograms (20° arc, thick sections) may be helpful (Fig 6). Compression images

Figure 6. Value of oblique imaging. (a) Ten-minute anteroposterior radiograph of the right kidney obtained with compression suggests a filling defect within the right interpolar collecting system (arrow). (b) Steep right posterior oblique radiograph demonstrates that the filling defect is caused by a posterior papillary tip (arrow).
obtained after an even greater delay can sometimes provide additional information.

Imaging during early bladder filling may be important in the assessment of patients with suspected bladder disease. With low-osmolar contrast materials, delayed bladder filling due to minimal osmotic diuresis may necessitate imaging during compression to prevent the opacity of contrast material in the bladder from becoming too great for adequate assessment.

Release of compression allows delivery of a bolus of concentrated contrast material into the ureters. We obtain a KUB radiograph immediately following compression release (15 minutes after contrast material administration) and supplement this image with fluoroscopic spot images to ensure that the entire luminal surface of the ureters has been imaged (Fig 7) (6,24,25). If fluoroscopy is not available, oblique KUB radiographs can be obtained for this purpose. In addition, it should be remembered that contrast material–opacified urine is heavier than nonopacified

Figure 7. Value of fluoroscopy. Fluoroscopic spot images demonstrate the entire luminal surface of the ureters.

Figure 8. Collapsed bladder. (a) On a radiograph obtained during bladder filling, the contrast material is smoothly defined and the bladder wall has become less evident. A normal uterine impression on the superior margin is noted. (b) Postvoid radiograph shows a normal collapsed bladder with mucosal ridges less than 3 mm in width.
urine. Gravity maneuvers such as imaging with the patient in the prone or dependent oblique position often assist with visualization of unopacified portions of the ureters, especially in cases of obstruction (26). In such cases, delayed images should be obtained until opacification to the level of obstruction is identified or until it is determined that renal excretion is insufficient for adequate opacification.

If the bladder is sufficiently distended and opacified, it may be adequately evaluated on previously obtained images. If, however, there is specific concern for bladder disease, delayed images may be obtained to improve bladder distention, and oblique, prone, or postvoid images may be obtained to evaluate filling defects (Fig 8) (27).

Urographic Interpretation
The renal parenchyma is optimally assessed during the nephrographic phase of urography. The entire renal contour should be assessed, and nephrotomography almost always affords better visualization than standard imaging. The renal contour should be smooth, and the inability to visualize a given portion of the contour requires explanation. There should be temporal symmetry of the nephrographic development (5). Nephrographic evolution requires adequate renal blood flow, normal parenchymal excretory function without obstruction, and normal venous outflow (Figs 9, 10) (5,19). The size of the kidneys should

Figures 9, 10. Abnormal nephrographic evolution. (9a) Final image of a tomographic sequence demonstrates symmetric nephrograms and pyelograms. Renal size is normal. (9b) On a 10-minute image, no pyelogram is evident. The nephrograms are persistent, and the kidneys are smaller. With this imaging sequence alteration, the patient should be evaluated immediately for the development of hypotension related to the procedure or as a reaction to contrast material administration. (10a) One-minute image shows slight asymmetry of the nephrographic opacity, with less opacity in the right kidney than in the left. (10b) Image obtained at 80 minutes shows a persistent, very dense right nephrogram, a typical finding in acute high-grade obstruction. A 2-mm stone was discovered at the right ureterovesical junction.
be assessed on every urogram, and this is best performed during the nephrographic phase. There is inherent magnification in conventional radiography compared with other imaging modalities. The normal kidney may range from 9 to 13 cm in cephalocaudal length, with the left kidney inherently larger than the right by 0.5 cm and the kidneys slightly larger in men than in women (7,28–30). Several methods of assessing renal size have been reported, but approximate symmetry should be anticipated. Significant discrepancies (right kidney ≥ 1.5 cm larger than the left kidney, left kidney ≥ 2 cm larger than the right kidney) require explanation (Figs 11, 12).

Contour abnormalities can be associated with a change in parenchymal thickness, which should always be interpreted with regard to the appear-

**Figure 11.** Right renal artery stenosis. (a) Fourth nephrotomogram from a “minute sequence” urogram (performed in the past for evaluation of renovascular hypertension) shows a small right kidney with decreased nephrographic density and temporal asymmetry of filling of the right collecting system compared with the left. (b) Fifteen-minute urographic image helps confirm the asymmetric renal size. Note the hyperconcentration of contrast material in the right collecting system compared with the left.

**Figure 12.** Enlarged kidneys in a young patient with early, asymmetric findings of autosomal dominant polycystic kidney disease. Nephrotomogram shows enlarged kidneys, the left more so than the right. Note the multiple parenchymal defects (“Swiss cheese” nephrogram).
ance of the underlying renal collecting system. It is often helpful to draw the “interpapillary line” to aid in the evaluation of parenchymal thickness. Parenchymal thickness averages 3–3.5 cm in the polar regions and 2–2.5 cm in the interpolar regions. Indentations or increased parenchymal thickness may be a reflection of congenital anatomic variation. These anomalies tend to occur in predictable locations. A decrease in parenchymal thickness with an underlying abnormal caliceal configuration may reflect postinflammatory or stone-related scarring, whereas parenchymal loss that occurs between the calices without underlying caliceal distortion may be secondary to renal infarction. Increased parenchymal thickness associated with underlying caliceal distortion is more typical of masses. Absence of nephrographic enhancement within the lesion suggests a simple cyst. A build-up of parenchyma at the margins of a lesion (parenchymal “beaking”), once considered a sign of a simple cyst, reflects only the slow growth of the lesion within the parenchyma and can be seen.

Figures 13–15. (13) Normal interpapillary line. Drawing illustrates how the renal outline should be closely paralleled by a line connecting the papillary tips (dotted line). Deviations from this pattern require explanation. (14) Normal indentation. Nephrotomogram shows an indentation at the junction of the middle and lower aspects of the kidney (sulcus interpartialis inferior) (arrow). A similar indentation may occur at the junction of the upper and middle portions of the kidney (sulcus interpartialis superior). Indentations in the renal contour frequently reflect persistent fetal renal anatomy. (15) Normal “increased” parenchymal thickness. Nephrotomogram shows prominent cortical tissue (arrowheads), a finding that can also reflect normal fetal renal anatomy. Typical areas of prominence include the hilar lips, cortical columns (usually seen at the junction of the upper and middle thirds of the kidney), and other “humps” that should be reflected in the interpapillary line.

Figure 16. Reflux nephropathy. Nephrotomogram demonstrates marked polar parenchymal loss associated with underlying caliceal “clubbing,” findings that are typical in reflux injury.
with both benign and malignant renal masses (Fig 19). Masses may also produce a “double contour” at tomography, an often overlooked finding (Fig 20). Urographic detection of masses requires further cross-sectional imaging for confirmation of the benign or malignant nature of the process. US is preferred when urographic findings suggest a cyst, whereas CT is recommended when the findings suggest a solid lesion.

The position of the kidney should also be assessed at nephrotomography. A portion of each upper renal pole usually extends above the 12th rib, with the right kidney normally slightly lower than the left due to the position of the liver. The vertical axis of the kidney should parallel the upper one-third of the psoas muscle. Alterations in axis and position may occur as a response to abdominal or retroperitoneal masses, alterations in visceral size, or congenital renal anomalies related to position or fusion (Fig 21).

On the 5-minute image, the nephrogram should be receding as the collecting system becomes opacified. On the 10-minute image, the pyelogram is the dominant urographic element. Alterations in this temporal sequence require ex-
Visualization of the collecting system and renal pelvis can be augmented with the use of abdominal compression, the Trendelenburg position, and other gravity maneuvers such as placing the patient with the side of interest in the ipsilateral posterior oblique position. The appearance of the calices and renal pelvis should be examined closely because intravenous urography is the most accurate imaging modality for visualizing the urothelium-lined surfaces and evaluating potential abnormalities (transitional cell carcinoma, mucosal striations, pyelitis cystica).

Compound papillae are likely to occur in the polar regions, whereas simple papillae with the classic chalice appearance of the calix and acutely angulated fornical margins are usually seen in the interpolar region. Early and mild obstruction is indicated by subtle rounding of the fornical margins (Fig 22), with increasingly more severe and prolonged obstruction evidenced by progressive loss of the papillary impression and eventual clubbing of calices. The recognition of contrast material within the papillae may reflect a continuum from papillary blush through benign tubular ectasia to medullary sponge kidney (Figs 23–25) (5,7,19). Larger parenchymal collections of contrast material may reflect an inflammatory...
Figures 24, 25. (24) Tubular ectasia in a patient with microscopic hematuria. Image of the left kidney obtained with compression shows resolvable linear striations in virtually all papillae. A retrograde pyelogram obtained later (not shown) showed no filling of the tubules, implying an intact antireflux mechanism. It is anticipated that other pathologic causes of papillary excavation would be identified at the time of retrograde pyelography. (25) Medullary sponge kidney. Urographic image shows resolvable collections of contrast material in the papillary tips. Stones that were evident within the papillae at preliminary radiography appeared to “enlarge” as the cavities filled with contrast material during urography (“growing calculus sign”), a finding that is indicative of medullary sponge kidney.

Figures 26, 27. (26) Papillary necrosis due to sickle cell anemia. Pyelographic-phase urographic image demonstrates a long extension of contrast material from the fornices into the renal substance in the upper (black arrow) and lower (white arrow) poles. (27) Papillary necrosis caused by analgesic abuse. Pyelographic image shows central cavities within multiple papillae (arrows). (Figs 26 and 27 reprinted, with permission, from reference 33.)
process such as tuberculosis, changes of papillary necrosis (Figs 26, 27), or neoplastic excavation related to transitional cell carcinoma. Contrast material–filled outpouchings from the collecting system may represent abortive calices or collecting system diverticula (Fig 28) (35). Because a diverticulum must fill via its communication with the collecting system, opacification is often delayed. Filling defects within the calices or collecting system are also an important finding (Figs 29, 30). Aberrant papillae may produce disconcerting

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**Figure 28.** Caliceal diverticulum. (a) Preliminary image demonstrates clustered calcifications in the upper pole of the right kidney. (b) Urographic pyelogram shows slowed temporal filling of a large cavity in communication with, but peripheral to, the uppermost calix, a finding that is consistent with a caliceal diverticulum.

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**Figures 29, 30.** (29) Oncocalix (tumor-filled calix) secondary to transitional cell carcinoma. Pyelographic image shows irregular filling in the calical structures of the upper pole of the left kidney (arrow). (30) Transitional cell carcinoma in a patient with gross hematuria. Urographic image of the collecting system demonstrates a large papillary filling defect (arrow) with irregularity of the contrast material in the renal pelvis and proximal ureteral lumen. This proved to be a transitional cell carcinoma.
findings and can be confused with other causes of radiolucent filling defects within the collecting system or renal pelvis, the most important of which is transitional cell carcinoma (Fig 31) (5). Parenchymal or renal sinus structures and pathologic processes may be reflected in impressions on the collecting system elements (Fig 32).

In addition to aiding in the evaluation of parenchymal thickness, the interpapillary line is important in ensuring the presence of calices subtending all portions of the renal parenchyma. Lack of filling of a portion of the collecting system (“phantom calix”) can be produced by benign or malignant processes (Fig 33). Although there is a tendency toward side-to-side symmetry in the number of calices (usually 7–14 calices), this is not always the case. This assessment is also helpful in determining the presence of a caliceal complement appropriate to the size of the kidney. The axis of the kidney should be reflected in the axis of the collecting system (Fig 34). There should be temporal symmetry in opacification and qualitatively equivalent contrast material opacity in the two collecting systems.

At the release of compression, the bolus of contrast material–laden urine entering the ureters provides optimal visualization throughout their length (25). Segmental nonvisualization of the ureter due to peristalsis can be overcome with compression release, and the entire ureter, filled from the ureteropelvic junction to the ureterovesical junction, may be identified on one or two images. Persistence of a standing column of contrast material on several images may indicate obstruction (Fig 35) or ureteral ileus (nonobstructive

**Figure 32.** Renal sinus cysts. (a) Longitudinal US image of the left kidney suggests hydronephrosis. Similar findings were seen in the right kidney. (b) Nephrotomogram obtained with compression shows narrowing and displacement of opacified collecting system elements and the renal pelvis bilaterally without hydronephrosis. This incongruity between US and urographic findings is typical of renal sinus cysts.

**Figure 31.** Aberrant papilla in a patient with a history of transitional cell carcinoma. Tomography performed with compression for collecting system distention showed a filling defect in the middle infundibulum, suggesting an aberrant papilla. Oblique image helps confirm this urographic finding. Note the rim of contrast material at the margin of the somewhat angular defect (arrow). The benign nature of this finding was confirmed with nephroscopy.
**Figure 33.** Tuberculosis. (a) Nephrotomogram shows decreased nephrographic opacity and nonfilling of the collecting system elements (phantom calices) in the lower pole of the left kidney. (b) Left retrograde pyelogram shows marked irregularity of the calices and infundibula in the left lower pole. Note the “moth-eaten” appearance of the calices. Urine samples obtained during this procedure were positive for urinary tract tuberculosis. Similar findings may be seen with an infiltrative process such as transitional cell carcinoma.

**Figure 34.** Renal cell carcinoma. Pyelographic image shows the axis of the lower pole of the right kidney parallel to the margin of the psoas muscle and reversal of the normal axis of the collecting system. This finding indicates a mass in the upper pole of the right kidney. Note also the marked caliceal distortion, which is further proof that a mass (in this case, renal cell carcinoma) is present.

**Figure 35.** Collecting system dilatation. Fifteen-minute urographic image demonstrates a standing column of contrast material from the ureteropelvic junction to the ureterovesical junction on the right, a finding that is associated with mild collecting system dilatation. A stone is impacted at the ureterovesical junction. Note also the edema in the right side of the interureteric ridge (arrow), which is normally less than 3 mm in thickness.
dilatation related to inflammation). This finding should be interpreted in the context of other urographic findings. The ureter usually begins as a smooth extension from the renal pelvis lateral to the lateral margin of the psoas muscle. At about the L3 level, the ureter passes ventral to the muscle, crossing from lateral to medial (36). In its upper retroperitoneal course, the ureter passes along the outer half of the transverse processes of the upper lumbar vertebra. It crosses anterior to the iliac vasculature at a slightly higher position on the right than on the left. At the point of vascular crossover, there is often minimal medial deviation of the ureter. Once within the anatomic pelvis, the ureter typically parallels the inner margin of the iliac bone until it enters the bladder at the ureterovesical junction. Medial deviation of the ureter should be considered when the ureter overlies the ipsilateral lumbar pedicle (25,36,37). There is greater specificity if the ureter is seen medial to the pedicle. Separation of the ureters by less than 5 cm is also used as a criterion for medial deviation. As a general guideline, lateral deviation should be considered when the ureter lies more than 1 cm beyond the tip of the transverse process, but comparison with the position of the contralateral ureter should always be made (Fig 36). Any abrupt change in ureteral course requires explanation (Fig 37). Some ureteral devia-
tions are characteristic (Fig 38) (25,31,36), whereas others, although they produce striking urographic images, represent normal variations (Fig 39). Because the ureter is highly mobile, determining the significance of ureteral deviation seen at urography often requires cross-sectional imaging.

An absolute ureteral diameter exceeding 8 mm is considered by some authors to represent a criterion for dilatation (25). In general, asymmetry of ureteral caliber is a more significant finding. Early in its course, high-grade ureteral obstruction may be associated with only minimal ureteral dilatation. More chronic forms of obstruction and other chronic ureteral conditions are typically associated with greater degrees of ureteral dilatation.

Figures 38, 39. (38) Circumcaval ureter. Urographic image shows the proximal right ureter with a “reversed J” appearance, a finding that is characteristic of circumcaval ureter. Associated moderate hydronephrosis is also seen in this case. (39) Psoas muscle hypertrophy. Urographic image shows the distal ureters centrally located and straightened bilaterally. Note the enlargement of the psoas muscles. There is also a slight alteration of the right renal axis and abrupt transition of the left midureter over the belly of the psoas muscle. These findings are typical of the ureteral position in patients with psoas muscle hypertrophy.
Nonobstructive dilatation may occur as a result of high urine flow (fluid diuresis, diabetes insipidus), reflux, or inflammatory processes.

Familiarity with the normal appearance of peristalsis, areas of anatomic narrowing including the ureteropelvic junction and ureterovesical junction, and the iliac vascular transition is critical for accurate diagnosis of ureteral disease.

Impressions by gonadal veins may become quite prominent in females. Other causes of ureteral narrowing are generally categorized as either intrinsic or extrinsic to the ureteral wall (Figs 40, 41).

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Figure 40. Ureteral obstruction secondary to orthotopic ureterocele. Urographic image demonstrates the typical “cobra head” configuration of an orthotopic ureterocele in the bladder (arrow). Occasionally, such a ureterocele can be associated with obstructive changes—in this case, marked ureteral dilatation, columnization, and associated fullness of the collecting system.

Figure 41. Primary megaureter. Late urographic image demonstrates tapered narrowing of the left ureter at the ureterovesical junction (arrow) associated with dilatation of the distal third of the ureter, with minimal upper urinary tract obstructive changes. These findings are typical of primary megaureter, but other causes of obstruction should be excluded with cystoscopy.

Figure 42. Extrinsic vascular narrowing in a patient who had recently given birth. Urographic image shows prominent indentations (ureteral “notching”) medially and laterally along the upper third of the left ureter (arrows). In this case, the finding was believed to be secondary to a prominent gonadal vein.
Ureteral filling defects may be single or multiple and can usually be attributed to luminal, mural, or extrinsic causes (Fig 44). Care should be taken to visualize the entire luminal surface of the ureter, especially in patients with hematuria (Fig 45).

By 15–30 minutes after the injection of contrast material, the bladder is often sufficiently filled, and the 15-minute KUB radiograph may be adequate for evaluation. If distention is incomplete, delayed images of the bladder may be necessary. As the bladder becomes progressively distended, the intraluminal contrast material should be spheric and smoothly marginated and the wall...
progressively less evident (Figs 46, 47). The position of the bladder within the anatomic pelvis should be assessed. Because the bladder is tethered only at the lower aspect of the anatomic pelvis, its position and appearance can be significantly distorted by masses and other pathologic processes (Figs 48–50). Bladder wall thickening and irregularity of the luminal contrast material associated with a bladder base defect is typical of changes of bladder outlet obstruction from prostatic disease (Figs 51, 52) (38). Contour abnormalities from cellule or diverticulum formation may also be seen. Although it is understood that imaging of the contrast material–filled bladder is significantly less sensitive than cystoscopy in the evaluation of bladder neoplasms, examination for filling defects should always be performed (Fig 53). Early filling images followed by a postvoid

**Figure 46.** Hemorrhagic cystitis. Bladder image shows contrast material with a lobulated and irregular contour within the lumen of the bladder. The thickness of the bladder wall can be appreciated (arrows).

**Figure 47.** Multiple bladder diverticula in a patient with a neurogenic bladder. Bladder image shows numerous bladder diverticula associated with wall thickening and irregularity of the intraluminal contrast material. The catheter tip (arrow) creates a defect in the contrast material.

**Figure 48.** Ovarian cyst in a patient with right lower quadrant pain who had previously undergone hysterectomy. Oblique bladder image shows a persistent, smoothly marginated impression on the right posterolateral aspect of the bladder (arrowheads). This finding proved to be associated with a hemorrhagic right ovarian cyst.
Figures 49, 50. (49) Pelvic lipomatosis. Urographic image shows medial deviation of the ureters and distortion of the bladder associated with increased lucency within the anatomic pelvis. These findings indicate pelvic lipomatosis. (50) Hematoma in a patient with pelvic trauma. Urographic image shows a pear-shaped bladder elevated out of the pelvis and elongated superiorly due to pelvic hematoma. Note the large filling defect within the bladder due to blood clot.

Figure 51. Prostate enlargement. Bladder image demonstrates a bladder base defect (arrow) associated with bladder wall thickening and cellule formation. Cellules represent early herniation of mucosa (usually as wide as they are tall) through bladder trabecula in response to bladder outlet obstruction. These findings are typical of changes seen with outlet obstruction from prostate enlargement.

Figure 52. Vaginal mass. Bladder image shows a bladder base defect (arrowheads) similar to that seen in males with prostatic disease (“female prostate” defect). In this case, the defect was associated with an anterior vaginal wall mass. Note the prominent uterine impression on the superior aspect of the bladder.
examination may constitute the most sensitive imaging sequence for the evaluation of filling defects (Fig 54) (27). Oblique images may also be useful in ensuring that filling defects are not related to enteric gas, which may project over the bladder on images obtained only in the anteroposterior projection. The postvoid image may also be helpful in evaluating patients with upper urinary tract dilatation. Persistence of the dilatation on the postvoid image suggests fixed obstruction, whereas decompression of the upper urinary tracts usually indicates physiologic distention. The postvoid image is most helpful in assessing residual volume when it is obtained immediately after voiding and demonstrates complete emptying of the bladder.

**Conclusions**

A tailored urographic study allowing optimal visualization of sequentially opacified portions of the urinary tract may provide diagnostic detail in certain portions of the urinary system beyond the current capabilities of other imaging modalities. This can be accomplished only with good technique, an understanding of the limitations of the procedure, and adherence to basic rules of interpretation. The ability to correlate urographic findings with those from other imaging modalities will remain an important skill until an ideal “global” urinary tract imaging technique emerges.
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References


This article meets the criteria for 1.0 credit hour in category 1 of the AMA Physician’s Recognition Award. To obtain credit, see accompanying test at http://www.rsna.org/education/rg_cme.html.