

IMAGING IN URINARY TRACT OBSTRUCTION

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ABSTRACT

There are a wide variety of imaging studies available for evaluation of a potentially obstructed patient. Selection of a specific test over another depends on the acuity of obstruction and the patient's age and renal function. Consideration must also be made for cost of the test, reliability and feasibility of long term follow up by repeated exams. In the non-acute setting where urinary tract obstruction is suspected either on the basis of a rising serum creatinine, history, or prior urinary tract abnormalities, an ultrasound may be used as the initial screening procedure. If ultrasound fails to show any evidence of significant hydronephrosis or hydroureter it is concluded that this patient does not have significant obstruction. Generally, no further studies relative to detecting urinary tract obstruction are performed.

If ultrasound demonstrates the presence of hydronephrosis or hydroureter further studies to determine the point and cause of obstruction are performed, unless the ultrasound examination has clearly demonstrated this, as in the case of an obstructing ureteral stone. In adults, an intravenous pyelography (IVP) is often performed to delineate the point and hopefully cause of an obstruction. If there is good renal function, the IVP will generally be successful in answering these questions. There is not always one "best" way to utilize the multiple studies available and it is often the results of a specific study that will determine if a further study is necessary and which modality to use.

The approach to the patient with acute renal colic has changed over the past few years. Up until recently, these patients were evaluated with either ultrasound or an IVP as the initial study. This is no longer the case as we now use non-contrast spiral computed tomography (CT) as the screening examination for flank pain and suspected ureteral stone. This is faster, more accurate and provides information regarding non-urologic causes of pain.

In children, the approach is somewhat different. Ultrasound is used as the primary screening tool for suspected obstruction. If hydronephrosis is demonstrated, a functional study such as a Lasix renogram is generally performed to evaluate the function of the two kidneys and the severity of the suspected obstruction. Further study would then depend on clinical consideration such as any need for surgical intervention.

Key words: urinary tract; obstruction; imaging; kidney; ureter; calculi
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IMAGING IN OBSTRUCTION

There are numerous studies available to the urologist in the diagnosis and management of obstruction. These include radiographic studies, such as the plain film (kidney, ureter and bladder – KUB), intravenous pyelography (IVP) and retrograde urography, ultrasound, computed tomography (CT),

Lasix renogram, magnetic resonance (MR) urogram and the Whitaker test. Selection of a specific test over another depends on the acuity of obstruction and the patient's age and renal function. Pregnant patients and those with contrast allergy require special provisions. Consideration must also be made for cost of the test, reliability and feasibility of long term follow up by repeated exams. We will explore each imaging

modality listed and then discuss our approach to the patient with suspected obstruction.

PLAIN FILM

Simple radiographic studies such as the KUB have a role, although limited, in the evaluation of obstruction. A single view plain film may be sufficient to diagnose the presence of a ureteral stone. It is low cost with low radiation exposure and may be done rapidly within the urology clinic. The plain film is limited by its low sensitivity for detection of opaque as well as non-opaque stones. Recent studies have shown a sensitivity of about 50% for stone visualization with the abdominal film. Occasionally a suspected ureteral calcification seen on plain film turns out to be a vascular phlebolith when more specific studies are performed (1).

The plain film also provides an easy way to follow the progression of an obstructing stone, even if the diagnosis of stone disease has been made with another imaging modality such as CT scan. Significantly, more stones can be seen on an abdominal film in retrospect following CT (2). Stones larger than 5 mm and with CT attenuation above 300H will likely be detected on abdominal radiography (3).

INTRAVENOUS PYELOGRAPHY

Intravenous pyelography (IVP) plays an important role in the diagnosis of obstruction. It is the classic test which can assess anatomy and to some ex-

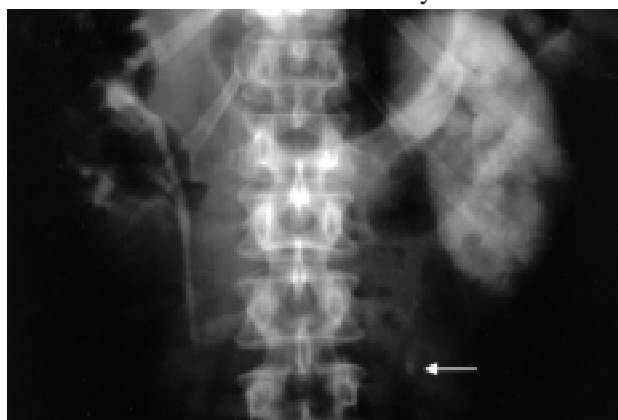


Figure 1 - IVP shows a delayed nephrogram and pyelogram on the left caused by a stone in the mid ureter (arrow).



Figure 2 - IVP shows a delayed nephrogram with extravasation of contrast (long arrow) and a stone with proximal edema blocking the mid ureter (arrow).

tent the function of the kidney. Acute obstruction is identified by the presence of a delayed and often increased nephrogram (Figure-1). Hydronephrosis or hydroureter helps to confirm the diagnosis of obstruction, but are not always visible (1). The level and cause of the obstruction may be determined with the visualization of filling defects or stones (Figure-2) in the renal pelvis or ureter, changes in renal contour and course of the ureters. In addition, bladder pathology may be revealed on IVP, such as filling defects, diverticula and a significant post void residual. Obstructions, which are not obvious initially, may, at times, be revealed after the administration of Lasix during the IVP. This technique is generally reserved for suspected intermittent ureteropelvic junction (UPJ) obstruction.

The IVP requires intravenous contrast and therefore should not be performed in a patient with decreased renal function. We accept creatinine values of 1.5 or lower for patients undergoing IVP in our department. Nephrotoxicity of iodinated contrast is most likely in patients with chronic renal insufficiency especially if diabetes is also present. Patients with contrast allergy need to be premedicated prior to an IVP and should have non-ionic contrast media. The need for the IVP must be balanced against potential risks. It may be wiser to perform alternate studies in certain situations, such as a noncontrast CT scan, ultrasound or magnetic resonance imaging (MRI). The

availability of multiple other modalities not requiring contrast has reduced dependence on the IVP. IVP may be time intensive, requiring delayed films in patients with high-grade obstruction and may not always have sufficient opacification to define the anatomy and point of obstruction. In addition, completion of an IVP requires a significant amount of radiation exposure and may not be ideal for young children or pregnant women (1).

RETROGRADE UROGRAPHY

Retrograde urography, although largely replaced by other imaging studies, can still be useful to delineate the precise location and severity of an obstruction when other studies fail to define the exact point or cause of obstruction. In addition, this study can usually be performed with greater safety in patients who are not candidates for an IVP due to an allergy to contrast media or renal insufficiency. This is not a first line study for patients with obstruction due to the necessity of anesthesia, either general or epidural blockade. However, we often perform retrogrades in the operating room just prior to pyeloplasty or ureteral stent placement to exactly delineate the point of obstruction and to rule out the presence of a second obstruction.

ULTRASOUND

Ultrasound is used extensively to detect hydronephrosis, the primary finding with an obstructed system. It is inexpensive, noninvasive and portable.

Ultrasound is an ideal first line technique to evaluate patients for renal obstruction. It is highly sensitive in detecting dilated systems (Figure-3) and the absence of hydronephrosis is generally a reliable sign that obstruction is not present. An exception is very early obstruction, such as might occur with an acute obstructing stone. Resistive index has been advocated to detect these cases of early obstruction (4) and is occasionally used in our clinic but has not proven to be reliable (Figure-4) (5,6).

Because not all dilated systems represent functional obstruction, ultrasound is therefore not specific. The imaging findings must be correlated with the clinical

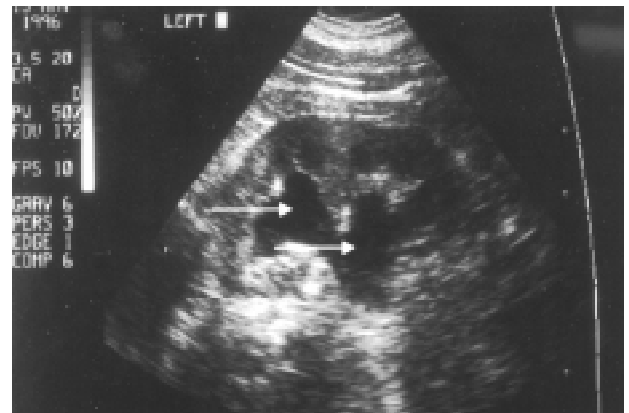


Figure 3 - Renal ultrasound reveals dilation of the renal pelvis and calyces (arrows).

picture. Hydronephrosis not due to obstruction can result from prior obstruction, reflux, enlarged extra renal pelvis, bladder over distension or a distensible collecting system in a well hydrated individual. Renal sinus cysts may be mistaken for a dilated renal pelvis on ultrasound, and a skilled ultrasonographer is needed to make this differentiation.

Ultrasound is very accurate in the identification of renal stones that may or may not be visible on plain radiograph, due to either stone composition or size. However, detection of ureteral stones by ultrasound is much more difficult. These stones often go undetected by ultrasound unless they are near the ureteral tunnel (Figure-5). The technical difficulties in detecting stones, operator dependence and relatively low sensitivity for ureteral stone detection with ul-

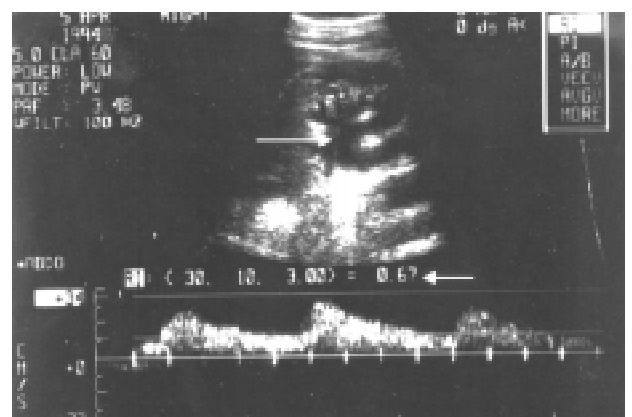


Figure 4 - Doppler ultrasound shows a normal resistive index of 0.67 (arrow) in the face of obstruction and hydronephrosis (long arrow), demonstrating the unreliable nature of the resistive index for diagnosis of obstruction.



Figure 5 - Bladder ultrasound shows a dilated ureteral tunnel (thick arrow) with a stone (arrow) and shadowing distal to the stone (long arrow).

trasound have led to widespread shift to non-contrast spiral CT to evaluate renal colic and suspected acutely obstructing stones.

Prenatal ultrasound is performed routinely and may pick up evidence of hydronephrosis in the developing fetus. In patients diagnosed with prenatal hydronephrosis, ultrasound should be repeated within several weeks of birth to evaluate for persistent hydronephrosis (7).

Because ultrasound is readily available within our clinic, we use it to monitor patients with known obstruction. A caveat to heavy reliance on ul-

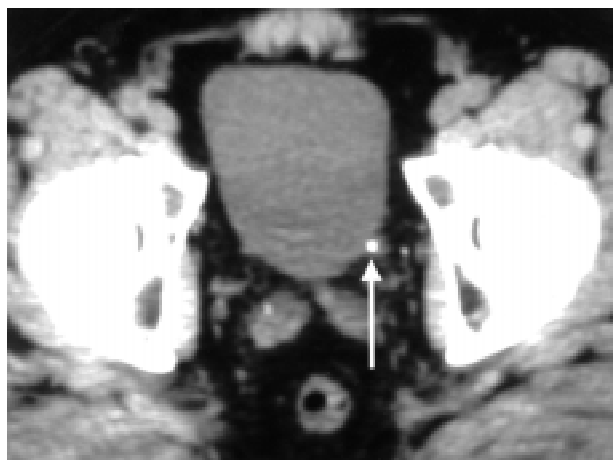


Figure 6 - Non-contrast helical CT scan reveals a stone (arrow) in the distal left ureter, just proximal to the ureteral tunnel.

trasound is that ultrasound is extremely operator-dependent. It is ideally performed by personnel experienced in uro-ultrasonography.

The ultrasonographer may also use color Doppler to evaluate the presence of ureteral jets. The periodic “jet” of urine effluxing from the ureteral orifice effectively rules out complete obstruction of the renal system (1,8).

COMPUTED TOMOGRAPHY

Computed Tomography (CT) scans can be performed with or without intravenous contrast. Spi-

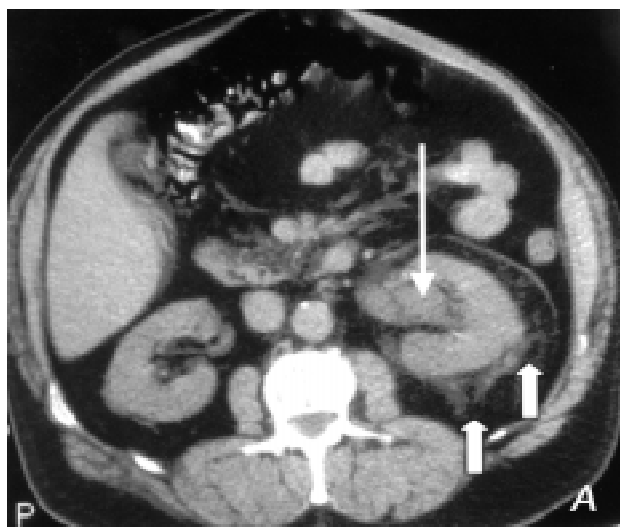


Figure 7 - A)- Non-contrast helical CT scan reveals hydronephrosis (long arrow) and perinephric stranding (thick arrows) caused by B)- A moderate sized stone (long arrow) in the distal ureter.

ral CT scans use 5 mm slices from the level of the kidneys down to the bladder specifically to look for stone disease. It has been shown that the “stone-protocol” CT scan is more effective in precisely identifying ureteral stones than the long time gold standard, the IVP (9,10). CT is ideally suited to detecting obstructing stones and is very effective in distinguishing the stone from other causes of obstruction such as clot or tumor (1). Spiral CT scans may pick up stones that cannot be seen on plain film (KUB) due to stone composition, size or artifacts such as bowel gas. It is also useful to differentiate between calcifications within the vascular system versus the urinary system.

CT diagnosis of a ureteral stone relies on both primary and secondary findings. The primary finding is unequivocal demonstration of a stone within the ureter (Figure-6). Secondary findings, which include hydronephrosis, hydroureter or stranding of the peri-

nephric fat, have a high positive and negative predictive value for the presence or absence of a ureteral stone (Figure-7) (1,11). Perinephric edema has been showed to be predictive of the degree of obstruction (12). However, it should be noted that non-contrasted CT scans could miss other causes of flank pain and hematuria, such as a solid renal mass. It has been suggested that patients with the diagnosis of a suspected ureteral stone that is not seen on CT be followed by a contrasted CT to rule out other diagnoses (13). Potential causes of extrinsic obstruction such as malignancy or aneurysm may also be identified on CT scan (1), (Figure-8). During a dynamic enhanced CT scan, a sign of obstruction is a delay in the nephrogram with persistence of corticomedullary differentiation as compared to the opposite kidney (Figure-8). Although CT picks up most stones, including those that are classically opaque on plain film, it may miss obstruction caused by non-



Figure 8 - A)- Retrograde urogram showing a ureteral stricture (black arrow) and proximal hydroureter; **B)-** Enhanced CT scan shows delayed corticomedullary separation (white arrows) and hydronephrosis (star) on the left; **C)-** A nodal mass (long arrow) surrounds the ureter at the level of the stricture.

opaque indinavir crystals. In patients with HIV on the protease inhibitor, indinavir, presenting with acute flank pain, the absence of a stone on helical CT should be followed with a contrasted CT scan (14).

We occasionally use contrasted CT scans following a spiral (non-contrasted) scan to help define the course of a ureter if we are unsure if a calcification resides within a ureter or a vessel. Contrasted CT scans will further assess function of a renal unit and more accurately detail the degree of hydronephrosis.

LASIX RENOGRAM

The Lasix renogram is very useful in the diagnosis and follow up of children with UPJ obstruction.

It is crucial in the identification of an obstructed hydronephrotic kidney versus a non-obstructed hydronephrotic kidney. Previously, it was assumed that any dilatation of an upper urinary system equaled obstruction. We now know that a hydronephrotic kidney may simply represent a dysmorphic or atonic collecting system, which has no functional significance and will not cause renal damage over time. Therefore, all children with suspected UPJ obstruction at our institution undergo diuretic renal scan to determine the functional significance of hydronephrosis. A radionuclide is administered and then the scintillation camera obtains individual counts from each kidney, which are then expressed as a percent of the total. We use ^{99m}Tc -MAG3, which collects

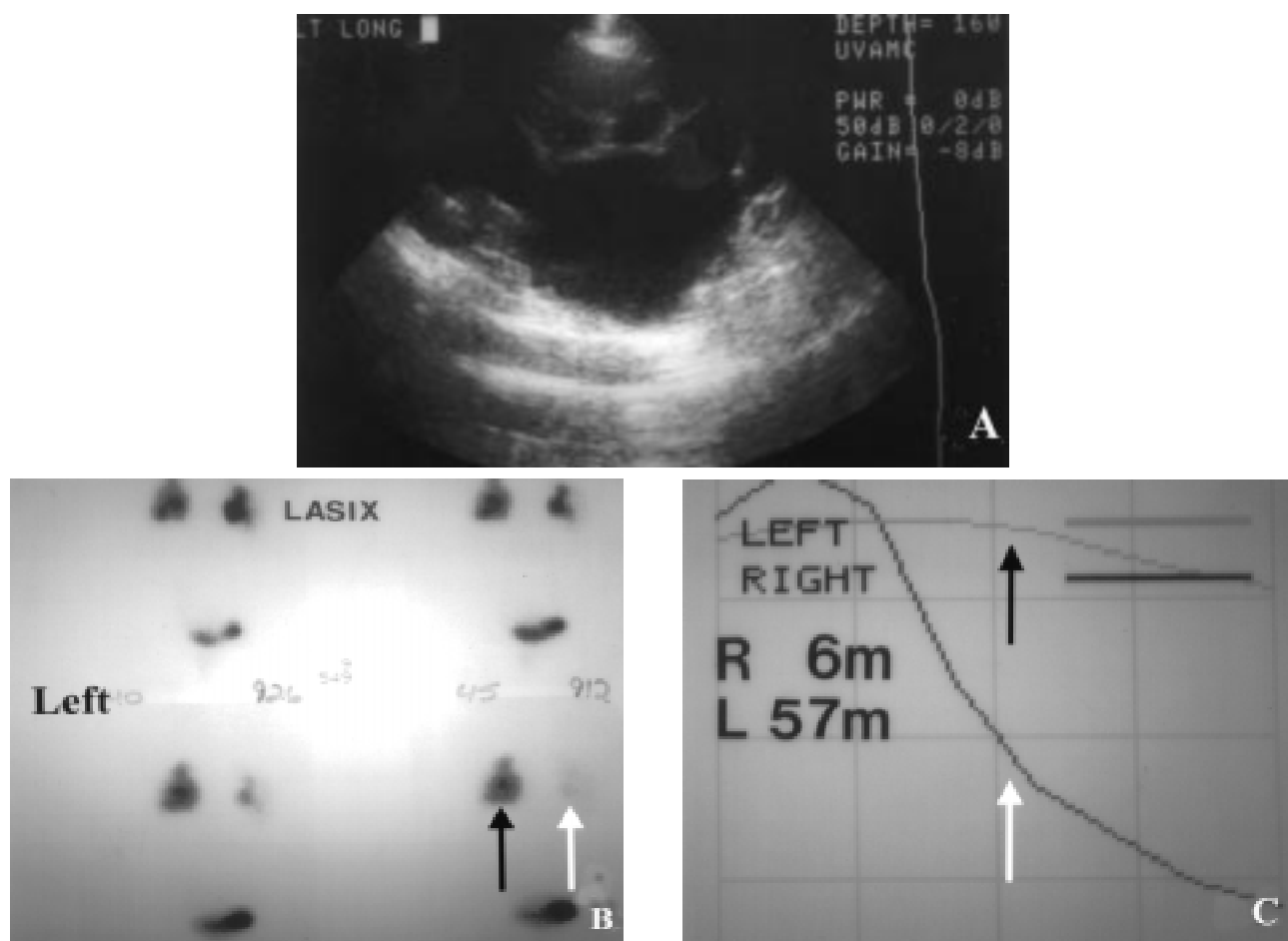


Figure 9 - A)- Renal ultrasound shows dilated pelvis and calyces in a patient with congenital left UPJ obstruction; **B)-** Lasix renal scan shows delayed washout of left kidney (black arrow) compared to the normal right kidney (white arrow); **C)-** Washout curves confirm delayed emptying of the left system (black arrow) with an elevated $T_{1/2}$ of 57 minutes compared to the normal right system (white arrow) with a normal $T_{1/2}$ of 6 minutes.

in the collecting system due to tubular secretion and has good uptake in patients with renal insufficiency (1). Diuretics are used as a part of the renogram in order to separate non-obstructive hydronephrosis from obstructive hydronephrosis. A diuretic is given after the radionuclide has accumulated in the collecting system. Then the “washout time” of the radionuclide is determined. In the absence of obstruction, the diuretic will fill the collecting system with urine not containing the radionuclide and the urine that contains radionuclide will be washed out of the system. However, in the presence of obstruction, the radionuclide is not washed out as quickly. The $T_{1/2}$ is a value measured as the time it takes for 50% of the tracer to leave the collecting system. This clearance half-time is based on the slope of the washout curve. A $T_{1/2}$ of less than 15 minutes is normal. In general, a $T_{1/2}$ of greater than 20 minutes represents obstruction. (Figure-9) (15). In addition to the $T_{1/2}$, the Lasix renal scan will also allow estimation of the split renal function. Split function allows the clinician to closely monitor renal function in patients managed conservatively and in postoperative studies (15).

Although the Lasix renogram can supply very useful information, urologists should keep in mind that there are several factors which can make the results unreliable. First of all, poor renal function may cause an inability to respond to the diuretic, resulting in a false delay in washout time. Poor hydration may also limit the response to diuretic (15). Secondly, there is no standard protocol for the administration or the interpretation of the Lasix renogram. Care should be taken when comparing studies performed in two different institutions (16). It is crucial that a standard protocol be developed and maintained at all times within a single center to facilitate comparison of scans over time. At the University of Virginia, we follow the protocol outlined by Conway (17) in an effort to standardize the protocol of performing a Lasix renogram. His guidelines include:

- a)- Oral hydration;
- b)- Bladder catheterization in any patient who cannot void on request;
- c)- Patient at least 1 month old;
- d)- Use of a standard radionuclide- $^{99m}\text{Tc-MAG3}$;

e)- Diuretic given at 1mg/kg when the abnormal collecting system is full.

Finally, the diuretic renogram identifies the presence of obstruction but not the cause of obstruction. There is very little anatomic detail provided with the Lasix renogram (1,18).

MAGNETIC RESONANCE UROGRAM

Magnetic resonance imaging provides more detailed anatomy than nuclear renograms without the radiation exposure or the use of potentially nephrotoxic contrast media, which is necessary for IVP. We occasionally employ the MR urogram (MRU) with gadolinium to replace the IVP in a patient with renal insufficiency or contrast allergy or in a patient population that requires reduced radiation exposure (i.e., pregnant women). The MR urogram delineates the presence and degree of hydronephrosis and may pick up filling defects within the collecting system (Figure-10). In a patient with poor renal function, MRU may provide more detailed anatomy than IVP. MR urography has not become popular at most institutions due to several shortcomings. Although there is good resolution of the renal parenchyma and the collecting system, the anatomy of the calices is not seen with optimal detail, as in an IVP. This may miss a diagnosis of papillary necrosis. The diagnosis of a small ureteral stone may also be missed on MRU (19). Patients who are severely claustrophobic or require close hemodynamic moni-

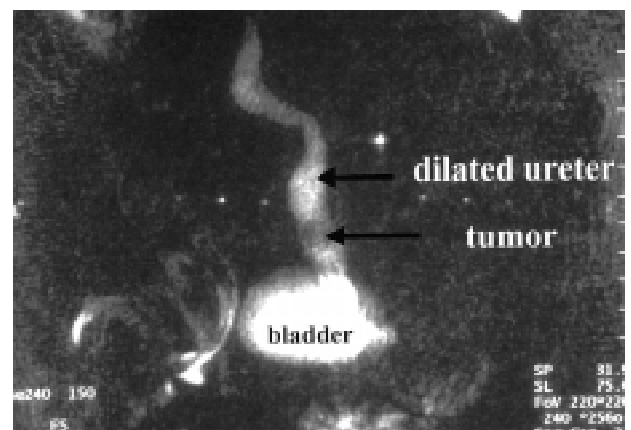


Figure 10 - Magnetic resonance urogram of patient with transitional cell carcinoma in distal ureter. Decreased renal function precluded use of iodinating contrast media.

toring or who are unable to cooperate may be inappropriate for MR. Patients with cardiac pacemakers, cochlear implants, brain aneurysm clips or prosthetic heart valves are not candidates for MR. Finally, MR is limited due to cost and availability (20,21).

WHITAKER TEST

The Whitaker test, a ureteral pressure-flow study, provides a precise but invasive measure of the presence or absence of obstruction in the face of hydronephrosis. It allows direct measurement of ureteral resistance by recording the pressure gradient across the suspected area of obstruction. Results delineate the functional significance of the obstruction. Performance of the Whitaker test requires placement of a catheter in the bladder as well as an antegrade pyelogram needle in the kidney. Contrast is delivered at a constant rate through the needle in the kidney, simulating diuresis, and pressures in the kidney and the bladder are measured. Inaccuracy may be encountered in the face of variable renal anatomy or compliance. Furthermore, the Whitaker test assumes that the obstruction is constant over time, which may produce false negative results (22).

The presence of hydronephrosis does not, in and of itself, imply obstruction. Other causes of hydronephrosis may include: high output by the renal unit, permanent dilation from an old obstruction that has since resolved, vesicoureteral reflux, calyceal dilation of congenital megacalycosis or papillary necrosis, or an extra renal pelvis (23). It is important to document the presence of functional obstruction before any intervention is planned.

URETEROPELVIC JUNCTION OBSTRUCTION

Ureteropelvic junction obstructions may be classified as either chronic or acute. The majority are chronic and congenital in origin although they may not become clinically apparent until childhood or even adulthood (24). Frequently, pathology of the obstructed segment reveals an aperistaltic ureteral segment in which the normal spiral musculature has been replaced by abnormal fibrous tissue and longitudinal muscle

bands. Other causes of chronic UPJ obstruction include congenital stricture, kinks or valves within the ureter caused by infoldings of the mucosa, angulation of the ureteral insertion on the pelvis and aberrant vessels entering directly into the lower pole of the kidney causing external compression of the ureter (22,25).

Acquired causes of chronic UPJ obstruction include vesicoureteral reflux which causes upper tract dilation and tortuosity of the ureter, benign fibroepithelial polyps, transitional cell carcinoma, post operative or post inflammatory scarring and stones (22).

UPJ obstruction is suspected in neonates and infants presenting with a palpable flank mass or hydronephrosis on prenatal ultrasound. Older children and adults may present with flank or abdominal pain that may be intermittent in nature. Alternatively, they may present with urinary tract infections or microscopic hematuria. The diagnosis is confirmed with ultrasound (Figure-9).

In chronic UPJ obstruction, there may be significant loss of renal function before the diagnosis is made. Studies should be performed to consider the amount of renal function still present and how much is salvageable. Lasix renogram studies with split function analysis are crucial for adding this information. Before operative intervention such as pyeloplasty is performed, retrograde urograms may be obtained to delineate the exact site of obstruction and to rule out a second, distal obstruction. This is often done on the same day as the planned repair in order to avoid the use of two general anesthetics.

APPROACH TO THE POTENTIALLY OBSTRUCTED PATIENT

There are a wide variety of imaging studies available for evaluation of a potentially obstructed patient. Our approach to this patient is determined by the clinical setting. In the non-acute setting where urinary tract obstruction is suspected either on the basis of a rising serum creatinine, history, or prior urinary tract abnormalities we will use ultrasound as the initial screening procedure. If ultrasound fails to show any evidence of significant hydronephrosis or hydroureter it is concluded that this patient does not have significant obstruction. Generally, no further

studies relative to detecting urinary tract obstruction are performed.

If ultrasound demonstrates the presence of hydronephrosis or hydroureter further studies to determine the point and cause of obstruction are performed, unless the ultrasound examination has clearly demonstrated this, as in the case of an obstructing ureteral stone. In adults, we will often perform an IVP to delineate the point and hopefully cause of an obstruction. If there is good renal function, the IVP will generally be successful in answering these questions. If there is reduced renal function due to a long-standing obstruction, or for other reasons, the IVP may not provide sufficient visualization of the collecting structures to define the etiology of the obstruction. In these instances retrograde pyelogram is performed which, if technically successful, will usually define the point of obstruction. If the etiology is intrinsic to the urinary tract further studies are generally not necessary. If, however, the studies demonstrate what appears to be an extrinsic cause of the obstruction, computed tomography, with contrast if possible, is performed to look for evidence of mass lesions (Figure-8C) or fibrotic change. There is not always one "best" way to utilize the multiple studies available and it is often the results of a specific study that will determine if a further study is necessary and which modality to use. Although not used often at our institution, MRI urography can demonstrate both intrinsic and extrinsic abnormalities related to the urinary tract and is particularly helpful in those patients in whom contrast cannot be used.

Our approach to the patient with acute renal colic has changed over the past few years. Up until recently, these patients were evaluated with either ultrasound or an IVP as the initial study. This is no longer the case as we now use non-contrast spiral CT as the screening examination for flank pain and suspected ureteral stone. This is faster, more accurate and provides information regarding non-urologic causes of pain. In most cases, the non-contrast study will determine the presence and cause of obstruction, especially if due to a ureteral stone. If an obstruction secondary to a ureteral stone is identified and the stone is to be followed, we will often obtain an abdominal film for the purposes of follow-up. Unfortunately, only

approximately 70% of stones detected on CT scanning will be demonstrable on an abdominal film even in retrospect. If the obstructing stone cannot be identified on an abdominal film and follow-up imaging is necessary because of the patient's clinical course then either a follow-up non-contrast spiral CT or in some cases an IVP can be obtained to assess the persistence and degree of obstruction as well as the position of the stone.

If the non-contrast spiral CT shows no evidence of a ureteral stone but does show hydronephrosis or hydroureter, correlation is made with clinical findings to determine if this may represent passage of a stone prior to the CT scan. If this is the case, clinical follow-up will determine further imaging. Otherwise, IVP will be performed to evaluate for other causes of obstruction.

In children, our approach is somewhat different. Ultrasound is used as the primary screening tool for suspected obstruction. If hydronephrosis is demonstrated, a functional study such as a Lasix renogram is generally performed to evaluate the function of the two kidneys and the severity of the suspected obstruction. Further study would then depend on clinical consideration such as any need for surgical intervention.

In summary, multiple techniques exist for the evaluation of renal obstruction. Each patient must be evaluated on an individual basis with consideration of the acuity of obstruction and the special needs of the patient. Certain centers may not have access to helical CT scanners, nuclear medicine capabilities or a MRI. Techniques must be reliable and accessible to allow the clinician to follow the disease over time.

REFERENCES

1. Keolliker SL, Cronan JJ: Acute urinary tract obstruction. Imaging update. *Urol Clin North Am*, 24: 571-582, 1997.
2. Levine JA, Neitlicht, Vergan: Ureteral calculi in patients with flank pain: correlation of plain radiography with enhanced of plain radiography with unenhanced helical CT. *Radiology*, 204: 27-31, 1997.
3. Zagoria RJ, Khatod EG, Chen MYM: Abdominal radiography after CT reveals urinary calculi:

- a method to predict usefulness of abdominal radiography on the basis of size and CT attenuation of calculi. *AJR*, 176:1117-1122, 2001.
4. Platt JF, Rubin JM, Ellis JH: Acute renal obstruction: evaluation with intrarenal duplex Doppler and conventional US. *Radiology*, 186: 685, 1993.
 5. Tublin ME, Dodd GD III, Verdile VP: Acute renal colic: diagnosis with duplex Doppler US. *Radiology*, 193: 697, 1994.
 6. Older RA, Stoll HL, Omary RA, Watson LR: Clinical value of renovascular resistive index measurement in the diagnosis of acute obstructive uropathy. *J Urol*, 157: 2053-2055, 1997.
 7. Ebel KD: Uroradiology in the fetus and newborn: diagnosis and follow-up of congenital obstruction of the urinary tract. *Pediatric Radiology*, 28: 630-635, 1998.
 8. Cox IH, Erickson SJ, Foley WD, Dewire DM: Ureteric jets: evaluation of normal flow dynamics with color Doppler sonography. *AJR*, 158: 1051-1055, 1992.
 9. Smith RC: Acute flank pain: comparison of non-contrast-enhanced CT and intravenous urography. *Radiology* 194: 789-794, 1995
 10. Niall O, Rusell J, MacGregor R: A comparison of noncontrast computerized tomography with excretory urography in the assessment of acute flank pain. *J Urol*, 161: 534-537, 1999.
 11. Zagoria RJ: Helical CT of urolithiasis: leaving no stone unturned. *Appl Radiol*, 10: 8-13, 1998.
 12. Boridy IC: Acute ureterolithiasis: Nonenhanced helical CT findings of perinephric edema for prediction of degree of ureteral obstruction. *Radiology*, 213: 663-667, 1999.
 13. Chong WK: Renal carcinoma presenting with flank pain: a potential drawback of unenhanced CT. *AJR*, 174: 667-669, 2000.
 14. Blake SP, McNicholas MM, Raptopoulos V: Nonopaque crystal deposition causing ureteric obstruction in patients with HIV undergoing indinavir therapy. *AJR*, 171: 717-720, 1998.
 15. Kass EJ, Fink-Bennet TD: Contemporary Techniques for the Radioisotopic Evaluation of dilated urinary tracts. *Urol Clin North Am*, 17: 273-289, 1990.
 16. Roarke MC, Sandler CM: Provocative imaging: diuretic renography. *Urol Clin North Am*, 25: 227-249, 1998.
 17. Conway JJ: "Well-tempered" diuresis renography: its historical development, physiological and technical pitfalls, and standardized technique protocol. *Seminars in Nuclear Medicine*, 22: 74-84, 1992.
 18. Dubovsky EV, Russell CD: Advances in radionuclide evaluation of urinary tract obstruction. *Abdominal Imaging*, 23:17-26, 1998.
 19. Hussain S: MR urography. *Magnetic Resonance Imag Clin North Amer*, 5: 95-106, 1997.
 20. Roy C: MR urography in the evaluation of urinary tract obstruction. *Abd Imag*, 23: 27-34, 1998.
 21. Dockery WD, Stolpen AH: State-of-the-art magnetic resonance imaging of the kidneys and upper urinary tract. *J Endourol*, 13: 417-423, 1999.
 22. Koff SA: Pathophysiology of ureteropelvic junction obstruction. *Urol Clin North Am*, 17: 263-272, 1990.
 23. Papanicolaou N: Urinary Tract Imaging and Intervention: Basic Principles. In: Walsh PC, Retik AB, Vaughan ED, Wein JA (eds.). *Campbell's Urology*, Philadelphia, WB Saunders, pp. 243-244, 1998.
 24. Jacobs JA: Ureteropelvic obstruction in adults with previously normal pyelograms: a report of 5 cases. *J Urol*, 121: 242-244, 1979.
 25. Park JM, Bloom DA: The pathophysiology of UPJ obstruction: current concepts. *Urol Clin North Am*, 25:161-169, 1998.

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