MINISTRY OF HEALTH OF UKRAINE
ZAPORIZHZHIA STATE MEDICAL AND PHARMACEUTICAL UNIVERSITY
Department of Propaedeutic of Internal Medicine, Radiation Diagnostic and therapy

O.G. Nordio, N.V. Tumanskia, S.O. Miahkov

RADIOLOGY OF THE URINARY SYSTEM

MANUAL

for the students of the 3rd year of specialty "Medicine"

Zaporizhzhia
2024

UDC 616.61-085.849
N78

Recommended for publication by the Central Methodical Council of Zaporizhzhia State Medical and Pharmaceutical University as a study guide (protocol № 4 of 25.04.2024)

Authors:

O.G. Nordio – assistant of department propedeutic of internal medicine, ZSMPhU.
N.V. Tumanskia – Candidate of Medical Sciences, assistant professor of department propedeutic of internal medicine, ZSMPhU.
S.A. Miahkov – Candidate of Medical Sciences, assistant professor of department propedeutic of internal medicine, ZSMPhU.

Reviewers:
V. A. Vizir - doctor of medical sciences, professor of department of internal medicine №2 of the ZSMPhU.
S.Ya. Dotsenko - Doctor of medical sciences, professor of the department of internal medicine №3 of the ZSMPhU.

O.G. Nordio
N 78 Radiology of the urinary system: manual for the students of the 3rd year of speciality "Medicine" / N.V. Tumanskia, S.A. Miahkov - Zaporizhzhia: [ZSMPhU], 2024. – 128 p.

The manual **«Radiology of the urinary system»** was prepared to facilitate the preparation of practical classes in radiology for third-year students of speciality "Medicine". The manual presents various types of urinary system radiation diagnostics (principle of their operation, application, indications, contraindications, advantages and disadvantages) and also the main urinary system pathology is presented (their classification, causes, and radiological signs). This study guide is intended for students of medical HEI.

Навчальний посібник **«Радіологія сечовивідної системи»** підготовлений з метою полегшити підготовку до практичних занять з радіології для англомовних студентів 3 курсу за спеціальністю «Медицина». У посібнику представлені різні типи променевої діагностики сечовивідної системи (принцип їх роботи, застосування, показання, протипоказання, переваги та недоліки). А також представлена основна патологія цієї системи (їх класифікація, причини і променеві ознаки). Цей навчальний посібник призначений для студентів медичних ВНЗів.

CONTENTS

Introduction

Imaging is a general term for techniques used to create pictures. In medicine, imaging produces pictures of bones, organs, and vessels inside the body. Imaging helps health care professionals see the cause of medical problems.

The pace of innovation in diagnostic radiology has increased exponentially, in tandem with computer advances and the rapid evolution of microprocessing power. Imaging of the urinary tract, as a result, has become more flexible and precise, with new procedures offering a great selection of options, and new imaging algorithms being implemented. Ultrasonography, computed tomography (CT), and magnetic resonance imaging (MRI) provide higher soft-tissue contrast resolution than conventional radiography, as well as multiplanar imaging capability, resulting in significant advances in almost all areas of uroradiology. In academic centers, metabolic and molecular imaging techniques have become the focus of new research, and have begun to enter the realm of daily clinical practice. While imaging advances have produced new algorithms for approaching diagnostic evaluation, appropriate use of imaging in each particular case also depends greatly on the equipment and professional talent available. One imaging modality or protocol may offer specific advantages over another depending on the clinical question, and the importance of a collaborative approach from the medical team cannot be overemphasized.

In summary, ever changing uroradiology remains indispensable in the diagnosis and treatment of patients with urologic disorders.

This manual will discuss the imaging techniques used in uroradiology, with summaries of the advantages and disadvantages of the various techniques, and as well as x-ray signs of pathologies of this system.

All visual materials (roentgenograms, tomograms, sonograms) created by the authors of the manual, otherwise the source is indicated.

Methods of investigations

Initial methods

- Ultrasound
- Plain radiograph
- Intravenous urography

Additional methods

1. Non-invasive

- Doppler ultrasound
- CT – scan
- MRI

2. Invasive

- Retrograde pyelography
- Antegrade pyelography
- Cystography
- Uretrocystograpy
- Renal angiography
- Angiography
- CT angiography
- MRI angiography
- Urological interventions

Nuclear medicine

- PET scan

1. *Ultrasound (US)*

Ultrasound is a useful technique for evaluation of the urinary tract, with its principal advantages including wide availability, no need for intravenous contrast material, and lack of ionizing radiation.

Indications

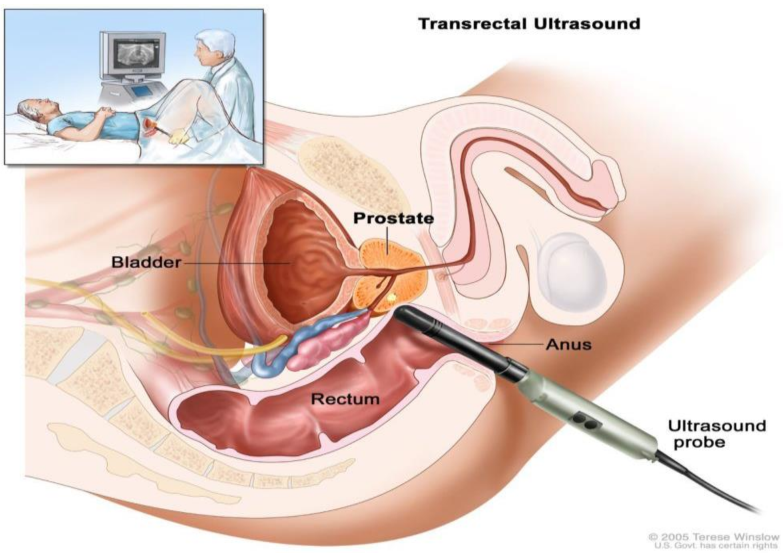
- renal size
- growth
- flank and/or back pain
- masses
- renal obstruction
- urinary tract infection
- hematuria
- congenital abnormalities
- renal failure
- abdominal trauma
- pretransplantation and posttransplantation evaluation
- transplants
- bladder residual volumes
- prostatic size
- planning and guidance for an invasive procedure

Abdominal ultrasound

In abdominal ultrasound, the technician applies a gel to the patient's abdomen and holds the transducer against the skin. The gel allows the transducer to glide easily, and it improves the transmission of the signals. Abdominal ultrasounds are well known for taking pictures of fetuses in the womb and of a woman's ovaries and uterus, but this approach can also be used to evaluate the size and shape of the kidneys.

Transrectal ultrasound

Transrectal ultrasound is most often used to examine the prostate. The transducer is inserted into the patient’s rectum so that it is right next to the prostate. The ultrasound image shows the size and shape of the prostate and any irregularity that might be a tumor. To determine whether an abnormal-looking area is in fact a tumor, the doctor can use the transducer and the ultrasound images to guide a biopsy needle to the suspected tumor. The needle collects a few pieces of prostate tissue for examination with a microscope.



https://www.teresewinslow.com/

Several common indications include evaluation of the patient with acute renal failure to exclude postobstructive (hydronephrosis) etiologies, to evaluate for sequelae (scarring) of vesicoureteral reflux in children, and to diagnose simple renal cysts. Ultrasound is generally the study of choice in evaluating the renal transplant as well.

However, the relatively small and sometimes technically limited (in large patients) field of view, lack of visualization of the ureters, and lack of functional assessment limit the use of ultrasound in some circumstances.

Additionally, solid renal masses are nonspecific on ultrasound and require further imaging, usually with CT. Ultrasound has only moderate sensitivity for detecting renal stone disease. Although the retroperitoneal position of the kidneys usually provides an excellent window for ultrasound, patients with a large habitus continue to become more common, and in these patient's sensitivity for small masses or calculi may be markedly diminished.

The renal US should always be performed in combination with a complete upper abdominal ultrasound.

Preparation

Usually, patient does not have to do anything special to prepare for a renal ultrasound.

It is important that patient have a full bladder for this test.

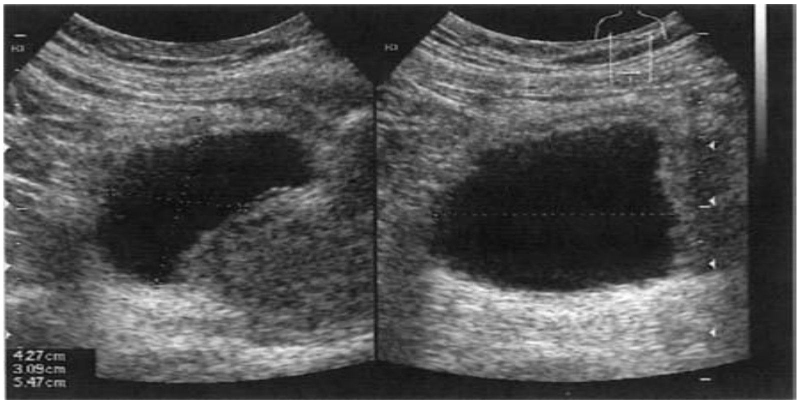
Procedure

Renal US is usually performed in supine position. The side to be examined can be slightly elevated. After visualizing the kidney from a posterior and lateral angle, the long axis of the transducer is aligned with the long axis of the kidney.

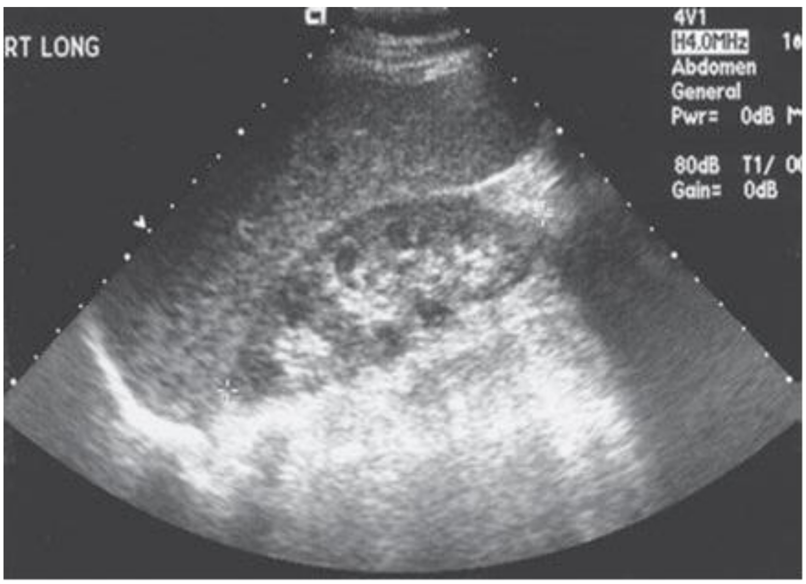
The resulting longitudinal cross sections are best suited to determining renal size and assessing cortical thickness as well as the configuration and size of the renal pelvis. The transducer is then rotated by 90 to scan up and down the kidney perpendicular to its long axis. As with all paired organs, comparison with the opposite side is essential for the evaluation of the images. Finally, cast an eye on the (hopefully) fluid-filled bladder.

The bladder volume can be estimated for most purposes by taking the product of three perpendicular measurements and multiplying by 0.56:

Bladder volume (ml) = length x *width* x
anteroposterior diameter (cm) .x *0.56*



https://onlinelibrary.wiley.com/doi/full/10.1002/jmrs.320
longitudinal section (LS) and TS scans through the bladder after micturition demonstrating an enlarged prostate (P) and a small residual urine volume of 40 ml



normal renal ultrasound

US. Transverse view of the urinary bladder. The uterus is seen posteriorly.

Advantages

- a kidney ultrasound is a noninvasive diagnostic exam
- safety and low cost
- generally, no discomfort from the application of the ultrasound transducer to the skin
- evaluation size and shape of kidney
- evaluation their position
- the procedure of choice for evaluation polycystic kidney disease
- detection renal masses
- detection congenital anomalies of renal system
- detection abscess, obstructions, fluid collection, and infection within or around the kidneys
- signs of injury to the kidneys, ureters and urinary bladder
- detection calculi of the kidneys and ureters
- may be performed to assist in placement of needles used to biopsy the kidneys, to drain fluid from a cyst or abscess, or to place a drainage tube
- indication of the residual volume
- measure of bladder function
- assess blood flow to the kidneys
- evaluation the transplanted kidney

Limitations of renal ultrasonography are as follows:

- interpretation is operator-dependent
- large body habitus renders the interpretation difficult
- barium within the intestines from a recent barium procedure
- intestinal gas

2. Duplex US (dopplerography)

Indications

- diagnosis of urinary obstruction independently of the kidney function, differential diagnosis of obstructing and functional dilatation of PCS after the value of the vascular resistance
- diagnosis of doubling a kidney due to visualization of two vascular pedicles
- evaluation of the degree of vascularization of voluminous formations of the urinary system
- evaluation of a renal transplantant
- diagnosis of stenosis, occlusions, thrombosis of renal vessels
- choice of a "blood – free" zone in invasive interventions under the control of US

Preparation

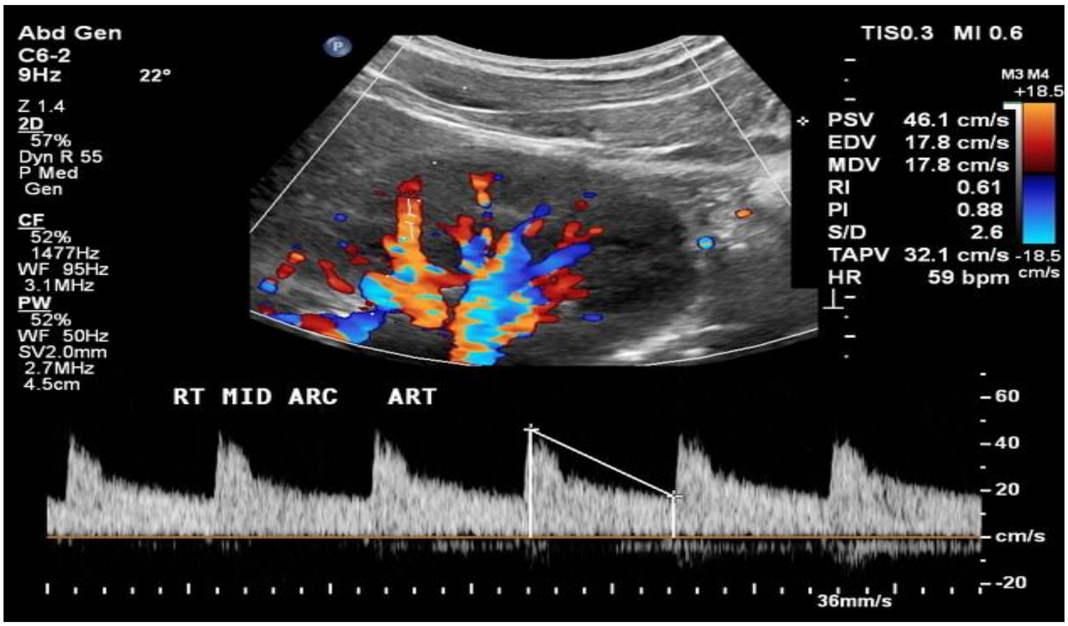
There is little preparation required for duplex ultrasound. Occasionally, patients may need to fast before an abdominal exam.

Procedure

The vascular tree of the kidney can be effectively demonstrated with colour Doppler. By manipulating the system sensitivity and using a low pulse repetition frequency (PRF), small vessels can be demonstrated at the periphery of the kidney.

Demonstration of the extrarenal main artery and vein with colour Doppler is most successful in the coronal or axial section by identifying the renal hilum and tracing the artery back to the aorta or the vein to the inferior vena cava (IVC). The best Doppler signals, that is, the highest Doppler shift frequencies, are obtained when the direction of the vessel is parallel to the beam, and taken on suspended respiration. The left renal vein is readily demonstrated between the superior mesenteric artery (SMA) and aorta by scanning just below the body of the pancreas in transverse section. The origins of the renal arteries may be seen arising from the aorta in a coronal section.

The normal adult renal vasculature is of low resistance with a fast, almost vertical systolic upstroke and continuous forward end diastolic low. Resistance generally increases with age. The more peripheral arteries are of lower velocity with weaker Doppler signals, and are less pulsate than the main vessel.



https://radiopaedia.org/cases/normal-renal-doppler-ultrasound?lang=gb
Normal renal Doppler ultrasound

Advantages

The main advantages of this technique are:

- include a lack of radiation and lack of contrast agents
- for people who are claustrophobic, this technique has another advantage of avoiding the MRI machine
- exact and quick stone localization
- minimal loss of renal function owing to preservation of the intrarenal vascular system
- no need for renal ischemia and cooling
- morphologic appreciation of atherosclerotic changes in the renal artery wall

- visualization of a narrowed lumen with markedly reduced flow that may help differentiate subocclusive renal artery stenosis from occlusion
- increased confidence in the diagnosis of renal vein thrombosis and in the assessment of caval tumor thrombus
- better appreciation of renal cortical perfusion defects

Disadvantages

- renal artery ultrasound is difficult in patients who have a short stature
- some anatomical structures are difficult to differentiate with renal artery ultrasound
- renal artery ultrasound can miss findings outside the blood vessels
- obesity and bowel gas are major limitations in renal artery ultrasound

3. Plain film

A plain abdominal film is essential prior to urinary tract investigation.

Plain x-ray (scout film)

It gives information about:

- renal outlines
- psoas muscles
- bony structures such as vertebra and its appendages, pelvis
- any stones
- abdominal mass
- foreign body

Conventional radiographs (plain films) can occasionally provide important clues to diseases of the urinary tract. Radiographs of the abdomen when used to evaluate the urinary tract are often referred to as KUBs (kidney, ureter, and bladder). KUBs may serve a role as preliminary films (scouts) prior to an examination such as an intravenous urography, or they may be used as a general evaluation of the abdomen or the urinary tract.

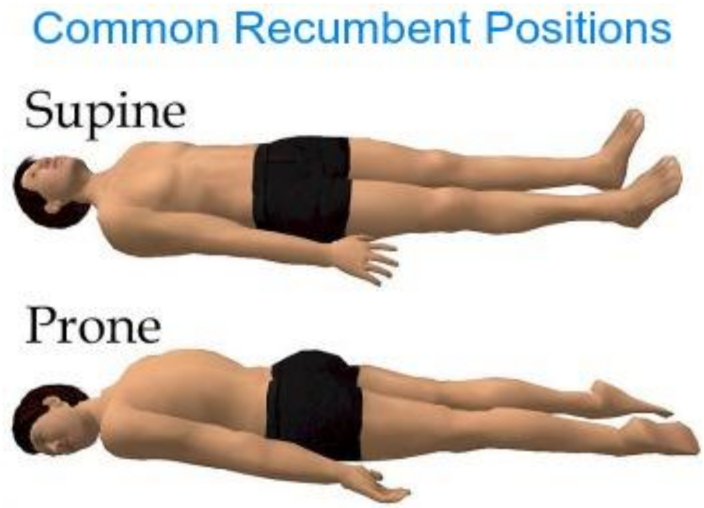
As stated, abnormalities of the urinary tract may be suggested on conventional radiographs and, among other things, the bones and soft tissues should be evaluated and abnormal densities, especially calcifications, should be sought. "Gas, mass, bones, stones" can be used as a reminder of main areas to examine on the KUB.

Soft tissue masses can occasionally be detected and suggest renal or pelvic lesions. Sclerotic bony lesions can suggest metastatic prostate cancer and lytic bony lesions can be seen with disseminated renal cell carcinoma. Additionally, the bony changes of renal osteodystrophy (diffuse bony sclerosis) may be identified on plain radiographs. Vertebral anomalies are associated with congenital malformations of the urinary tract.

In the setting of trauma, fractures of the lumbar transverse processes suggest possible renal injuries and pelvic fractures raise concern for coexistent bladder or urethral trauma.

Air and calcifications should be specifically sought over the urinary tract. Emphysematous pyelonephritis, a urologic emergency with high mortality, is the result of a renal infection by gas-producing organisms and may be diagnosed on plain films by mottled or linear collections of air within the renal parenchyma.

Finally, radiographs are useful for detecting and evaluating urinary tract calculi. The sensitivity for detection of stones is limited when the calculi are small, of lower density composition, or when overlapping stool, bony structures, or air is
obscuring the stones.



https://mlmlovevs.live/product_details/29533132.html

Antero-posterior supine plain image of the abdomen showing a left lower pole renal calculus and a calculus in the upper right ureter

Additionally, the specificity of conventional radiography is somewhat limited because a multitude of other calcifications occurs in the abdomen, including arterial vascular calcifications, pancreatic calcifications, gallstones, leiomyomas, and many more. Phleboliths, which are calcified venous thrombosis, are especially problematic because they frequently overlap the urinary tract and are difficult to differentiate from distal ureteral stones. Lucent centers are a hallmark of phleboliths, whereas renal calculi are often most dense centrally.

Normal calcification

- costal cartilage
- mesenteric lymph nodes
- pelvic vein phleboliths

Abnormal calcification

Calcium indicates pathology in:

- pancreas
- renal parenchymal tissue
- blood vessels and vascular aneurysms
- gallbladder fibroids (leiomyoma)
- uterine fibroid

Calcium can make the following pathology visible:

- biliary calculi
- renal calculi
- prostate gland
- appendicolith
- bladder calculi
- teratoma

Plain abdominal film
calcification of mesenteric lymph nodes pancreatic calcifications

Preparation

Bowel preparation to the kidney radiography and intravenous urography is routinely administered in many radiologic centers to improve the image quality and visibility of the urinary tract details.

Fluid and food restriction and bowel preparation have been considered to reduce overlying bowel gas and feces that may obscure details on the images.

Functional constipation may also increase bowel gas and fecal residue and impair the quality of images.

Procedure

Plain film is taken in supine position. The radiograph should include the upper poles of both the kidneys and lower border of symphysis pubis (for prostatic urethra).

Advantages

- abdominal x-ray imaging is a painless, minimally invasive procedure with rare complications

- radiology examinations can often provide enough information to avoid more invasive procedures
- x-ray equipment is relatively inexpensive
- abdominal x-ray imaging is fast and easy
- no radiation remains in a patient's body after an x-ray examination
- it’s have no side effects in the typical diagnostic range for this exam
- may be used to help diagnose unexplained pain, nausea or vomiting
- abdominal x-ray may also be used to help properly place catheters and tubes used for feeding or to decompress organs such as the kidneys

Disadvantages

- It is difficult to distinguish vascular calcifications from ureteral calcifications with plain radiography
- plain films are not sensitive enough to exclude tumors of the kidney or urothelial tract
- this imaging technique does provide general information regarding kidney size and shape

4. Intravenous urography IVU

The IVU consists of a series of plain films taken after administration of an intravenous injection of a water-soluble iodine containing contrast medium.

Indications

1. Obstructive calculi
2. Haematuria or pyuria
3. Diseases of renal collecting system and renal pelvis
4. Abnormalities of the ureter
5. Tuberculosis of the urinary tract
6. Prior to endourological procedures and surgery of the urinary tract
7. Suspected renal injury

8. Renal colic or flank pain
9. In children- polycystic kidney diseases, pelvi-ureteric junction obstruction, anorectal anomalies
10. Pelvic malignancies to see uretic involvement

Traditionally the patient was prepared with a period of 4 h starvation and fluid deprivation and the bowel purged with a strong laxative. Occasionally the patient will feel nauseated after the IVU injection and rarely there will be a severe reaction with the need for cardiovascular and occasionally cardiopulmonary support. With this in mind, it seems reasonable to persist with avoidance of food for 2-4 h prior to the procedure.

Radiological anatomy

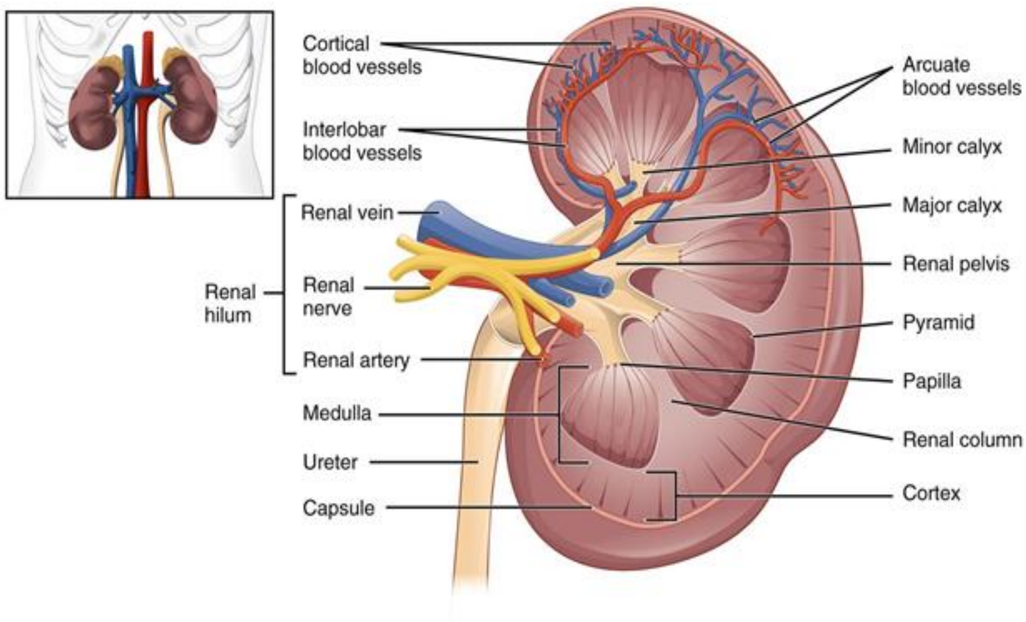
The kidneys are typically located at the level of the upper lumbar spine with the right kidney slightly lower than the left. They generally lie with their axes along the psoas muscles with the upper pole slightly more medial than the lower. Alterations in position and orientation of the kidneys may be related to congenital anomalies such as pelvic kidneys or may be secondary to mass effect from an adjacent lesion.

The size of the kidneys is somewhat variable depending on age and sex of the patient, but on the intravenous urogram, the kidneys normally range from 11 to 14 cm. The right kidney is typically slightly smaller than the left.

The kidneys should be symmetric in size with a discrepancy greater than 2 cm requiring an explanation. There are a number of causes of abnormal renal size, ranging from incidental anomalies such as congenital renal hypoplasia to significant conditions such as renal artery stenosis (small kidney) or infiltrating renal neoplasm (large kidney).

The kidneys should have a reniform shape and a smooth contour.

The intrarenal collecting system consists of calyces, infundibula, and the renal pelvis. Normally, each kidney consists of 7 to 14 evenly distributed calyces.



Normal renal anatomy (Source: https://commons.wikimedia.org/wiki/File:2610_The_Kidney.jpg)

The normal ureters exhibit continual peristalsis and on a single film, it is uncommon to demonstrate the entire length of both (or even either) ureters.

They will often demonstrate smoothly narrowed areas (especially at the pelviureteric junctions and as they cross the iliac vessels in the pelvis) and more relaxed capacious areas. This is normal. Proximally, the ureter passes over the psoas muscle and should generally lay just lateral to the lumbar spine. The midportions of the ureters course over the lateral sacrum with the distal portion gently curving laterally in the pelvis before entering the bladder.

The ureter should be inspected for filling defects, which can be caused by stones or tumor, and should be symmetric in size. Evaluation of the ureteral course is important. Deviations of the normal ureter generally suggest extrinsic diseases, such as mass lesions. However, in patients with large psoas muscles the ureters may be displaced laterally as an incidental result.

The bladder is an oval to rounded structure that normally lies just above the pubic symphysis on the IVU. In women, the dome of the bladder may normally be indented by the uterus. These normal findings must be differentiated from abnormal extrinsic mass effects. Bladder wall thickness can sometimes be visualized and assessed, especially if thickened. Additionally, the bladder mucosa should be scrutinized for irregularity or filling defects that may suggest a mass.

Patient preparation

• blood urea and serum creatinine level should be within normal limits

• if patient is asthmatic premedication in the form of steroids is administered two days' prior

• fasting after 10 pm (previous night) (as contrast injection sometimes induces nausea which might lead to vomiting and aspiration)

• patient should be well hydrated (dehydrated patients are prone for renal damage)

• bowel preparation is necessary, as gas and fecal matter filled bowel loops will obscure the kidney shadows

• low residue diet with plenty of oral fluids, the day previous to the IVU

Contrast media

Contrast materials currently in use are excreted almost exclusively by glomerular filtration, with subsequent concentration in the renal tubules and progressive opacification of the urinary tract.

They are two types:

1. ionic (urograffin, angiograffin)
2. non-ionic (omnipaque, ultravist)

Ionic contrast media have a higher incidence of reaction but they are cheaper as compared to the non-ionic contrast media.

Procedure

Patient is placed in supine position. The patient is asked to void the bladder before the procedure.

Contrast media is injected intravenously into a prominent vein in the arm. Test injection of 1ml of contrast is given and patient observed for 5 min for any contrast reactions. Then the rest of the contrast is rapidly injected within 30-60 seconds.

The dose of contrast media is 2 ml/kg body wt.

Intravenously injected iodinated contrast is excreted primarily by glomerular filtration in the kidney, opacifying the urinary tract as it progresses from the kidney through the ureter and to the bladder. Capturing this sequential "opacification" on radiographs is the fundamental basis of the IVU. There are many variations in the filming sequence for the urogram that are acceptable as long as it optimizes visualization of specific anatomy of the urinary tract during maximum contrast opacification. Optimal visualization of the kidney is accomplished very early in the examination. Within 1 to 3 minutes after injection, the contrast bolus is filtered by the glomeruli and fills the nephron, resulting in intense opacification of the renal parenchyma; this phase of contrast opacification is called the nephrogram.

The kidneys should be evaluated for:

- their position
- orientation
- size
- contour
- radiographic density.

Soon after the nephrographic phase, contrast begins filling the intrarenal collecting system including the calyces and renal pelvis. This portion of the study is termed the pyelographic phase.

- ***5-10 min film***

Shows nephrogram, renal pelvis

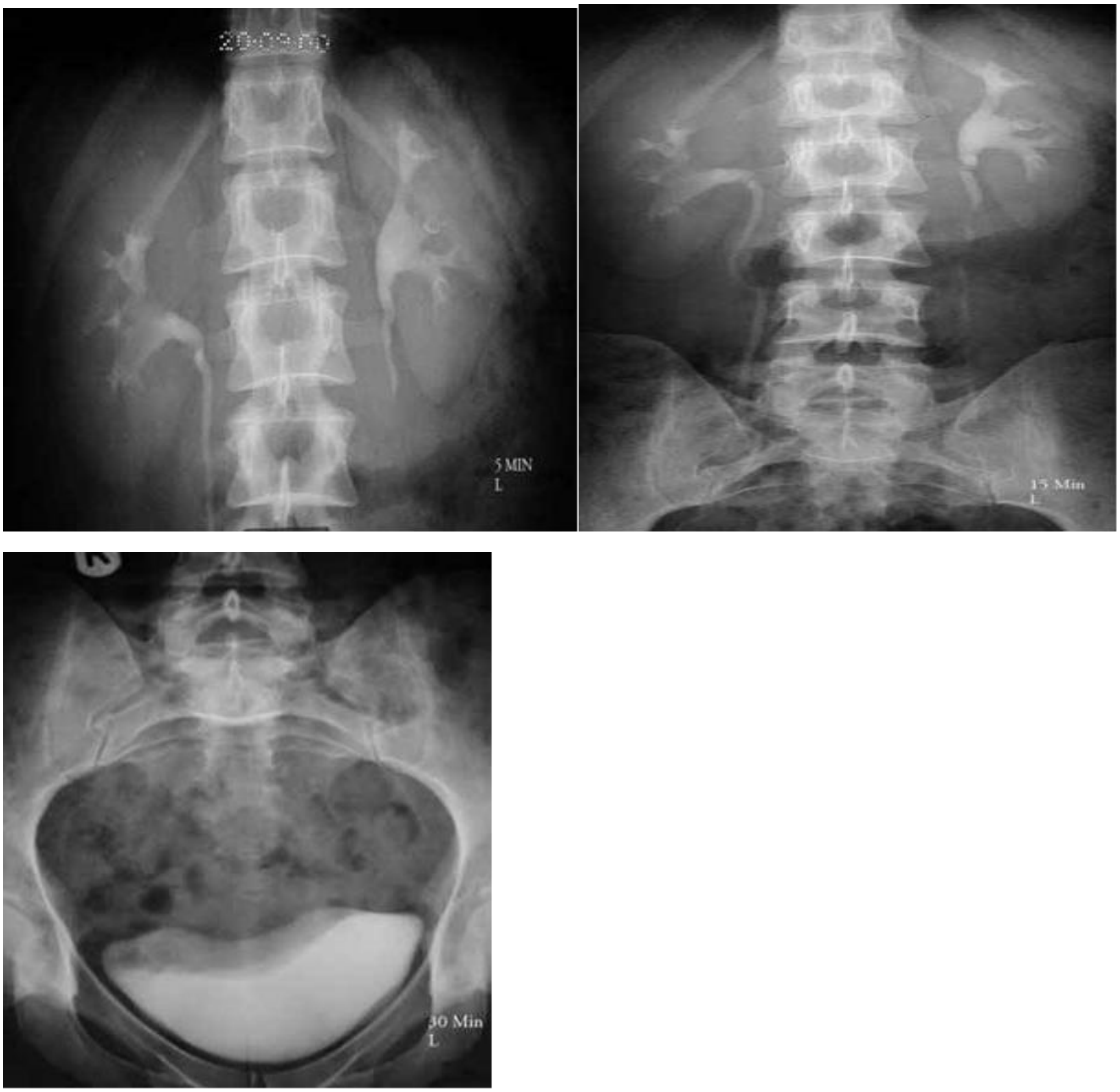
- ***15-20 min film***

A complete visualization of the pelvicalyceal system entire ureters is possible in this film, especially with the patient in prone position as the ureters will be antedependent in prone position.

- ***30-35 min film***

A complete visualization of the urinary tract: kidney, ureter, bladder can be done and bladder distension can be evaluated in the later film.

The series is varied according to the individual patient. Renal obstruction may require a delayed study up to 24 hours to outline the pelvicalyceal system.



intravenous urography IVU (normal)

Advantages

- IVU is low cost
- anesthesia is not needed
- detailed anatomy of the collecting system
- rapid overview of the entire urinary tract
- demonstration of calcifications

- demonstrate renal function and allow for verification that the opposite kidney is functioning normally
- it is sensitive for obstruction
- can show non opaque stones as filling defect
- IVP is an excellent modality to diagnose medullary sponge kidney and papillary necrosis

Disadvantages

- contrast material must be avoided in patients with a history of allergy, hay fever or asthma until steroid cover has been given; those on metformin must stop this drug for 24 h before any contrast. These groups cannot safely undergo an emergency IVU.
- the differentiation from a phleboliths is difficult, especially when there is no ureteric dilatation proximally
- contraindications renal insufficiency
- contraindications hepatorenal syndrome, thyrotoxicosis, pregnancy
- do not differentiate solid or cystic lesion
- requires contrast medium and radiation
- missing small stones
- quality of study may be limited by inadequate bowel preparation
- inconvenience of a long filming sequence

Retrograde and antegrade pyelography

Direct injection of water-soluble iodinated contrast material is a useful method of examining various regions of the urinary tract. The advantage of this method of evaluation is the direct control over the contrast injection rather than reliance on secondary excretion from the kidney.

5. Retrograde pyelography

Indications

This investigation aims to optimally opacify the pelvicalyceal system and ureter. It usually follows an IVU and is indicated when there is persistent uncertainty about the diagnosis, particularly if there is haematuria and suspicious cytology. It is indicated to confirm or refute the presence of one or more filling defects within the collecting system, or to improve demonstration of the collecting system, when there has been inadequate demonstration of part or all of the system or when the IVU is normal but the abnormal laboratory findings persist. It is occasionally used to demonstrate the lower end of an obstructed ureter.

Patient preparation

Laxatives or enemas may be necessary before the procedure, as the bowel must be relatively empty to provide visualization of the urinary tract.

Procedure

Retrograde pyelography, often carried out in conjunction with cystoscopy, is performed by placing a small catheter into the distal ureter. Contrast material is then injected through this catheter into one or both ureters. Fluoroscopy and conventional radiographs should then be obtained. This study usually results in excellent evaluation of the ureter and intrarenal collecting system.

The ureter is typically seen in its entirety, which rarely occurs with other imaging studies. Interpretation is similar to that of CT urography, with the caveat that the contrast within the collecting system is under greater pressure than physiologic conditions and mild ballooning of the calyces as well as occasional extravasation can occur normally.

The retrograde pyelogram was once used as a method of clearly defining the anatomy of the renal drainage system in the patient with a non-functioning kidney or with a poorly functioning kidney when intravenous pyelography had failed to provide adequate visualisation.

Retrograde pyelography is still sometimes used to confirm or disprove the relationship of a suspected small calculus to the ureter.

Advantages

- retrograde pyelography is an essential tool for localizing the site of urinary tract obstruction
- it may also prove therapeutic (eg, ureteral stents can be placed to relieve an obstruction).

Disadvantages

Possible complications of retrograde pyelogram include:

- urinary tract infection
- bladder tear
- bleeding and injury to the ureter
- nausea or vomiting

Retrograde pyelography of the right ureter showed mild hydronephrosis

6. Antegrade pyelography

This is a relatively simple procedure.

Indications

Percutaneous antegrade pyelography is a useful method of demonstrating the renal calyces, pelvis and ureter in cases of suspected urinary tract obstruction where the intravenous method has been unsuccessful or inconclusive. Unlike retrograde pyelography, it does not require general anaesthetic and it has a lower incidence of urinary tract infection. It is also useful in infants and children where cystoscopy is difficult or impossible.

Generally, no preparation is necessary prior to this test.

Patient preparation

Laxatives or enemas may be necessary before the procedure, as the bowel must be relatively empty to provide visualization of the urinary tract.

Procedure

A dilated renal calyx is punctured percutaneously from the lumbar region using a fine needle, and contrast medium is injected. The technique can also be used to insert a catheter and provide temporary drainage. The catheter tract can also be used for a percutaneous approach to renal calculi and for stent insertion.

Advantages

- this procedure can be used to relieve obstruction by insertion of a nephrostomy tube
- there is relatively low radiation exposure during this test

Disadvantages

Possible complications of antegrade pyelogram include:

- bleeding
- infection
- formation of a urine-filled cyst (urinoma)
- blood clots in the nephrostomy tube if used, or clots in the bladder

antegrade pyelography shows corkscrew ureters

7. Cystography

Imaging of the bladder is performed with a cystogram.

Indications

- the extent of vesicoureteral reflux
- urinary stress incontinence can be assessed
- urinary tract infections
- suspected obstruction
- suspected bladder trauma or rupture
- detection tumor
- detection diverticula
- detection stones
- to investigate suspected fistulas involving the bladder (usually into the gastrointestinal tract, occasionally elsewhere such as the vagina)

Procedure

A catheter is placed into the bladder and contrast material is then injected. The contrast material is optimally injected under fluoroscopic observation but occasionally is performed with only static conventional radiographs, such as in the trauma setting. Anatomic considerations and evaluation are similar to the IVU with a few caveats.

The method is useful for outlining tumors of the bladder when intravenous urography has been unsuccessful or equivocal.

One advantage to cystography is that vesicoureteral reflux can be evaluated during the conventional cystogram unlike during IVU.

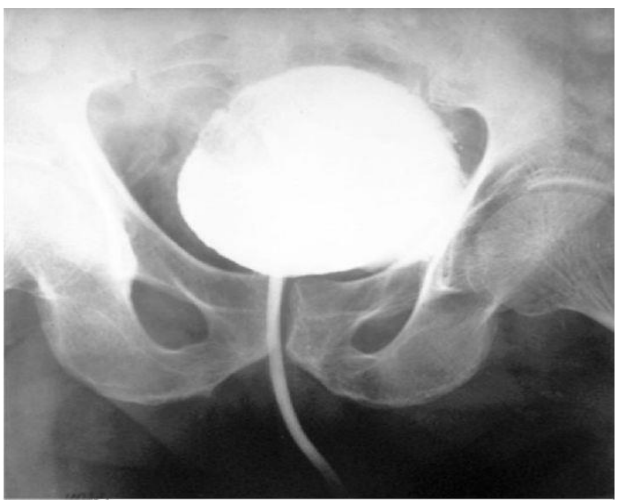
Cystography can be classified into three groups:

- micturiting cystourethrography (MCUG)
- dynamic cystography
- simple cystography.

The MCUG is primarily performed for an investigation of childhood.

Dynamic cystography is part of the urodynamics investigation of the lower urinary tract.

Simple cystography is a relatively frequently performed and straightforward investigation in the adult.



normal cystography

Patient preparation

For two days before the examination, medical experts recommend limiting intake of products that provoke flatulence. On the eve of the research (in the evening), as well as immediately before cystography (morning) held enema.

Advantages

- these imaging tests provide the basic anatomy of the bladder and urethra
- show urethral movement
- low cost
- wide availability
- general familiarity

Disadvantages

- cystography is contraindicated spend in acute inflammation of the bladder, urethra, scrotum, prostate and seminal vesicles (If the research is still necessary, the doctor can perform a downward cystography)
- the catheter could damage the urethra, bladder or nearby structures
- they require catheterization
- the images contain no information about the pelvic musculature and adjacent soft tissue structures
- only structures in direct contact with the urethral and bladder lumen opacify with contrast

8. Urethrocystography

This can be performed via ***an ascending*** or ***descending*** approach.

Descending urethrocystography

Indications

- it allows both an exploration of the morphology and dynamics of the bladder, urethra and ureter junction bladder
- the urethrocystography is mainly indicated in the assessment of voiding dysfunction in adults, and urinary incontinence in children and infants to recurrent urinary tract infections

Procedure

When it is performed in adults the bladder should be adequately filled (with at least 200 ml of 150 strength contrast). The screening table should be positioned erect. Imaging is performed directly anteroposterior in females and in a 45° oblique projection in males.

Males are generally used to micturating while standing, often in unusual situations, and can manage with a bottle while screening is performed and spot films taken of the urethra and bladder base.

Females are provided with a special drainage receptacle that is held between the thighs.

Ascending urethrography is essentially confined to the male.

It is used:

1. in the investigation of trauma,
2. stricture
3. filling defects
4. masses
5. and fistulas

Procedure

The patient is positioned in a 45° oblique position with the dependent hip partly flexed to provide stability and ensure the urethra is not projected over hone. A I2-16 gauge Foley catheter is positioned with its balloon a Couple of centimeters into the distal urethra. The balloon is gently partially inflated to provide a seal without undue trauma. Between 5 and 10 nil 150 strength contrast is injected gently into the urethra under direct screening and spot filets arc taken. The urethra is usually easily opacified hack to the urogenital diaphragm. In a minority of patient's contrast will reflux into the posterior urethra and bladder. Usually, however, with ascending urethrography the prostatic urethra is not demonstrated.

Female urethrography is rarely required, virtually all urethral pathology being better demonstrated on urethroscopy or trailsvaginal sonography.

Radiological anatomy

The male urethra

The male urethra extends from the bladder neck to the external urethral meatus (∼20 cm), passing through the body of the prostate gland, the urogenital diaphragm and the penis.

The male urethra is approximately 20 cm long and is divided into posterior (prostatic and membranous) and anterior (spongy) parts. The posterior urethra is 4 cm long and the anterior approximately 16 cm.

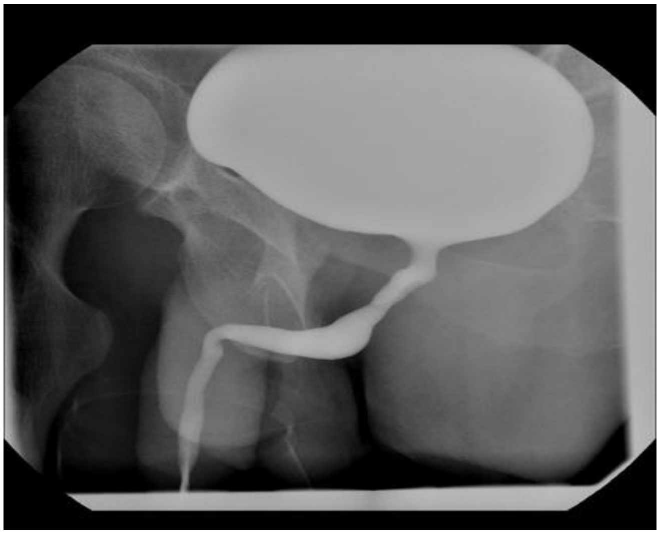
The prostatic urethra is 3 cm long. It is the widest part of the urethra. On its posterior wall is a ridge, the urethral or prostatic crest. In the middle of the crest is a further prominence, the verumontanum. On either side of this, the ejaculatory ducts open.

The membranous urethra, 1.5 cm long, runs through the external urethral sphincter within the urogenital diaphragm. This is the narrowest, most fixed part of the urethra and is therefore most prone to injury.

The spongy urethra is further subdivided into the bulbous and penile urethra. It is surrounded by the corpus spongiosum. The long penile urethra is relatively narrow apart from a dilatation within the glans penis, the navicular fossa. The external urethral orifice is narrow and calculi may lodge at this site.

The female urethra

This is 3–4 cm in length and extends from the neck of the bladder to the vestibule, where it opens 2.5 cm behind the clitoris.



normal voiding cystourethrogram

Patient preparation

There is no specific preparation for a urethrogram examination.

Advantages

- the method gives a clear picture of any changes in the bladder, whether these be of an organic or functional nature
- the micturition films also give important information regarding the urethra such as its course and degree of dilatation
- presence of the formation of valves, strictures, diverticula, etc
- x-rays usually have no side effects in the typical diagnostic range for this exam.

Disadvantages

- they do not give sufficient information about the mucosal pattern of the urethra - especially in its distal portion
- this investigation involves exposure to x-rays
- the contrast dye that is used contains iodine which some people are allergic to
- some children experience discomfort during urination immediately after the procedure; this discomfort usually resolves in less than 12 hours

9. *Computed Tomography*

Multidetector (spiral) CT (MSCT) is now the dominant radiologic imaging modality for evaluation of the urinary tract and adrenal glands. Several factors make CT quite effective. The high contrast and spatial resolution afforded by CT allow detection and evaluation of subtle differences in very small structures. Examinations can be performed quickly and reproducibly with thin CT slices of the entire urinary tract now obtainable in just a few seconds.

With these advances, CT can now be used to evaluate much of the urinary tract, including vascular, parenchymal, and urothelial components as well as adjacent structures including the adrenal glands.

It is used:

- in the characterization of renal masses
- staging of urinary tract tumours
- in the assessment of inflammatory processes
- in the assessment of traumatic processes
- detection calculi
- detection the causes of obstruction
- to direct biopsies and the positioning of percutaneous drains
- to assess renal artery stenosis
- for the detection of ureteric leaks or fistulae
- for investigation of living related donors before renal transplantation

Patient preparation

Patients with diabetes cannot take drugs containing Metformin (Glucophage, Glucovance, Metaglip, Actoplus, Prandimet, Kombiglyze, Janumet, Avandamet, Fortamet, and Riomet) on the day of the study and within 48 hours after.

Patients with allergies in the history of the disease recommends the following premedications:

- Take 30 mg prednisolone on the night before the scan.

- Another 30 mg prednisolone on the morning of the scan.

The patient should have nothing to eat or drink for a minimum of 3 hours prior to exam. The patient should drink 16 ounces of water 1 hour prior to the exam.

Non-IV Contrast examinations do not require special preparation.

Creatinine/eGFR is to be obtained for patients at risk for reduced renal function including the following:

- age 60 years and older
- history of multiple myeloma
- history of renal disease, renal transplantation, renal carcinoma, renal nephrectomy
- history of liver transplantation, hepato-renal syndrome
- history of sickle cell anemia
- diabetes
- history of hypertension requiring medical therapy

Creatinine needs to be drawn within 30 days of the exam date.

Procedure

Careful techniques and protocols are critical to CT accuracy. CT scans of the urinary tract may be performed with and/or without intravenous iodinated contrast material depending on the indications. CT performed without contrast is typically used for the detection of renal or ureteral calculi, for which it is exquisitely sensitive.

Additionally, noncontrast views of the kidneys serve as a baseline to evaluate for lesion enhancement after contrast administration, a critical factor in mass evaluation.

Intravenously administered iodinated contrast is excreted by the kidney primarily by glomerular filtration, opacifying the urinary tract progressively from the kidney through the ureter and to the bladder. Contrast "opacification" during CT is most accurate, exquisitely demonstrating and evaluating the urinary tract.

CTU is most often indicated for evaluation of hematuria and typically consists of three scanning phases:

- noncontrast
- nephrographic (90 seconds)
- delayed (8 to 10 minutes) excretory phase

The noncontrast phase allows for stone detection and serves as a baseline to assess possible mass enhancement. The kidneys are homogeneous and have a density similar to softest tissue.

The nephrographic phase is predominately used to evaluate the kidneys for mass lesions.

The excretory phase allows assessment of the collecting system, particularly for the detection of urothelial carcinoma.

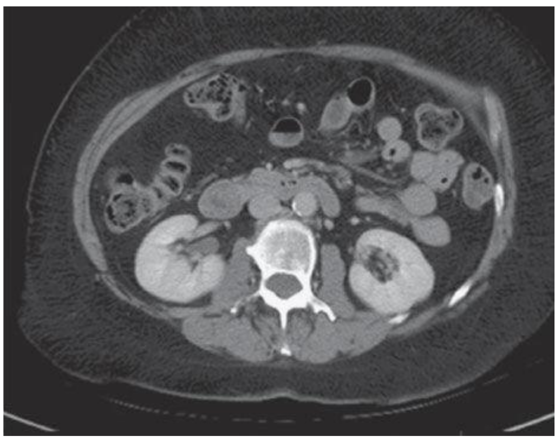
Frequently, the axial CT images are augmented with multiplanar and three-dimensional reconstructions.

With rapid scanning after contrast administration, several sequential phases of opacification within the kidney can be delineated by CT including the:

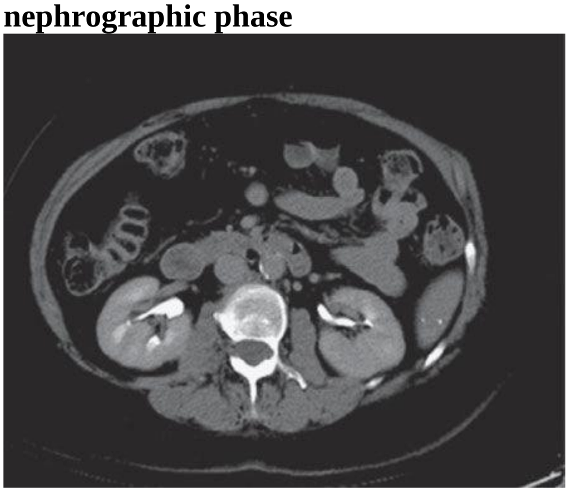
- corticomedullary
- nephrographic
- excretory phases

The corticomedullary phase can be seen if scanning is performed during the first 20 to 70 seconds after contrast administration and represents the early preferential blood flow to the renal cortex. Subsequently, contrast begins to pass into the distal collecting tubules within the renal medulla, resulting in a more homogeneous opacification of the renal parenchyma termed the CT ***nephrographic phase.*** This generally occurs around 90 to 120 seconds after contrast medium injection. Finally, the excretory phase is seen when contrast opacifies the collecting system. Each different phase of opacification may better demonstrate different disease processes, and thus various scanning protocols are used to evaluate the kidneys depending on the clinical indication.

noncontrast



nephrographic phase



excretory phase

On CT, the kidneys should be evaluated for size, location, orientation, and contour.

There are a number of causes of abnormal renal size, ranging from incidental anomalies such as congenital renal hypoplasia to clinically significant conditions such as renal artery stenosis (small kidney) or infiltrating renal neoplasm (large kidney). The kidneys should have a reniform shape and a smooth contour.

The kidneys should be evaluated for calcifications, hydronephrosis, and inflammation. A critical role for CT is mass/cyst detection and characterization.

CT is very specific in identifying a lesion as a simple cyst when the lesion is homogenous and of water density, typically -10 HU. Lesions of higher density may represent hyperdense (complex) cysts or solid masses, and further evaluation with contrast CT to detect enhancement may be needed to differentiate these causes.

Advantages

- CT scanning is painless, noninvasive and accurate
- CT examinations are fast and simple
- CT scan is an excellent tool to evaluate masses, traumatic injury to the kidney, stones, and pyelonephritis
- noncontrast helical CT scanning is the procedure of choice to evaluate kidney stones
- CT scanning is also used to differentiate malignant from nonmalignant renal masses
- moreover, CT scanning is essential to evaluate the local spread of a renal malignancy
- high sensitivity and specificity in diagnosing bladder pathology
- may further help define perivesical invasion and involvement
- may help guide treatment
- high-resolution CT angiography is excellent in defining the anatomy of the renal arteries and veins (eg, renal vein thrombosis)
- CT scanning is superior to ultrasonography in identifying renal cysts, since it is capable of detecting small cysts (2-3 mm in diameter)

- a CT scan, however, can be performed within just a few minutes, whereas delayed films are often required with an IVU
- CT is less sensitive to patient movement than MRI
- CT imaging provides real-time imaging, making it a good tool for guiding minimally invasive procedures such as needle
- a diagnosis determined by CT scanning may eliminate the need for exploratory surgery and surgical biopsy
- no radiation remains in a patient's body after a CT examination
- x-rays used in CT scans should have no immediate side effects

Disadvantages

- the primary limitation of CT scanning is the risk of radiation and administration of contrast
- contrast should be avoided if the patient is allergic, has renal failure, or is pregnant
- CT scanning has a higher radiation dose than plain x-ray

10. Magnetic resonance imaging (MRI)

Indications

- detailed assessment of the kidney anatomy
- noninvasive assessment of kidney function
- estimated glomerular filtration rate (GFR)
- assessment of congenital anomalies of the kidney, bladder, and urinary tract
- detection intraluminal neoplasia
- assessing size of lesions
- assessing adenopathy and involvement of other pelvic structures
- evidence of obstructed urinary tracts
- staging of malignant disease

- assessment of the viability of kidneys after transplantation
- assessment of renal injury in trauma

In children:

- MR urography can be used in the preoperative anatomic assessment of vascular anatomy
- in the evaluation of duplicated collecting systems
- in the evaluation renal dysplasia, ectopic ureter, retrocaval ureter, and primary megaureter
- distinguish hydronephrosis from cystic renal disease

Principle

The MRI urography requires neither ionizing radiation no iodinated contrast medium, and is capable of producing an image of the entire urinary tract in one imaging session.

Contrast media

Contrast media in MRI are agents capable of interacting with the magnetic fields of the tissues being imaged. In so doing, they cause a reduction in relaxation time and an increase in T1 signal intensity, depending on the perfusion of the tissue. There are three main groups of substances capable of acting as contrast media: ferromagnetic, paramagnetic and superparamagnetic. The most commonly used contrast medium in urological imaging is gadolinium (dimeglumine gadopentate or Gd-DTPA). This is a paramagnetic substance which can be given intravenously and the main effect of which is to increase the signal intensity on T1-weighted images.

Patient preparation

No patient preparation is necessary prior to this test.

On MR imaging, the kidneys appear of variable signal intensity depending on the imaging factors, and as in CT, contrast-enhanced phases of imaging (arterial, corticomedullary, nephrographic, and excretory) are all visible.

Magnetic resonance angiography has proven useful in the evaluation of stenosis in the mid and proximal renal arteries

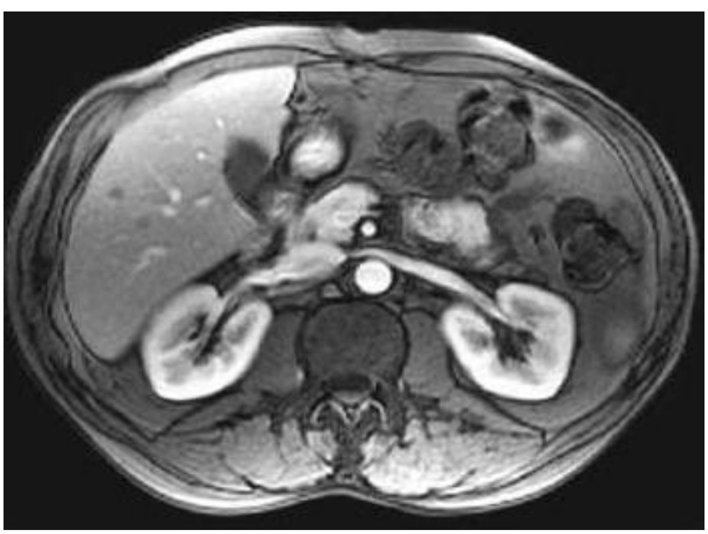
MRI anatomy

The normal anatomy of the kidney as seen on spin-echo sequences has been described. Using this method, fat has a short T1 value, consequently resulting in a high-intensity signal on the images. Therefore, the perirenal fat appears as a high-intensity area while the renal cortex is of lower intensity and the renal medulla lower still. A line of low signal intensity around the perirenal space indicates Gerota's fascia. The hilum of the kidney, with its blood vessels, also contains fat and gives an image of high signal intensity. Blood flow through these vessels produces a signal void and therefore they can be visualized within the hilum with no need for contrast medium.

The bladder is commonly imaged using sagittal and axial planes and a surface coil. This allows visualization of the bladder wall, the contents of the bladder, the extravesical fat and adjacent organs. The appearance of the normal bladder wall on MRI has been described as a single band of intermediate signal intensity on T1-weighted images, compared with T2-weighted images which show the wall to consist of two layers, the inner layer being of low and the outer layer being of intermediate signal intensity. Distinguishing these layers may not be possible if the bladder is trabeculated. These layers have been found to correlate with the inner and outer smooth muscle layers of the bladder on histopathological examination, the difference in signal intensities being caused by the density differences of the smooth muscle bundles in the different layers. The muscle layer between prostate and bladder can usually be visualized, although it is often very thin; in cases of BPH it may not be seen at all.

For normal anatomy, the prostate is best imaged in sagittal and coronal section, although transverse images also provide useful information. Both T1- and T2-weighted images are required to image the prostate fully, and STIR sequences may also assist in providing valuable information by suppressing the signal from fat. The normal prostate is homogenous with a medium-intensity signal on T1 weighting. It should be readily distinguished from adjacent structures such as the bladder base, rectum, fascia of Denonvillier and periprostatic fat. The seminal vesicles produce a similar signal to the prostate but are separate from the gland. Tumors of the seminal vesicle, such as the rare leiomyoma, have been described using endorectal coil imaging as a mass of low signal intensity arising from the seminal vesicle, not connected to the prostate or bladder. Endorectal coil imaging is required to visualize the true (anatomical) prostatic capsule, as this is too thin to be seen with body coil MRI.

On T1 weighting, BPH has a similar homogeneous medium-intensity signal to the normal gland, although the appearance on MRI can differ depending on the predominant constituents of the prostate. The appearances of four types of BPH on MRI have been described. The first is a type composed mainly of glandular tissue which tends to appear as nodules. When nodularity is present the prostate may have a heterogeneous appearance with higher signal intensity within the nodules. Second, BPH which is more fibromuscular produces a lower intensity signal without the heterogeneity of glandular tissue. BPH may also produce an enlarged prostate gland composed mainly of collagen and this produces lower signal intensity still. Finally, BPH made up of mixed elements of stroma and gland has a heterogeneous appearance. The glandular tissue produces an image of high signal intensity, whereas the stroma contrasts this with a low-intensity image.



MRI normal kidneys.

Advantages

- MRI images can be obtained in any plane
- the images can be obtained relatively quickly
- it does not involve the use of ionizing radiation and there is no evidence to suggest that the procedure causes cellular toxicity
- magnetic resonance imaging (MRI) provides a useful alternative to CT scanning in individuals at risk for toxicity from intravenous contrast
- magnetic resonance angiography has proven useful in the evaluation of stenosis in the mid and proximal renal arteries
- magnetic resonance urography is commonly used in children and pregnant women to avoid the risk of ionizing radiation
- the contrast material used in MRI exams is less likely to produce an allergic reaction than the iodine-based contrast materials used for conventional x-rays and CT scanning.

Disadvantages

- the major limitation of MR urography is the limited sensitivity for calculi relative to CT
- this technique is limited to use in patients with distended urinary collecting systems
- it is also a relatively expensive procedure

the image may be subject to distortion by metal foreign bodies, causing the production of artefacts

11. Nuclear medicine

11.1 MAG3 renography

99mTc-MAG3 (mercaptoacetyltriglycine) has become the agent of choice for dynamic radionuclide imaging of the renal tract in most centers. It was first developed as an alternative to hippuran, but has a plasma clearance 50–65% slower than that of hippuran. Nevertheless, it gives images comparable to 123I-hippuran. Following intravenous injection, it remains loosely bound to serum proteins, and only a small proportion undergoes glomerular flirtation. Clearance is predominantly by tubular secretion. The 30-minute excretion of 99mTc-MAG3 is approximately 70%, and by 3 hours 90% of the tracer is cleared by the kidneys. Renography can be combined with administration of a diuretic (usually frusemide) to produce a high urine flow diuresis renogram. The 99mTc-MAG3 is an adequate tool for the assessment of urinary uptake, transit, excretion, and split renal function. In addition, simple conversion methods will allow reproducible estimations of ERPF from the 99mTc-MAG3 activity curve.

Indications

- assessment of whole or relative kidney function
- before and after surgical intervention (e.g., pyeloplasty, partial/total nephrectomy)
- investigation of acute or chronic renal failure
- assessment of the transplanted kidney
- assessment of renal function following trauma
- assessment of kidney drainage in obstructive uropathy (e.g., uretero-pelvic junction obstruction, renal stones)
- assessment of congenital renal abnormalities (e.g., duplex, horseshoe, absent, ectopic, or cystic kidneys)
- identify vesico-ureteric reflux

Patient preparation

- adequate hydration (500 mL of oral fluid 15–30 min before examination) is vital to ensure good diuresis (urine flow of 1–3 mL/min). Avoid study if patient appears clinically dehydrated

Procedure

The patient may be placed supine or erect, reclining against the camera**.** Assess need for catheterization. If not, patient must void before study.

Position patient in either supine or sitting up position. The posture of the patient may have an effect on the renography curve.

A typical adult dose of 50–120 MBq is carefully injected intravenously to avoid local extravasation. An image is taken every 10–20 seconds for up to 40 minutes following administration of radiopharmaceutical.

Analog images are taken every 5 minutes and the hard copy must include several serial analog images as well as the renogram curve. The first 12 and last 12 frames may be summed to exhibit the kidneys more clearly. If the kidney fails to empty by 20 minutes, frusemide may be administered (F+20). Data is collected for 30–45 minutes (or 20 min following diuretic injection). The patient is asked to void at the end of the procedure (minimizes radiation to the bladder as well as allowing assessment of urine production rate). The renogram curve demonstrates change in kidney activity over time.

The radiation activity detected by the gamma camera is first stored as a computer image. Regions of interest (ROI) are mapped out for the kidneys and bladder, in addition to a background region to enable precise measurement of activity count for each time frame. The background region is usually chosen just lateral to the kidneys, but care must be taken to avoid the liver, due to its high tracer uptake.

Additional ROIs (different moieties of a duplex kidney) may also be delineated.

The renogram curve can be obtained following subtraction of the background count from the kidney and bladder ROI count and is displayed as a percentage of the injected dose (y-axis) against time (x-axis). The relative function of each kidney is calculated by comparing the percentage dose at 2 and 3 minutes' uptake. Following the procedure, the patient is informed about the possibility of a prolonged diuresis. Frequent voids will help reduce bladder irradiation.

Diuresis

If diuresis renography is indicated, an intravenous bolus of frusemide (dose 1 mg/kg in infants, 0.5 mg/kg in children aged 1–16 years, and 40 mg in adults) is commonly used. Ensure there are no contraindications to diuretic therapy. Frusemide will produce a maximal diuretic response within 5–10 minutes and rationale is to increase the sensitivity of the dynamic renal study by increasing urine flow rates to stress the system, such that minor degrees of obstruction are unmarked. The timing of diuretic administration is a matter of local policy but the various techniques have distinct advantages. The traditional technique
(F+20) involves frusemide administration 20 minutes after injection of the radiopharmaceutical. The study must continue for at least 20 minutes following frusemide injection. This enables study of initial unmodified renal handling, followed by the response to increased urine flow rate.

The F-15 technique (frusemide given 15 min before radiopharmaceutical) ensures maximal diuresis at commencement of data acquisition, thereby revealing minor levels of obstruction. Administration of the tracer simultaneously with frusemide (F+0 technique) has been practiced in pediatric units and has the advantage of significantly reducing examination times. The F+0 technique is not recommended in patients with significant renal failure (GFR < 15 mL/min per kidney) and renal units with significant hydronephrosis.

The timing of diuretic does not significantly alter split renal function result, but centers should standardize practice to enable meaningful comparisons (e.g., before and after surgical intervention). The F-15 technique will separate the majority of equivocal curves on F+20 renography in to either unobstructed or obstructed, and therefore is preferred in patients with equivocal results or with gross hydronephrosis.

Factors influencing MAG3 renography

***1. Renal function*: ** a GFR of <15 mL/min per single kidney will result in urine flow rates of <10 mL/min, with poor subsequent tracer washout. This may result in an "obstructed" (false positive) curve. Frusemide is usually insufficient to increase diuresis significantly and perfusion pressure-flow studies (Whitaker test) ought to be considered. Renal disease affecting the parenchyma (e.g., acute tubular necrosis) may diminish the response to diuretics.

2. Hydration: minor levels of obstruction may be masked in dehydrated individuals. In addition, diuretic administration may be perilous if the patient is already dehydrated. Oral hydration (500 mL of water 30 min before study) will usually suffice although on occasions intravenous fluids may be required.

3. *Collecting system capacity:* in the massively dilated system, urine flow may be inadequate to prevent tracer accumulation in the renal pelvis. In such cases, a false-positive "obstructed" curve may be the end result. The F-15 technique will help minimize the effects of a capacious system.

4. *Collecting system compliance:* increased diuresis, within a normo-compliant system, should result in distension of the renal pelvis with no signify can't increase in pressure. However, poor compliance may cause rapid elevations within a non-dilated system, such that any obstruction is overcome and there is reasonable tracer flow distal to the obstruction (false negative). Conversely, a hyper-compliant upper tract will result in renal pelvic tracer accumulation, in spite of the absence of obstruction, resulting in a false-positive curve.

5. *Bladder effects:* a full bladder may inhibit drainage from the ureters and cause artifacts. The patient must be asked to void prior to commencement and again before completion of data acquisition. Alternatively, in patients with chronic retention or a neurogenic bladder, catheterization should abolish any effects of a full bladder.

6. *Ureteric dilatation or obstruction*: in cases of gross ureteric dilatation, an ROI drawn around the kidney and renal pelvis may miss the distal obstruction, resulting in a false-negative study. Care must be taken to study the analog images and ROI
must include the ureter proximal to the obstruction. Furthermore, multiple simultaneous levels of obstruction will not be apparent by MAG3 renography.

The maximal recommended activity per test is 100 MBq for MAG3 renography, which corresponds to an effective radiation dose of 1 mSv (equivalent to 6 months of background radiation).

Interpretation

Normal renogram curve

The shape of the renogram curve (following subtraction of background activity) is dependent on—

1. MAG3 uptake from blood into kidney
2. MAG3 elimination from kidney into bladder

Classically, the normal MAG3 renogram curve has **three phases:**

• ***The first phase***: steep upward rise following intravenous contrast injection; this is indicative of the speed of tracer injection and its delivery to the kidneys (i.e., renal vascular supply).

• ***The second phase:*** a more gradual slope which represents renal handling of MAG3 (renal uptake by tubular secretion and glomerular filtration) and peaks between 2 and 5 minutes. Time taken for the curve to peak following tracer injection is referred to as Tmax. This may be delayed in patients with renovascular insufficiency, renal failure, and obstruction

• ***The third phase:*** commences after the peak. Associated with the emergence of tracer in the bladder. Represents elimination (but also delivery) of tracer from the kidney. After 3 minutes both elimination and uptake are in competition, but the former subsequently dominates. It is this elimination curve that is dependent on the upper tract urodynamics. The elimination curve may have a smooth or stepwise (variant of normal) pattern and when normal, excludes the presence of obstruction.

A delayed upward deflection may indicate intermittent obstruction or vesico -ureteric reflux.

Renogram curve patterns

When interpreting MAG3 renography, five distinct patterns (based on the F+20 technique) are recognized. It is important not merely to assess the shape of the curve, but also to examine the sequential analog images to determine the level of obstruction, as the calyces, pelvis, and ureter may all be easily visible

Type I—normal response

This is characterized by a rapid uptake curve leading up to a peak within 2–5 minutes, followed by gradual (but sometimes stepwise) elimination of tracer. Administration of furosemide results in no appreciable difference in speed of elimination. A normal curve virtually excludes obstruction, although it may be argued that increasing urine flow rate (i.e., using the F-15 technique) may expose lesser degrees of impedance.

Type II—obstructive response (high-pressure system)

In the absence of any other factors affecting drainage (e.g., dehydration, renal impairment, etc.), an obstructive pattern is denoted by a rising curve. In addition, the lack of an exponential tracer elimination curve is also suggestive of a degree of obstruction. Typically, there is little or no response to frusemide. On the analog images, the affected kidney will often display good parenchymal uptake and accumulation of tracer above the level of obstruction (e.g., in the renal pelvis in patients with UPJO). The diagnosis of obstruction cannot be satisfactorily made (even in the presence of a rising curve) if the affected kidney has a GFR of <15 mL/min, since the rate of urine production may be in sufficient to produce tracer washout (usually 1–3 mL/min urine production is required).

Type IIIa—dilated but not obstructed (low pressure/hypotonic system)

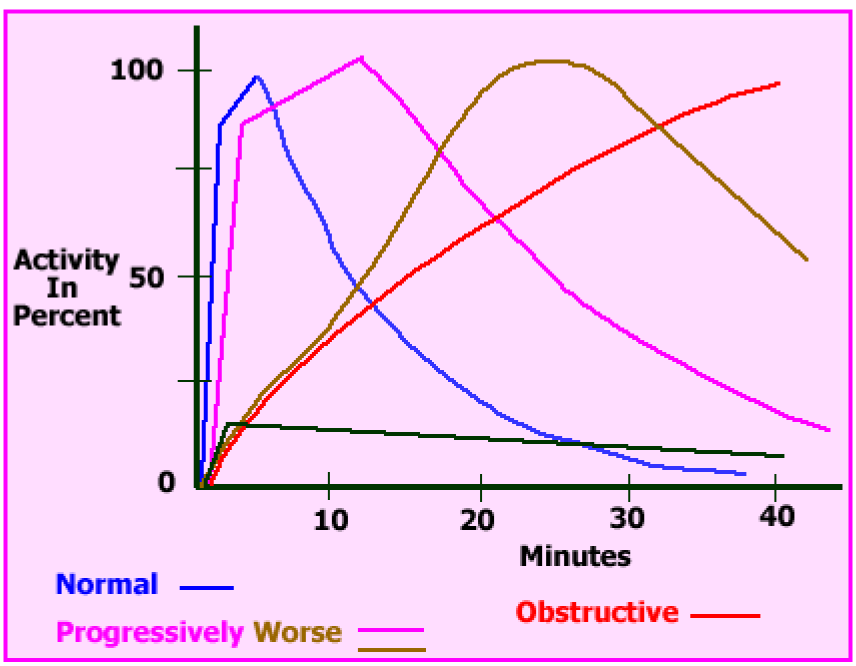
There is an initial accumulation of tracer in the kidney, resulting in a rising curve similar to an obstructive response, but there is prompt elimination following furosemide injection. The analog images usually demonstrate tracer accrual in a dilated system secondary to stasis rather than obstruction. The increased urine flow produced by the diuretic is adequate to effect free drainage.

Type IIIb—equivocal response

Following an initial “obstructed” rising curve, a furosemide injection produces a somewhat languid response. The curve demonstrates some tendency to washout, albeit incompletely. Examination of the analog images may help clarify whether this represents partial obstruction or inadequate tracer elimination (e.g., due to a dilated renal pelvis). In this situation, an F-15 study will help categorize the majority of equivocal curves into either obstructed or non-obstructed.

Type IV—delayed compensation (Homsy’s sign)

Described by Yves Homsy in 1988, the characteristic shape is a “double peak” response to diuretic. This pattern is seen in patients with subclinical intermittent obstruction. A repeat F-15 diuresis renography will often reveal an obstructed pattern. The first “peak” is due to an initial rising curve, which then exhibits a good response to furosemide. However, as the diuretic effect increases, the threshold is reached and tracer accumulation causes the curve to either flatten or rise.



https://www.people.vcu.edu/~mhcrosthwait/clrs319web/renalcurves.html

11.2 DMSA renography

• 99mTc-DMSA ***(dimercaptosuccinic acid)*** has a high affinity for the renal cortex

• 99mTc-DMSA is the preferred radiopharmaceutical for static parenchymal imaging

Provides the most accurate assessment of relative renal function compared to other tracers.

Following tracer injection, 99mTc-DMSA is mostly plasma protein bound, and therefore clearance by GFR is minimal. In the kidney, the cells of the proximal convoluted tubules (and the distal tubules to a lesser extent) extract the 99mTc-DMSA by tubular secretion allowing slow concentration of radioactivity in the renal cortex. After 3 hours, about 50% of the injected tracer is concentrated in the kidneys, remaining there for up to 24 hours. The majority of the other 50% is excreted unchanged in urine. Increased hepatic accumulation, and subsequent biliary excretion is noted in patients in renal failure. Owing to the slow renal extraction of 99mTc-DMSA, the optimal time for imaging is between 2 and 4 hours after tracer injection. 99mTc-DMSA scanning represents functioning tubular mass, yields excellent cortical images, and is an invaluable tool in the assessment of both adults and children.

Indications

• assessment of relative renal function

• detection of renal scarring with a sensitivity of 96% and specificity of 98% (due to urinary tract infections or reflux nephropathy in children)

• investigation of renal anomalies (e.g., horseshoe, solitary, or ectopic kidneys)

• examination of space occupying renal lesions

Interpretation

Normal kidneys should have a homogenous parenchymal distribution with visible demarcation between the cortex and medulla. Preservation of cortical thickness is indicative of acute changes, while cortical thinning is in keeping with chronic damage. The size, shape, and location (normal or ectopic) of the kidneys is readily demonstrated.

Scars or other deformities are seen as areas of decreased or absent activity within the parenchyma.

Artifacts may arise in kidneys with congenital fetal lobulations or due to splenic overlapping of the left kidney.

Advantages

• provides excellent cortical images

• accurate split renal function estimation

• non-nephrotoxic

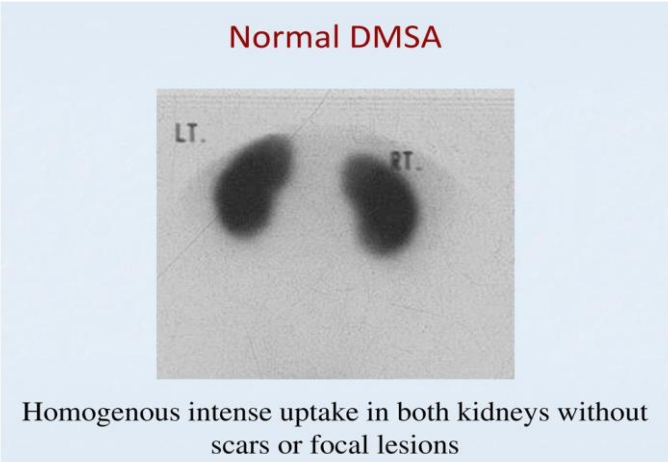
• no signify can't complications

• allergic reactions are exceptionally rare

Disadvantages

• involves radiation

• does not allow dynamic assessment of renal excretion



Renal Scintigraphy (part 1) - ppt download

12. Positron emission tomography (PET) scan

PET is a nuclear medicine functional imaging technique that is used to observe metabolic processes in the body. The system detects pairs of gamma rays emitted indirectly by a positron-emitting radionuclide (tracer), which is introduced into the body on a biologically active molecule. Three-dimensional images of tracer concentration within the body are then constructed by computer analysis. In modern PET-CT scanners, three-dimensional imaging is often accomplished with the aid of a CT X-ray scan performed on the patient during the same session, in the same machine.

Indications

PET may contribute in the following pathological processes:

- Testicular tumors
- primary tumor staging
- early detection of recurrent disease
- assessment of residual tumor burden after therapy
- Renal cell cancer
- initial staging of local and distant disease
- detection of recurrence
- bladder cancer
- detection of recurrent disease (if other imaging ambivalent)
- Detection of bony metastases (if bone scan equivocal)

The are no specific contraindications to PET scanning except for women who are pregnant and breastfeeding.

Patient preparation

• patients advised to avoid food for 4–6 hours and oral intake restricted to non-sugary clear fluid

• blood glucose estimation is performed just prior to the examination to ensure low glucose levels (high levels inhibit FDG uptake by cells)

• in addition, buscopan (20 mg) and/or diazepam may be administered to reduce FDG uptake by the intestines and muscles, respectively

• a preliminary background scan is performed before up to 400 MBq of FDG is injected intravenously

• imaging is performed between 45 and 90 minutes after tracer injection

• a whole body scan can be performed or imaging restricted to the area of interest, with or without simultaneous CT scanning

A maximal injected dose of 400 MBq corresponds to an effective radiation dose of 10 mSv (equivalent to up to 6 years of background radiation).

Interpretation

Since FDG-PET is a function of glucose metabolism, any organ with a higher metabolic rate will demonstrate greater tracer activity under normal circumstances (e.g., brain, intestines, liver, heart, etc.). Tracer uptake by malignant lesions will also depend on the rate of glycolysis. Although most tumors will demonstrate an inherently higher metabolic rate, some tumors (e.g., prostatic cancers) may have decreased proliferative activity and therefore not be apparent on PET images. The lower limit of the size of lesion detectable by PET scanning is 5 mm in diameter but is likely to improve in the future with improved resolution scanners PET is inferior to conventional bone scintigraphy in the detection of skeletal metastases but can be used to provide additional information if the latter is equivocal.

Advantages

• uses biologically important radionuclides to provide pertinent functional and metabolic information

• proven efficacy in other non-urological cancers

• generally high specificity for malignant disease

• whole body can be imaged at once

• spatial resolution of 5 mm

• can be combined with simultaneous CT to improve image resolution

Disadvantages

• involves radiation

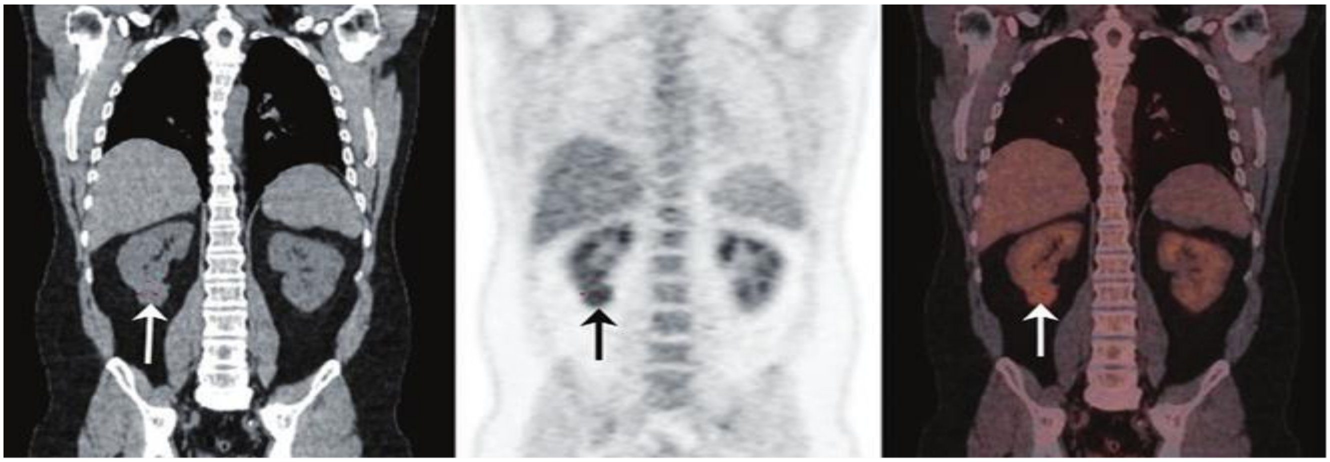
• length of procedure

• expensive (cost of collimator, scanner, and radiochemistry facility is high)

• radionuclides with a short half-life may need to be produced on site

• lack of anatomical landmarks (especially in the thorax and
abdomen)

• urinary excretion limits detection of bladder and prostate malignancies



Renal Scintigraphy (part 1) - ppt download
(PET)/CT appearances of a renal cell carcinoma (RCC) with intermediate grade uptake.

13. Renal angiography

Angiography, the study of the vascular system, is performed by injection of water-soluble contrast media intra-arterially (or intravenously, for venous studies) through a percutaneously placed catheter under fluoroscopic guidance. Pathologic processes involving both the vasculature and parenchyma can be characterized by fluoroscopic monitoring using either digital or conventional image recording.

Indications

• ***assessment*** of vascular disease (atherosclerosis, aneurysm, vaculities)

• determination of vascular injury

• vascular mapping for preoperative purposes (organ transplantation) or prior to therapeutic interventions (stent placement)

• detection arteriovenous malformations and fistulas

• characterization of tumor vascularity prior to endovascular procedures (embolization)

• assessment of renal masses

• differentiation renal cysts from tumors

• evaluation hypertension

• angiography of the bladder and prostate is also largely performed as a prelude to intervention for troublesome or life-threatening hematuria, either due to inoperable tumor or postsurgical (usually transurethral prostatectomy) bleeding

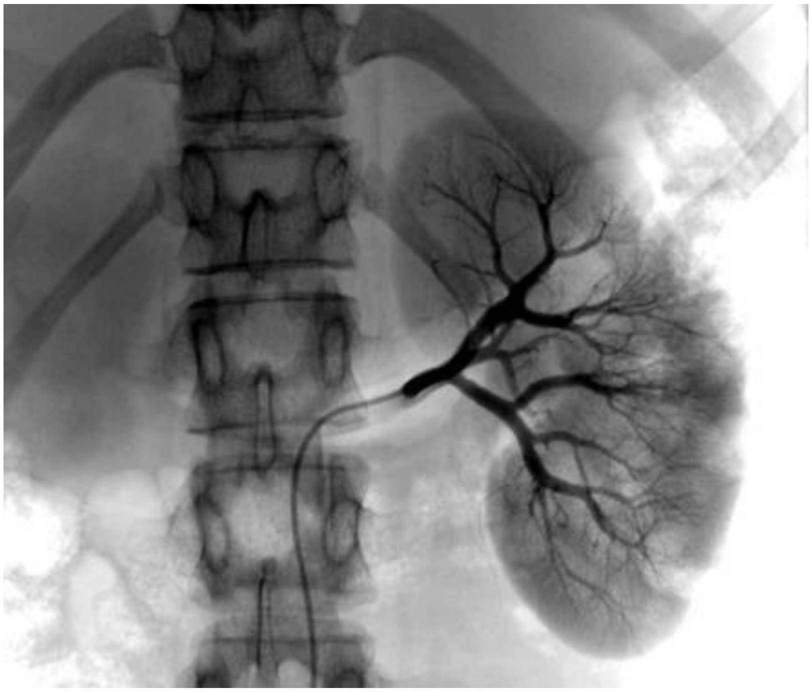
Patient preparation

Before the procedure, a laxative may be prescribed to evacuate the colon so that unobstructed x-rays can be obtained.

Procedure

The renal arteriogram is performed after puncture of a more peripheral vessel such as the common femoral artery, with advancement of a catheter into the renal artery origin. Contrast material is injected via the catheter and rapid, typically digital, conventional radiographic images are obtained. The renal arterial vessels are well demonstrated, along with nephrographic images of the kidney and views of the venous drainage.

Delayed images may be obtained to demonstrate the renal collecting system.



https://radiopaedia.org/cases/renal-angiogram-arterial-anatomy
Renal angiography

14. CT angiography

CT angiography is an extremely useful investigation but exposes the patient to a considerable amount of radiation and should not therefore be used as a first-line investigation.

Indications

- renal artery stenosis
- renal artery aneurysm, dissection or thrombosis
- arteriovenous malformation
- delineation of vascular anatomy prior to laparoscopic surgery
- renal vein thrombosis
- tumor

Patient preparation

The same preparation as for CT.

Advantages

- CT angiography is a powerful and cost effective tool for vascular imaging suited for critically ill patients
- CT angiography provides excellent spatial resolution in all directions
- images can be reconstructed in multiple planes and maximum intensity projection performed for a 3D display

Disadvantages

- in comparison with MRI angiography, CT angiography needs an iodinate contrast medium; this is an imperative drawback of CT angiography and may be unacceptable in those patients with severe renal dysfunction
- CT angiography is somewhat low resolution examination in comparison with catheter angiography
- CT does not allow for functional measurements such as flow direction or flow rates

- in patients with larger body habitus, CT angiography performed with narrow collimation can have an unacceptably low signal - to - noise ratio.

15. MR angiography

Magnetic Resonance Angiography involves the use of magnetic resonance imaging to examine blood vessels in key areas of the body.

Indications

- renal vascular malformation
- for the evaluation of renal artery stenosis
- hypertensive chronic kidney disease
- atherosclerotic renal artery stenosis
- fibro muscular dysplasia
- renal artery aneurism
- renal artery dissection
- renal donors

Advantages

- no ionizing and safe
- the main advantage of MRI over CT is that it gives far better contrast resolution (the ability to distinguish the differences between two arbitrarily similar but not identical tissues) and thus its ability to demonstrate changes between normal and pathological tissues
- MRI angiography can produce images in any plane
- MRI angiography can be performed with or without the use of IV contrast materials; this concept is quite beneficial to those patients with severe contrast allergies, as well as those with poor kidney function

Disadvantages

- has been image degradation by patient movement (especially respiration), inability to see distal renal arteries and poor resolution compared with CT

- invasive procedure

16. Image-guided urological interventions

Uroradiological interventions may be broadly classified as ***non-vascular and vascular.***

Non-vascular procedures mainly include tissue sampling (fine needle aspiration or biopsy), percutaneous nephrostomy (PCN) and stone extraction.

Vascular procedures mainly include embolization of pseudoaneurysms, arterio-venous malformations and fistulas most commonly presenting with hematuria. Others include prostate artery embolization (PAE), recanalization of renal artery stenosis (RAS), gonadal vein embolization (varicocele, pelvic congestion syndrome), etc.

Anatomical location, use of iodinated contrast and real-time guidance are the most important factors in choosing a preferred imaging modality.

16.1 Non-vascular procedures

1. Tissue sampling

Imaging-guided percutaneous renal biopsy has evolved to become
a safe, minimally invasive technique to sample renal parenchyma for the evaluation of malignancy or diffuse renal disease. Current biopsy techniques involve CT or ultrasound guidance with small-gauge needles. The risks of renal biopsy are minimal.

Image-guided urologic biopsies include

- non-focal biopsies
- focal renal biopsies
- renal cyst aspiration
- adrenal biopsy
- transrectal prostate biopsies

a) Non-focal renal biopsy

Indications

- histological characterization of renal parenchymal diseases
- unexplained acute or rapidly progressive renal failure
- nephrotic syndrome and significant non-nephrotic proteinuria
- persistent glomerular hematuria
- systemic diseases with renal involvement
- renal allograft dysfunction.

Procedure

After placing the patient in the appropriate position (supine for transplant and prone or prone oblique with target side dependent for native kidneys), the biopsy needle (15–18 G) is advanced obliquely into the renal cortex near the lower pole. The cortical sample ensures that the specimen contains a few glomeruli necessary to make a diagnosis. Puncture of the renal medulla or renal sinus must be avoided.

b) Biopsy of renal masses

Indications

- differentiation benign small renal masses from tumors
- differentiation a concurrent renal cancer from a metastasis in known primary extra-renal malignancy

Procedure

Renal mass biopsy may be performed under CT or USG guidance. If the mass is not visible on a non-contrast CT scan, it may be demonstrated following administration of intravenous iodinated contrast. The mass is first approached using a 17 G cannula into which an 18 G coaxial biopsy needle or gun is introduced to obtain several cores. The use of a co-axial system allows multiple samples to be taken by only one puncture of the renal capsule.

c) Renal cyst aspiration

Minimally invasive techniques are currently used to treat symptomatic renal cysts.

Indications

- aspiration is performed to differentiate benign cysts from malignant cysts (renal cell carcinoma RCC)

Procedure

The technique is identical to focal renal biopsies. Aspiration can be coupled with biopsy if the cyst wall has solid nodule(s). Various techniques like injection of water-soluble contrast or air may be used to make such nodules apparent on non-contract CT.

d) Adrenal biopsy

The adrenal glands are an important site of both primary and secondary disease processes. Image-guided percutaneous biopsy of the adrenal gland is an accurate and safe alternative to surgical biopsy.

Indications

Clinical scenarios in which needle biopsy may be indicated:

- include an adrenal lesion in patients with multiple malignancies
- the need for staging a known malignancy
- defining an unknown primary source
- or differentiating benign from malignant adrenal masses with equivocal imaging findings

Procedure

It can be easily performed using CT or sonographic guidance. For the histologic diagnosis of right adrenal masses that are either invisible or inaccessible via the standard extrahepatic route, the transhepatic core route appears to be feasible and safe. CT-guided adrenal biopsy has a high success rate (80–95%).

Image-guided percutaneous biopsy of the adrenal gland is usually performed under CT guidance via an anterior transhepatic/transpancreatic approach, a lateral transhepatic/transsplenic approach or a posterior transpulmonary/transpleural approach.

The ideal body position to carry out biopsy varies from patient to patient. The preferred position is the one that makes the patient more comfortable during the procedure, which in the majority of cases is the prone position. However, in some cases the oblique or lateral position is required to move structures that are in the needle path, such as the lung and inferior vena cava. In the lateral or oblique position, the inferiorly located lung tends to expand less, thereby reducing the risk of pneumothorax. In cases of right adrenal biopsy, in which the inferior vena cava lies on the needle path, the left lateral or oblique position can help to move it and improve access for biopsy.

e) Prostate biopsy

A prostate gland biopsy is a test to remove small samples of prostate tissue to be looked at under a microscope. The tissue samples taken are looked at for cancer cells.

Indication

- suspicion of prostate cancer based on abnormal digital rectal examination and/or elevated serum prostate-specific antigen (PSA) levels

Procedure

It is most commonly performed using transrectal ultrasound (TRUS) guidance with the patient in the left lateral decubitus position. For a prostate biopsy, a thin needle is inserted through the rectum (transrectal biopsy), through the urethra, or through the area between the anus and scrotum (perineum).

2. Drainage procedures

Drainage procedures are either used to divert an obstruction or to drain collections.

a) Percutaneous nephrostomy (PCN)

Percutaneous nephrostomy, or nephropyelostomy, is an interventional procedure that is used mainly in the decompression of the renal collecting system.

Indications

There are four broad indications for the placement of a PCN:

- relief of urinary obstruction
- diagnostic testing
- access for therapeutic interventions
- urinary diversion

Procedure

A posterolateral sub-costal approach targeting the lower (or middle) calyx prevents entering through the pleural recess and permits access through the Brodel's avascular plane of the kidney. A soft tip wire is then inserted into the collecting system and is replaced with a stiff wire using a 6 F fascial dilator. The tract is serially dilated up to 8 or 10 F and a pigtail catheter or Malecot nephrostomy tube is then placed into the renal pelvis. The latter is a better choice if the collecting system is either small or filled with calculi.

b) Suprapubic catheter

Indications

- acute and chronic urine retention that cannot be adequately drained with a urethral catheter or where urethral catheterisation is contraindicated
- preferred by patient due to needs for comfort and access to catheter care, such as wheelchair user
- acute prostatitis
- obstruction, stricture, abnormal urethral anatomy
- traumatic injury to lower urinary tract or pelvic trauma
- to minimise complications of long-term urethral catheterisation, such as urethral trauma
- when long-term catheterisation is used to manage incontinence

- complex urethral, abdominal surgery or gynecological surgery
- faecally incontinent patients who are constantly soiling urethral catheters or experience moisture lesions
- sexually active patients
- neuropathic disorders causing frequent catheter expulsion
- restricted hip mobility, spasticity

Procedure

It may be inserted under ultrasound guidance or even fluoroscopy in a contrast-opacified urinary bladder. A 12 F Foley catheter loaded over a trocar is used to enter the bladder.

A urinary bladder catheter inserted through the skin about 1 inch above the symphysis pubis. It is inserted under a general or local anesthetic. It is used for closed drainage and may be left in place for a time, sutured to the abdominal skin.

3. Stone management

Ureteric stent

Ureteral stenting help restore urine flow through blocked ureters and return the kidney to normal function.

Indications

Stents may be uses for a short of long-term period depending on the indication:

- obstruction from urolithiasis
- malignant obstruction (typically pelvis malignancies)
- benign strictures
- retroperitoneal fibrosis

Procedure

An antegrade, percutaneous route may be required to place a ureteric stent. The choice of approach (retrograde or antegrade) is based on the accessibility and the location of ureteric pathology.

4. Thermal ablation for renal cancer

It is providing local treatment for renal carcinomas in patients unsuitable for surgery. Patients having renal insufficiency at presentation and tumors requiring a more nephron-conserving approach (solitary kidney, multiple synchronous RCC, von Hippel Lindau/familial RCC) are also candidates for these minimally ablative therapies.

Indications

- renal cell carcinoma of a single or transplanted kidney, when even an organ-preserving operation can disrupt the function of the kidney
- synchronous bilateral primary renal cell carcinoma
- patients with von Hippel-Lindau syndrome, prone to the development of renal cell carcinoma with multifocal growth, for which alternative treatment can only be bilateral nephrectomy followed by dialysis
- unwillingness of the patient or the inability to perform an organ-preserving or organ-bearing operation due to severe physical status

Procedure

An important aspect of the preparation for the intervention is to determine the distance between the tumor and the renal hilum as the local thermal ablation effect may be reduced by heat loss via blood and urine flow close to the target tissue volume (heat sink effect).

Radiofrequency ablation (RFA) and cryoablation (CA) are typically performed under sedation and analgesia. The ablation probe is inserted percutaneously into the target lesion under tomographic guidance. Where bowel is located immediately adjacent to the tumor, a safety distance to the ablation probe can be created by means of hydrodissection. This is achieved by advancing a 20G tap cannula between the tumor and the bowel and then injecting 100–500 mL of 5% dextrose solution or air to create a protective thermal insulation zone.

5. MR-guided ablation of prostate cancer

Focal ablative therapy of prostate cancer is an emerging therapy that is being investigated for the treatment of localized tumor.

Indications

- treatment of localized tumor

Procedure

Laser ablation refers to the destruction of tissue using a focused beam of electromagnetic radiation emitted from a laser. Other terms for laser ablation include photothermal therapy, laser interstitial therapy, and laser interstitial photocoagulation.

The principle of focal laser ablation therapy is to destroy a tissue target using laser radiation energy. The resulting rapid temperature elevation of the targeted tissue induces protein denaturation, resulting in in vivo tissue destruction. Prostate tissue is well suited for focal laser ablation due to its optical absorption rate without excess vascularity, which allows for finely controlled ablation.

Accurate ablation of the target is accomplished through transperineal or transrectal introduction of a laser fiber into the focal abnormality. Accurate laser fiber localization to soft tissue targets is feasible, and real-time MRI during the ablative procedure allows precise estimates of the extent of tissue necrosis.

Minimal thermal destruction to surrounding tissues and neurovascular structures is achieved through real-time monitoring during the tissue ablation. This can be achieved by proton-resonance frequency (PRF) shift MR thermometry, which allows near real-time quantification of temperature using changes in the phase of gradient-recalled echo (GRE) images to estimate relative temperature changes (ΔT).

6. Contrast-enhanced ultrasound (CEUS)-aided renal biopsy

Indications

- acute renal failure (ARF)
- suspicious vascular origin

- suspicious renal lesions

Procedure

CEUS uses stabilized microspheres filled with gas as a new type of ultrasound contrast (sulfur hexafluoride) medium. It enhances tumors and other vascular structures without the use of potentially nephrotoxic iodinated contrast media. Ultrasound contrast is excreted via the lungs and has no serious side-effects. Currently, there is paucity of literature using CEUS-assisted renal biopsy.

16.2 *Vascular interventions*

1. *Endovascular embolization*

It is a minimally invasive procedure where the lumen of the intrarenal vessel is occluded by embolizing material.

Indications

- include persistent hematuria as a result of pseudo-aneurysm
- arteriovenous fistula following a biopsy
- surgical or accidental trauma
- it is also employed to reduce vascularity of renal tumors, e.g. angiomyolipoma or renal carcinoma prior to surgery

Procedure

Vascular access is generally obtained via the common femoral artery with an 18- or 19-gauge puncture needle via a modified Seldinger puncture technique. If the femoral arteries are occluded, an alternative access site such as the axillary or brachial artery can be used. While a 5-French sheath is generally used, a larger caliber sheath may be needed for more complex procedures that involve balloon catheters.

Gel foam and vascular coils are the usual materials used for this purpose.

2. Transjugular renal biopsy

Transjugular renal biopsy (TJRB) is still a novel technique of renal tissue sampling exploiting the transjugular route.

Indications

The procedure is carried out in patients where percutaneous biopsy is contraindicated, usually due to a deranged coagulation profile.

Procedure

A special biopsy needle is wedged into the peripheral renal vein branch via the transjugular route. It provides diagnostic yield and safety similar to percutaneous renal biopsy. It has an added advantage that it allows multiorgan biopsy during the same procedure, e.g. simultaneous liver and renal biopsy.

3. Gonadal vein embolization

Indications

It is performed in males for scrotal varicocele causing pain and infertility and in women for pelvic congestion syndrome as a result of retrograde flow in incompetent ovarian veins, causing chronic pelvic pain. The veins are approached via a jugular or femoral route.

Procedure

After diagnostic angiography, the veins are embolized using steel coils. The clinical outcomes of technically successful percutaneous internal spermatic vein embolization are similar to surgical treatment. In both-sided varicocele, treatment can be performed in the same session through the same skin entry site. In surgery, two different incisions are necessary.

- ***Prostate artery embolization***

This is a new, minimally invasive endovascular technique to treat lower urinary tract symptoms due to benign prostatic hypertrophy. It is undertaken sporadically in few centers in patients, especially with prostates over 80 g, who are refractory to medication or at high risk for surgery.

Indications

- lower urinary tract symptoms (LUTS) secondary to benign prostatic hyperplasia (BPH)

Procedure

It is performed under local anesthesia as an outdoor procedure with low morbidity and rapid recovery. The prostate arteries arising from the anterior division of the internal iliac artery are super selectively catheterized followed by slow injection of diluted embolic agents. Both polyvinyl alcohol (PVA) (size 100–200 μm) and gelatin microspheres have been used. The end point is identified by near stasis of flow in the injected arteries and gland opacification.

6. Renal sympathetic denervation

Is a minimally invasive, endovascular catheter based procedure using radiofrequency ablation or ultrasound ablation aimed at treating resistant hypertension (high blood pressure not controlled by medication). Nerves in the wall of the renal artery are ablated by applying radiofrequency pulses or ultrasound to the renal arteries. This causes reduction of sympathetic afferent and efferent activity to the kidney and blood pressure can be decreased.

Indications

- chronic kidney disease
- resistant hypertension (high blood pressure not controlled by medication)
- heart failure

Procedure

The procedure is performed like renal angiography using the transfemoral route under local anesthesia. A 6 F sheath is placed in the femoral artery through which an electrode-tipped catheter is advanced into the renal artery under real-time fluoroscopic guidance. Once the desired position is reached, the catheter is connected to a RF generator and low-level radiofrequency energy is delivered through the renal artery wall to disrupt the surrounding renal nerves. Simplicity HTN-2 trial involving patients with uncontrolled hypertension showed that this procedure leads to notable and sustained reductions in blood pressure

1. Congenital renal anomalies

Classification

1. ***number***
- renal agenesis
- renal hypoplasia
- supernumerary kidney

2. ***fusion***
- horseshoe kidney: most common
- cross fused renal ectopia
- pancake kidney

3. ***location***
- pelvic kidney
- crossed renal ectopia (fused or unfused)
- abnormal renal rotation (renal malrotation)
- nephroptosis (floating kidney)
- intrathoracic kidney

4. ***shape***
- persistent fetal lobulation
- hypertrophied column of Bertini
- hilar lip
- dromedary hump

5. ***vasculature***

- accessory renal arteries
- renal vein anomalies
- retro aortic or circumaortic left renal vein
- supernumerary renal veins

6. ***collecting system***

- duplex collecting system: most common (overall)
- bifid collecting system
- retrocaval ureter

1. number

Renal agenesis.

Renal agenesis may be unilateral or bilateral. Bilateral renal agenesis is a rare anomaly that is incompatible with life. It is traditionally known as the classic Potter syndrome. Renal agenesis and dysgenesis (malformation of the kidney) occur in around one in 1500 births.

Unilateral renal agenesis is usually an incidental finding.

Radiological features:

Intravenous urography (IVU)

- the contra lateral kidney of this patient may be quite large secondary to compensatory hypertrophy

On ultrasonography, CT, MRI:

- the kidney is absent with absent ipsilateral renal artery

-the adrenal gland will be absent in 8–17% of the patients with renal agenesis

-it may be difficult to differentiate between renal agenesis and a small, hypoplastic or dysplastic kidney

-the contra lateral kidney is enlarged due to compensatory hypertrophy

-usually, the colon falls into the empty renal bed (care should be taken not to confuse a loop of gut with a normal kidney)

- renal vessels are absent on same side

IVU: right renal agenesis

Renal hypoplasia

Renal hypoplasia refers to congenital small kidney with lesser number of calices and papilla (< 6) due to incomplete renal development. It is often unilateral and can have normal or mildly reduced function.

It can be global or segmental. Global hypoplasia needs to be differentiated from atrophic kidneys due to pyelonephritis or chronic vascular diseases in adults.

Atrophic kidneys from pyelonephritis usually show irregular outline from scarring with focal dilatation/clubbing of calices in contrast to smooth outline and non-dilated calices in global hypoplasia. Segmental renal hypoplasia also known as Ask-Upmark kidney is a cause of secondary hypertension in young adults.

https://radiopaedia.org/articles/renal-hypoplasia
CT right renal hypoplasia

Supernumerary kidneys

Supernumerary kidneys are a rare congenital anomaly of the urogenital system, where there are one or two accessory kidneys. Patients may be asymptomatic. Supernumerary kidney has a completely separate renal parenchyma and a renal capsule with a greater number of calyces.

Radiographic features:

On ultrasonography, IVU, CT, MRI:

- usually a supernumerary kidney is small in size and located caudally to the ipsilateral normal kidney
- it is encountered more frequently on left side of the abdomen
- more often, a bifid ureter is present with a caudally located supernumerary kidney
- in cases where the supernumerary kidney is present cranially, two separate ureters are seen which may ectopically enter into the urinary bladder or vagina

https://radiopaedia.org/articles/renal-hypoplasia
***IVU*: supernumerary kidneys**

2. fusion

***Horseshoe kidney*.**

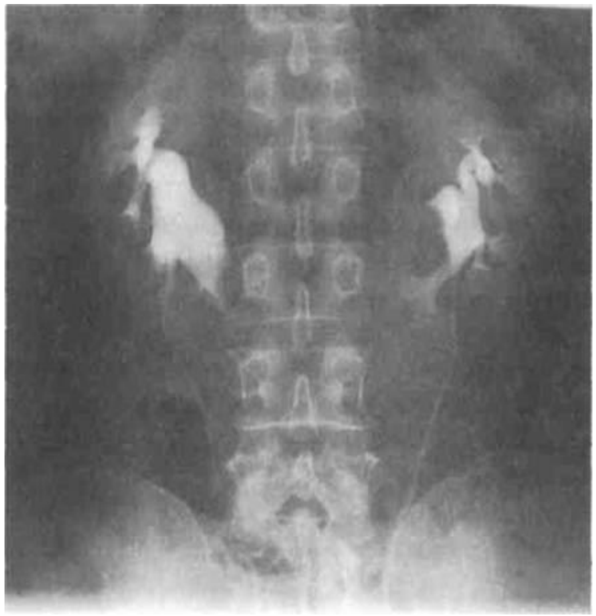
The term horseshoe kidney refers to the appearance of the fused kidney, which results from fusion at one pole. In more than 90% of cases, fusion occurs along the lower pole.

Horseshoe kidneys are, in themselves, asymptomatic and thus they are usually identified incidentally. They are however prone to a number of complications as a result of poor drainage, which may lead to clinical presentation.

Radiographic features:

On ultrasonography, IVU, CT, MRI:

- renal tissue of normal imaging appearance, but with abnormal configuration
- soft tissue mass on either side of the midline with a central isthmus
- the kidneys are also orientated with the lower pole closest to the midline
- following intravenous contrast the orientation of the pelvicalyceal system is clearly outlined, and may illustrate associated complications such as a PUJ obstruction



IVU: horseshoe kidney

Crossed fused renal ectopic.

Crossed fused renal ectopia is a rare congenital malformation, which is reported to be usually asymptomatic but may have varied presentations.

In crossed fused ectopia, one kidney crosses over to opposite side, and the parenchyma of the two kidneys fuse. Most commonly, the upper pole of the inferiorly positioned crossed ectopic kidney is fused to the lower pole of the superior, normally positioned kidney. The ureter of the ectopic kidney crosses the midline and enters the bladder on the opposite side. The left kidney is most frequently ectopic (crossing to the right side of the abdomen).

McDonald and McClellan classified crossed ectopic kidney into four types:

- crossed renal ectopia with fusion (85%)
- crossed renal ectopia without fusion (10%)
- solitary crossed renal ectopia
- bilaterally crossed renal ectopia

Six variations of crossed fusion have been described.

In decreasing order of frequency, they are:

type 1 -inferior crossed fused ectopia

type 2 - sigmoid or S-shaped kidney

type 3 - unilateral lump kidney

type 4- unilateral disc kidney

type 5 - L-shaped kidney

type 6 - superior crossed fused ectopia

Radiographic features:

On ultrasonography, IVU, CT, MRI:

- one kidney is displaced across the midline and fused to the other normal kidney
- ureteric orifices lie in a normal position
- the parenchymal band joining the two kidneys can be better visualized on CT or MRI

Ultrasonography: crossed fused ectopic left kidney lying within the right side of the abdomen

Cake kidney (complete renal fusion)

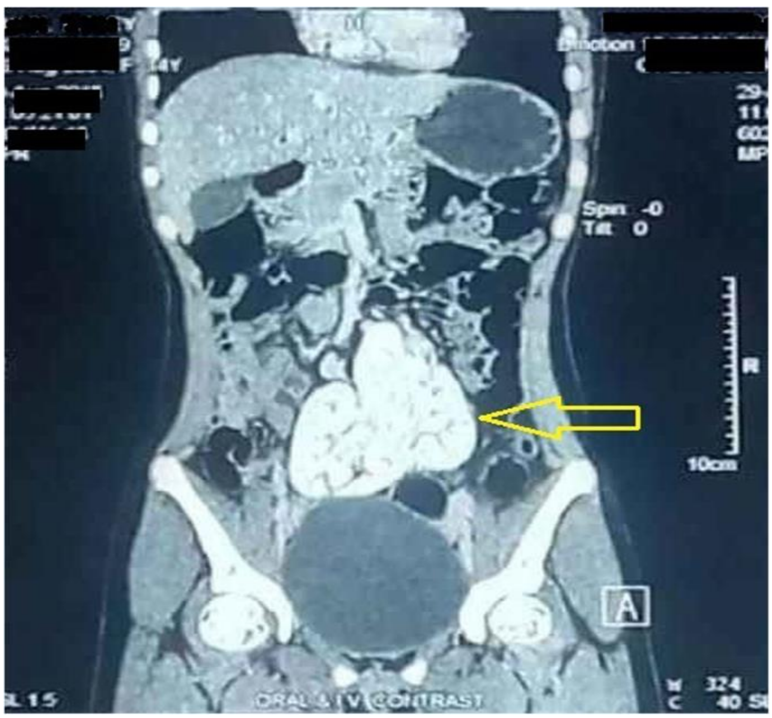
Cake kidney is a rare congenital anomaly of the genitourinary system. Glenn as an anomaly in which "the entire renal substance is fused into one mass, lying in the pelvis, and giving rise to two separate ureters, which enter the bladder in normal relationship,

defined the term cake kidney or fused pelvic kidney”. In rare instances, such kidneys possess one ureter. The fused kidney occupies paravertebral or presacral space.
The cake kidney may remain asymptomatic and be detected at autopsy.

Radiographic features:

On ultrasonography, IVU, CT, MRI:

- abnormally located kidney in the bony pelvis as a single fused mass
- a fused mass with short course uncrossed ureters opening separately into the urinary bladder



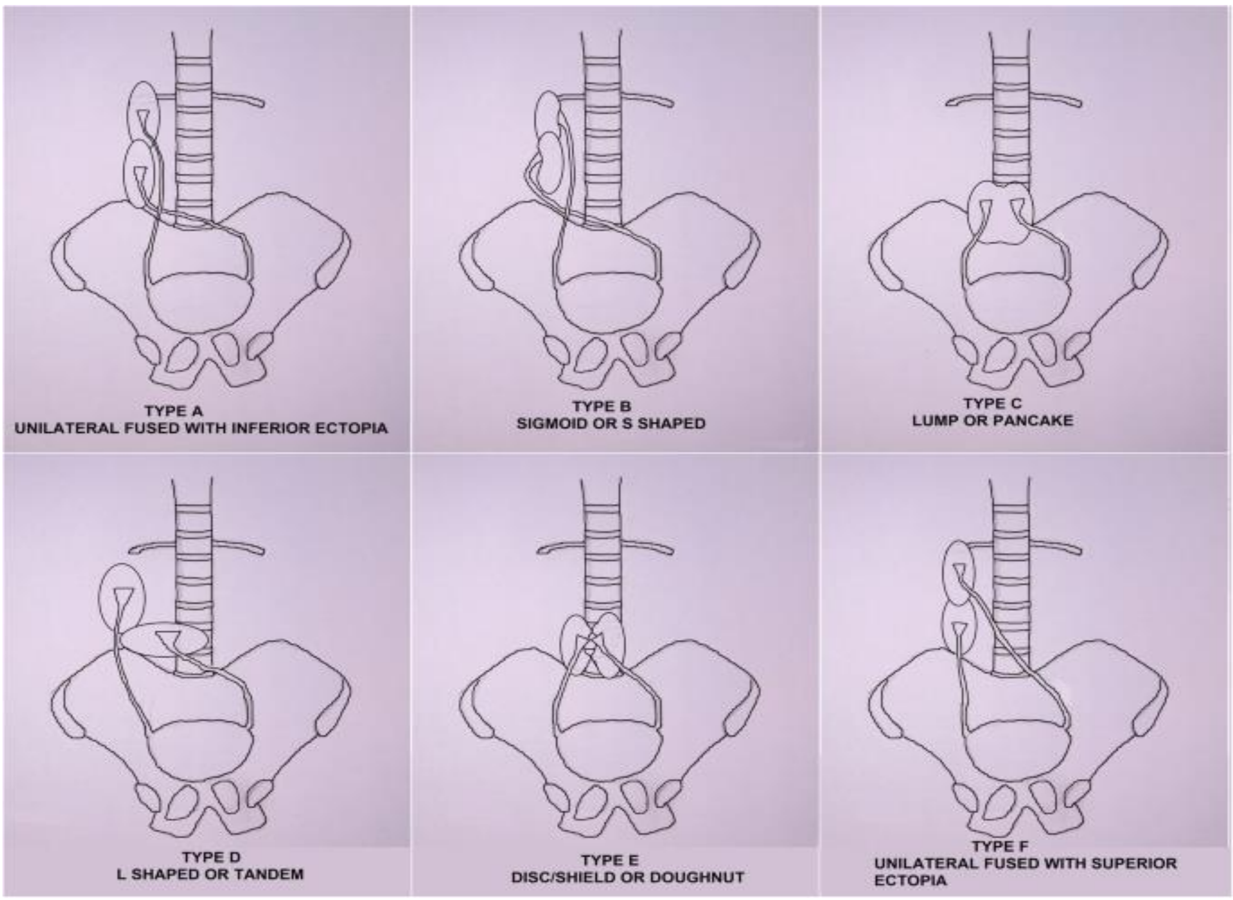
https://jmedicalcasereports.biomedcentral.com/articles/10.1186/s13256-020-02455-0
CT scan with urogram phase: cake kidney

3. location

Anomalies of renal location

Renal ectopia

Renal ectopia is congenital abnormal location of a kidney is described as renal ectopia. It is important to differentiate this entity from renal ptosis, which is defined as renal descent by 5 cm or more (two lumbar vertebrae) in upright position. In renal ectopia, the arterial blood supply arises ectopically and the length of the ureter may be short or long depending on the location of the ectopic kidney whereas in ptotic kidney the ureter is of normal length (may be redundant when the patient stands) and the renal arteries arise from the normal sites.



https://jmedicalcasereports.biomedcentral.com/articles/10.1186/s13256-020-02455-0

Pelvic kidney

Radiographic features:

On ultrasonography, IVU, CT, MRI:

- the kidney is not completely located in the renal fossa
- the kidney is found in pelvic cavity
- ectopic kidney is nearly always accompanied with anomalous renal vasculature

Intrathoracic kidney

Intrathoracic kidney is a rare congenital abnormality with the lowest frequency among all renal ectopia.

Thoracic kidney is normally asymptomatic and most of the cases present thoracic tumors on chest X-rays requested for any reason other than the suspect of this anomaly.

Ptister-Goedek&Brunir classified thoracic kidney into four groups:

- thoracic renal ectopia with closed diaphragm
- eventration of the diaphragm (relaxation of the diaphragm)
- diaphragmatic hernia (subdivided into congenital diaphragmatic defects and acquired hernia such as Bochdalek hernia, with a percentage lower than 0.25%)
- traumatic rupture of the diaphragm with renal ectopia

Radiographic features:

On ultrasonography, IVU, CT, MRI:

- rotation anomalies
- elongated urethra
- high origin of renal vases
- medial deviation of the lower pole of the kidney

IVU: Intrathoracic kidney

Abnormal renal rotation (renal malrotation)

Abnormal renal rotation (renal malrotation) refers to an anatomical variation in the position of the kidneys, in particular to anomalous orientation of the renal hilum. It may occur unilaterally or bilaterally. It is usually an asymptomatic incidental finding.

The renal hilum is normally directed anteromedially. The renal hilum is initially oriented anteriorly, but during its ascent from the pelvis, the kidney rotates 90° along its longitudinal axis to its more typical orientation.

Anomalies in this process can result in:

- incomplete rotation or nonrotation (most common): hilum faces anteriorly, ureters are located laterally
- excessive rotation (hyper-rotation): hilum faces posteriorly; renal vessels are located posteriorly
- reversed rotation: hilum faces laterally, renal vessels are located anteriorly, ureter is located laterally

Radiographic features

On ultrasonography, IVU, CT, MRI:

- malrotation can be demonstrated when the calyces project medially to the renal pelvis
- on CT urography the renal pelvis may be seen projecting anteriorly

IVU: abnormal renal rotation of the left kidney

Nephroptosis (floating kidney)

Anatomically, it is defined as a significant descent (>5 cm or two vertebral bodies on IVU) of the kidney as the patient moves from supine to erect. The kidney might move into an abnormal position but is capable of moving back into a normal anatomical site, which differentiates it from an ectopic kidney, which would constantly remain in an abnormal position. The gross downward displacement of the kidney can give rise to symptoms either due to effects on the ureter or the renal hilar vessels.

Radiographic features:

On ultrasonography:

US can readily show

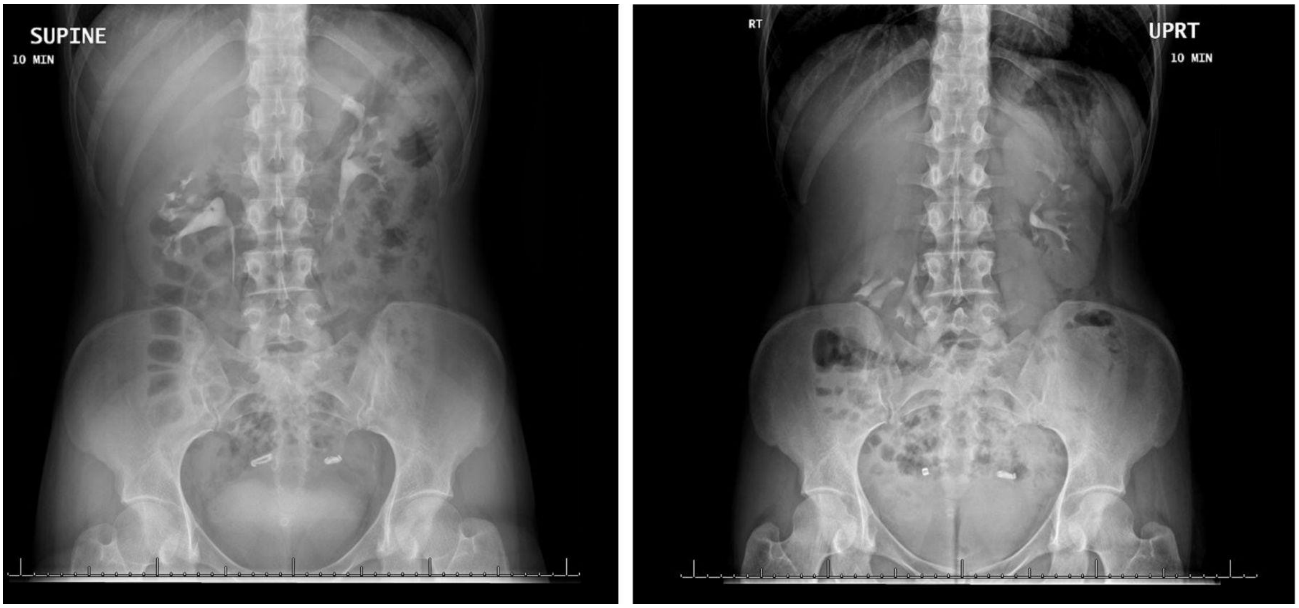
- a mobile, ptotic and occasionally hydronephrotic kidney
- the affected kidney often will not only descend while the patient is upright, but will also rotate on its short axis such that the lower pole moves anteriorly and the upper pole posteriorly, and the kidney adopts an orientation almost transverse to the axis of the spine

On IVU:

IVU typically do during expiration with the patient supine and during inspiration with the patient upright. Simply taking a traditional supine IVU might make nephroptotic kidneys appear deceptively normal. Films while upright are therefore mandatory in suspected cases. Reproducing the symptoms while upright or after intravenous diuretic administration aids the diagnosis.

The findings at IVU include:

- ptosis of >5 cm, often with associated malrotation
- development of obstruction when upright, but not supine
- renal pelvic dilatation or gross hydronephrosis
- delayed emptying
- kinking of the PUJ or proximal ureter



https://casereports.bmj.com/content/2018/bcr-2018-224921
IVU: nephroptosis (floating kidney) of right kidney

4. *shape*

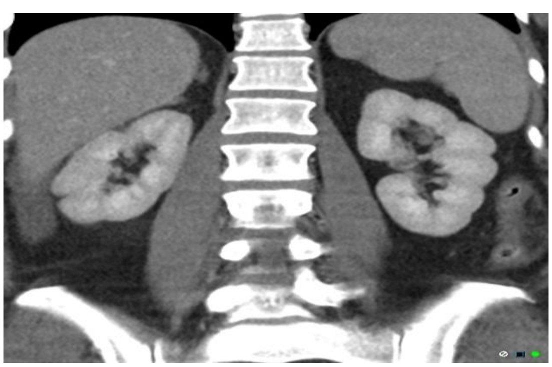
Persistent fetal lobulation

Persistent fetal lobulation is a normal variant seen occasionally in adult kidneys. It occurs when there is incomplete fusion of the developing renal lobules. Embryological, the kidneys originate as distinct lobules that fuse as they develop and grow.

Radiographic features:

On ultrasonography, CT, MRI:

- smooth indentations of the renal outline in between the renal pyramids



CT: persistent fetal lobulation

Hypertrophied column of Bertin (HCBs)

Columns of Bertin represent the extension of renal cortical tissue which separates the pyramids, and as such are normal structures. They become of radiographic importance when they are unusually enlarged and may be mistaken for a renal mass (renal pseudotumour).

Nomenclature of such enlarged columns is a little confusing, sometimes referred to as septa (although this may also refer to normal columns). Ideally, the term hypertrophied column of Bertini or prominent column of Bertini should be used to avoid confusion.

Key to correct identification of a hypertrophied column of Bertini is the fact that it is in continuity with, and of similar appearance to, normal renal cortical parenchyma, and that the renal outline is preserved.

They are usually located in the mid-portion of the kidney and are more commonly found on the left side

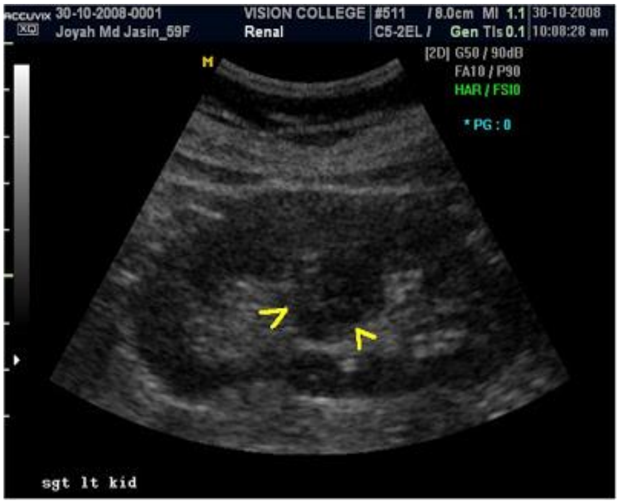
Radiographic features:

On ultrasonography:

- ovoid lesions that extend from the medullary pyramids to the renal sinus
- although HCBs are often isoechoic with renal parenchyma, it might be hyperechoic
- there could be some hyperechoic areas inside of the isoechoic mass

On CT, MRI:

- hypertrophic column of Bertin is isodense/isointense with the normal renal parenchyma on non-contrast- and contrast-material enhanced CT or MR images and MRI examination is more sensitive than CT



US: hypertrophied column of Bertin of left kidney (arrows)

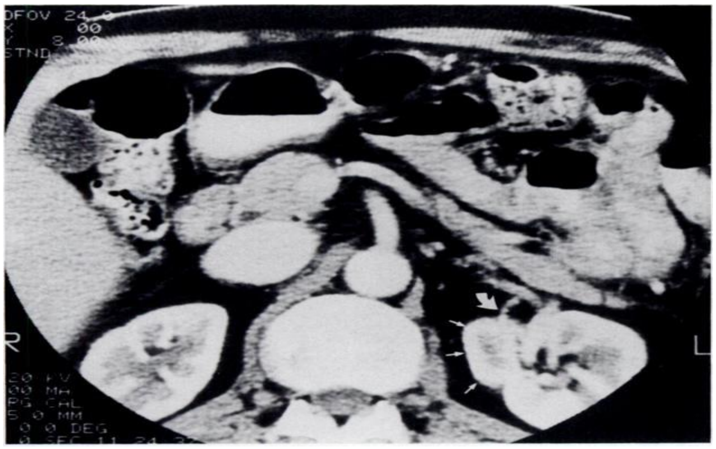
Hilar lip

A renal hilar lip is a developmental anomaly of the kidney. It is an infolding of the cortex at the level of the renal sinus and in this region the renal cortex appears thicker.

Radiographic features:

On ultrasonography, CT, MRI:

- on imaging it appears as supra- or infra-hilar cortical bulges
- at certain levels of cross-sectional imaging this lip may appear to be entirely separate from the kidney and mimics a mass lesion, thus it is considered as one of the renal pseudotumours



Hilar lip CT scan made without contrast material reveals a soft tissue mass (arrow) medial to the left kidney that might represent either an intrinsic or an extrinsic abnormality.

Dromedary hump

Dromedary humps are prominent focal bulges on the lateral border of the left kidney. They are normal variants of the renal contour, caused by the splenic impression onto the super lateral left kidney.

Dromedary humps are important because they may mimic a renal mass, and as such is considered a renal pseudotumour.

Radiographic features:

On ultrasonography, CT, MRI:

- the calyces underlying the hump extend further laterally into the hump than the other calyces
- a dromedary hump must have the same radiological features as the adjacent cortex, whatever the modality

5. vasculature

Accessory renal arteries

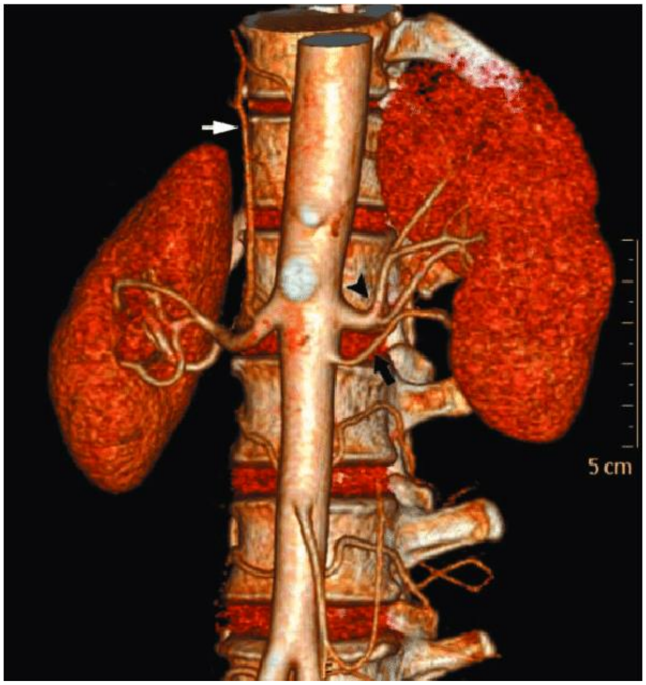
Accessory renal arteries are a common variant and are present in ~25% (range 20-30%) of the population.

The term extra renal artery may be used 4, with a subclassification into:

- aberrant renal artery: supplying the superior and/or inferior pole of the kidney
- accessory renal artery: supplying the renal hilum

Accessory renal arteries occur bilaterally in 10-15% of cases:

- single renal artery arising from the abdominal aorta: 70%
- double renal arteries: ~20% (range 14-23%)
- triple renal arteries: ~2.5% (range 1-4%)
- quadruple renal arteries: <1%



https://www.research gate.net/figure/Accessory-renal-artery-and-early-branching-in-50-year-old-female-voluntary-kidney-donor_fig2_44590898
Accessory renal artery and early branching in 50-year-old female voluntary kidney donor. Anterior volume rendered image shows early branching of main left renal artery (black arrowhead) and presence of accessory renal artery arising from aorta (black arrow). Right inferior phrenic artery is seen arising from right main renal artery (white arrow).

Renal vein anomalies

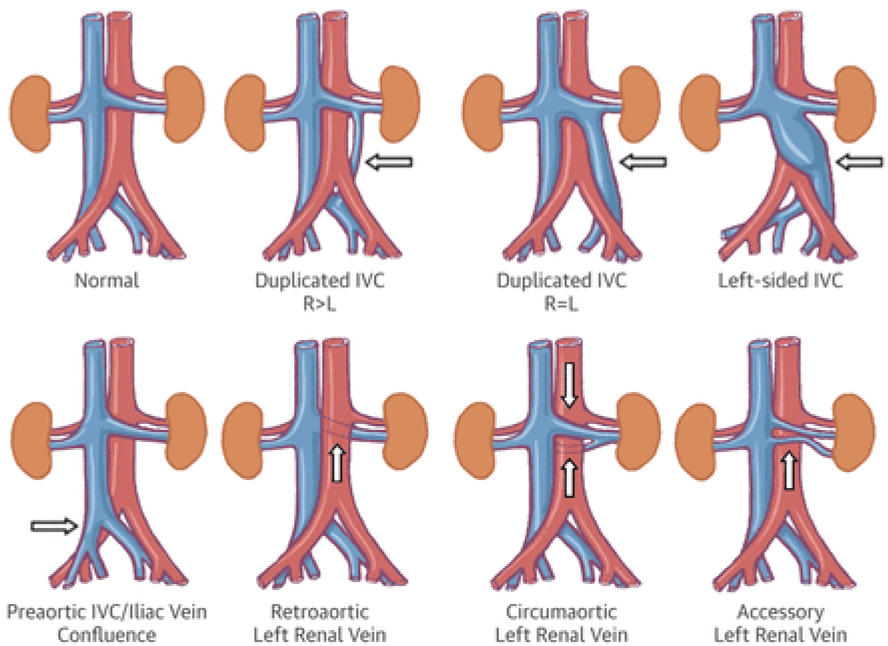
There are several variations in renal venous anatomy. Some of these are specific to the left renal vein.

Left renal vein anomalies are generally classified into four types:

- **type I** - the ventral pre-aortic limb of the left renal vein is obliterated, but the dorsal retro-aortic limb persists and joins the inferior vena cava (IVC) in the normal position
- **type II** - results from the obliteration of the ventral pre-aortic limb of the left renal vein and the remaining dorsal limb turns into a retro-aortic left renal vein (RLRV)
- left renal vein lies at the level of L4 to L5 and joins the gonadal and ascending lumbar veins before joining the IVC

- **type III** - is the circumaortic left renal vein or venous collar - due to the persistence of subsupracardial and intersupracardial anastomoses and the dorsal limb of the left renal vein
- if all small retroaortic veins that empty into the IVC are considered, the incidence of a circumaortic left renal vein could be as high as 16%
- **type IV** - the ventral pre-aortic limb of the left renal vein is obliterated, and the remaining dorsal limb becomes the RLRV

Other (non-classified) supernumerary renal veins: can involve either kidney



https://anatomyjournal.ir/browse.php?a_id=231&sid=1&slc_lang=en&html=1

6. collecting system

Duplex collecting system

A duplex collecting system is one of the most common congenital renal tract abnormalities. It is characterized by an incomplete fusion of upper and lower pole moieties resulting in a variety of complete or incomplete duplications of the collecting system. While considered an anatomical variant, duplex collecting systems may be complicated by vesico-ureteric reflux, obstruction or ureterocele.

Duplex collecting systems are seen in 0.7% of the healthy adult population and 2-4% of patients investigated for urinary tract symptoms.

Most duplicated systems asymptomatic and diagnosed incidentally. However, where symptoms do occur (infection, reflux or obstruction), the patient is likely to have completely duplicated ureters.

Duplex systems may be unilateral or bilateral and can be associated with a variety of other congenital abnormalities of the urinary tract.

Duplex collecting system anomalies can be classified into the following categories depending on the level or lack of fusion:

- ***duplex kidney:*** two separate pelvicalyceal systems draining a single renal parenchyma
- ***duplex collecting system:*** a duplex kidney draining into:
- ***single ureter:*** i.e. duplex kidney's duplication pelvicalyceal systems uniting at the pelviureteric junction (PUJ)
- ***bifid ureter*** (ureter fissus): two ureters that unite before emptying into the bladder
- ***double ureter (***complete duplication)
- ***bifid collecting system:*** refers to a duplex kidney with the two separate pelvicalyceal collecting systems uniting at the PUJ or as bifid ureters
- ***double/duplicated ureters***: two ureters that drain separately into the bladder or genital tract

Radiographic features:

On IVU, ultrasonography, CT, MRI:

- duplicated ureters extending a variable distance down to the bladder

- obstruction of the upper pole moiety down to the bladder, often with a ureterocele

- vesico-ureteric reflux into the lower pole moiety, often due to distortion in its insertion by the aforementioned ureterocele

- drooping lily sign is a classic urographic sign which refers to the inferolateral displacement of the opacified lower pole moiety due to an obstructed (and unopacified) upper pole moiety

- ectopic insertion of the upper pole moiety e.g. into the prostatic urethra in males or vaginal vault in females

IVU: duplex collecting system

2. CONGENITAL URETR ANOMALIES

Retrocaval ureter

Retrocaval ureter is a term used to describe an abnormal course of a ureter that encircles the inferior vena cava.

There are two types:

- high loop
- low loop

Many patients with this anomaly are asymptomatic. Depending on the degree of compression patients may develop partial right ureteral obstruction or recurrent urinary tract infections due to urinary stasis.

This congenital abnormality occurs as a result of the right supracardinal system failing to develop normally. The right posterior cardinal vein persists, and therefore ends up passing in front of the ureter.

With one reported exception, the anomaly always occurs on the right side, as this is the side of the normal IVC.

Radiographic features:

On IVU, ultrasonography, CT, MRI:

- the proximal ureter courses posterior to the IVC, then emerges to the right of the aorta, coming to lie anterior to the right iliac vessels
- any chosen imaging modality will usually show a right hydroureteronephrosis above the segment embracing the IVC

CT: retrocaval ureter

Ureterocele

Ureterocele means hernia of the ureter. It is the result of a congenital stenosis of the ureteral orifice and a concomitant weakness of the wall of the lower ureter so that there is a resultant ballooning of the terminal ureter into the bladder.

- most common in white females
- most are left-sided but about 10% are bilateral
- most ureteroceles found in adults are orthotopic whereas those in children are far more commonly ectopic

Radiographic features:

On IVU, ultrasonography, CT, MRI:

- cobra-head appearance of the dilated distal ureter
- elliptical collection of contrast in ureterocele surround by this radiolucency of wall of ureterocele
- opaque calculi on the ureterocele will be seen on the pre-contrast scout image
- non-opaque calculi in ureteroceles will be seen on the post-contrast studies as filling defects within the ureterocele

IVU: bilateral "cobra head" appearance of the distal ureter

Primary megaureter

A **congenital (primary) megaureter** encompasses causes of an enlarged ureter which are intrinsic to the ureter, rather than as a result of a more distal abnormality; e.g. bladder, urethra (see secondary megaureter).

It includes:

- obstructed primary megaureter
- refluxing primary megaureter
- non-refluxing unobstructed primary megaureter

Symptoms, when present, are usually arising from complications due to urinary stasis and/or (e.g. urinary sepsis and nephrolithiasis).

Radiographic features:

On IVU, retrograde pyelography, ultrasonography, CT, MRI:

- in all three types the ureter is enlarged (>7 mm) sometimes markedly so. On all modalities able to visualize the ureter (CT, US, MRI, IVP) it appears as a tubular structure usually posterior to the bladder.

- in obstructive primary megaureter the ureter tapers to a short segment of normal caliber or narrowed distal ureter, usually just above the vesico-ureteric junction (VUJ); the distal ureter above this narrowed segment is most dilated (similar to achalasia): there is associated hydronephrosis, and active peristaltic waves can be seen on ultrasound

- in refluxing primary megaureter, vesico-ureteric reflux is demonstrated

- in non-refluxing unobstructed primary megaureter, there is absent or only a minor degree of hydronephrosis; although rare, a congenital megaureter may co-exist with congenital megacalyces, making the assessment of hydronephrosis more difficult

IVU: primary megaureter of the left solitary kidney

Vesicoureteral reflux

Vesicoureteral reflux (VUR) is the abnormal flow of urine from the bladder into the upper urinary tract.

The pathophysiology behind this anomaly is either primary maturation abnormality of the vesicoureteral junction or a shorter intramural submucosal segment of ureter.

Radiographic features:

On voiding cystourethrography:

Grading of VUR: According to International Reflux Committee Study

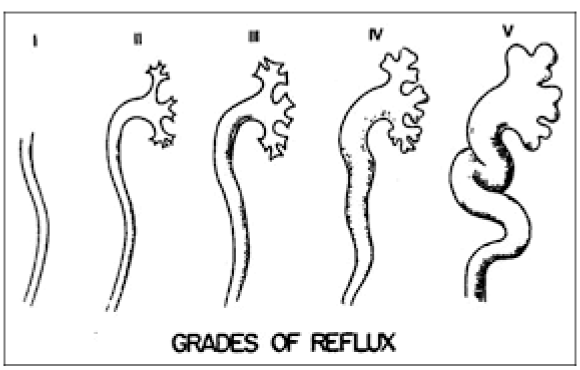
Grade I: Ureter only.

Grade II: Ureter, pelvis, and calices; no dilatation; normal calyceal fornices.

Grade III: Mild or moderate dilatation or tortuosity of the ureter and moderate dilatation of the renal pelvis; no or slight blunting of the fornices.

Grade IV: Moderate dilatation or tortuosity of the ureter and moderate dilatation of the renal pelvis and calices; complete obliteration of the sharp angle of the fornices but maintenance of the papillary impressions in the majority of calices.

Grade V: Gross dilatation and tortuosity of the ureter; gross dilatation of the renal pelvis and calices; papillary impressions are no longer visible in the majority of the calyces.



https://urology.ucsf.edu/patient-care/children/additional/vesicoureteral-reflux

Posterior urethral valve

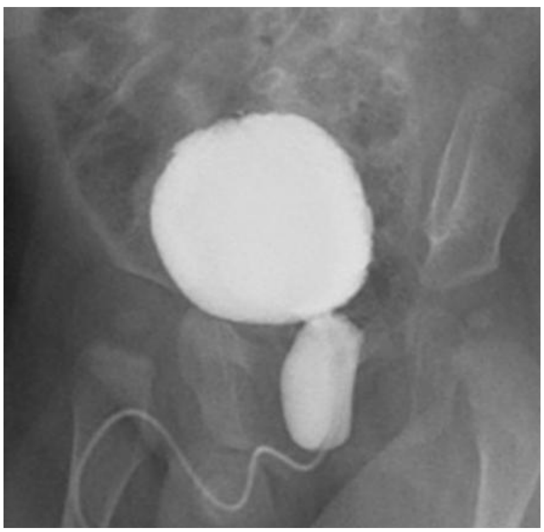
It occurs only in boys.

Formed by thickening and invagination folds into the urethral lumen or a result of a transverse membrane dividing urethra.

Radiographic features:

On cystourethrography:

- obstruction and consequently to widen posterior urethral
- bladder wall hypertrophy
- formation of vesico-ureteral reflux



Cystourethrography: posterior urethral valve

3. Cystic disease

Adult cystic renal disease comprises several distinct disease processes:

1) adult polycystic kidney disease (APCKD) [also known as autosomal dominant polycystic kidney disease (ADPCKD)]

2) acquired renal cysts: extremely common, 50% of which occur in those over the age of 50, many causes including lithium nephropathy

3) renal cell carcinoma: not a renal cystic disease but essential to remember as 10% of cases of renal cell carcinoma are primarily cystic

Radiographic features:

On IVU:

- renal cysts are well-marginated, thin walls with no enhancement of the cyst

On ultrasonography:

uncomplicated renal cyst

- well-marginated anechoic lesion with thin walls
- a few thin septa may be present (5% of cysts) the back wall should be visible
- posterior acoustic enhancement may be present, although this finding is nonspecific and also may not be seen with smaller cysts
- a small amount of intracystic hemorrhage/debris may be present, and may require further evaluation (5% of cysts)

complicated cyst

- cystic lesions with thickened or irregular walls or septa are suspicious for renal cell carcinoma and warrant further work up
- vascularity of the septa on color or spectral Doppler is suspicious for renal cell carcinoma

***On* CT:**

The Bosniak criteria were introduced to allow the use of specific computed tomographic (CT) findings to help separate nonsurgical from surgical cystic masses and guide patient management. These criteria use five separate categories (I, II, IIF, III, and IV) to help communicate the appropriate management to radiologists, urologists, and internists. Cystic renal masses are characterized and differentiated by attenuation, contrast material enhancement (perceived vs. measurable), and the presence of calcifications and septations.

Bosniak I Cyst

A Bosniak I cyst is a simple cyst. At CT, these cysts have fluid attenuation (0–20 HU) and a hairline-thin wall, do not contain calcifications or septations, and do not demonstrate contrast enhancement. These cysts are benign and require no further evaluation.

Bosniak II Cyst

Bosniak II cysts are minimally complicated. They may demonstrate fine calcifications or a short segment of slightly thickened calcification in the cyst wall or septa. They may contain a few hairline-thin septa, in which there may be perceived (as opposed to measurable) enhancement. Homogeneously hyperattenuating (>20 HU) nonenhancing lesions measuring 3 cm or less that are not completely intrarenal are also included in this category. Ideally, at least one-fourth of the hyperattenuating cyst wall should extend outside the renal parenchyma for verification that the cyst wall is smooth.

Bosniak IIF Cyst

A Bosniak IIF cyst is a cyst that requires follow-up imaging to determine whether it is benign. These cysts contain more complex elements than Bosniak II cysts but are not believed to be complex enough to warrant surgical intervention. These lesions may show several thin internal septations without measurable enhancement, a few nodular calcifications, and a smooth thickening of the cyst wall. Nonenhancing hyperattenuating cysts that are larger than 3 cm or completely intrarenal are included in this category.

According to one study, 95% of these lesions are benign and therefore have a low probability of being small renal cell carcinoma and a low chance of metastasis. A more recent study reported a malignancy rate of 25% in surgically excised Bosniak IIF lesions, but the patients with respected Bosniak IIF lesions in that series were highly selected and had a high number of risk factors associated with malignancy, such as a coexisting Bosniak IV lesion or a history of renal cell carcinoma. No patients in this series developed locally advanced or metastatic disease from a Bosniak IIF lesion. Bosniak IIF lesions are followed up with CT or MR imaging to assess for increasing complexity that may indicate malignancy. Variable recommendations for the duration of follow-up range from 1–2 years to more than 4 years, depending on the complexity of the lesion.

Bosniak III Cyst

A Bosniak III cyst may contain thick irregular walls and/or septa that demonstrate measurable enhancement. Septations are more numerous than in a Bosniak II cyst. The cyst walls and septa may also contain thick nodular calcifications.

These cysts have a reported 30%–100% chance of malignancy, depending on the case series. Aside from renal malignancy, the differential diagnosis for a Bosniak III cyst includes cystic nephroma, mixed epithelial and stromal tumor (MEST), benign multiloculated cyst, hemorrhagic cyst, and renal abscess. Patient management can be difficult because of the broad differential diagnosis, which contains both benign and malignant entities. Given the risk for malignancy, these patients usually undergo surgical resection. However, the risks and benefits of surgery in a particular patient must be weighed against the possibility that the lesion may be benign. Some authors recommend lesion biopsy. However, the relatively small volume of tumor cells within the cyst may increase the risk for a false-negative biopsy result.

Bosniak IV Cyst

A Bosniak IV cyst contains enhancing nodular soft-tissue components and is considered malignant until proven otherwise. A small percentage of these lesions have a benign pathology (e.g., a MEST). Surgical resection is recommended unless factors such as patient comorbidities or a limited life expectancy militate against this treatment strategy.

On MRI:

Simple cyst characteristics are similar to ultrasound and CT:

T1: hypointense (hemorrhagic debris may mildly increase signal)

T1+C: no postcontrast enhancement

T2: strongly hyperintense (hemorrhagic debris may mildly decrease signal) and separate from the collecting system

DWI: increased DWI signal, but no restricted diffusion

CT: simple cyst (Bosniak I)

Polycystic kidney

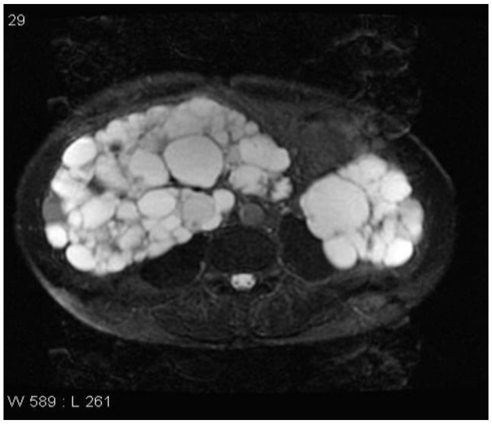
In this, the kidney contains a large number of cysts. This condition is familial. It is always bilateral. Great enlargement produces a uniform lobulated tumor. The kidney may look like a bunch of grapes.

Radiographic features:

On IVU:

- may show elongation, deformity and distortion of the calyces
- the renal pelvis may also be deformed by cysts protruding into it
- the alteration of the axis of the kidney which comes to lie parallel to the spine
- the enlargement of the calyces and pelvis may become so much that the term spider leg deformity is used

Ultrasound is an excellent choice for repeated imaging as it is fast, relatively inexpensive and lacks ionising radiation. It is able both to suggest the diagnosis and to assess for cyst complications.



CT: Polycystic kidney disease

4. Pyelonephritis

Pyelonephritis refers to an upper renal tract infection with associated renal pelvic, renal calyceal and renal parenchymal inflammation.

Clinical presentation is fairly specific and classical in most cases, consisting of rapid onset of high fevers and flank pain and tenderness. In many instances less specific or non-urinary symptoms and signs may also be present which may lead to clinical confusion. White cells and bacteria are usually present in the urine, and blood tests reveal the expected changes: increased WCC, CRP and/or ESR. In severe cases, systemic sepsis may be present. In many instances patients respond promptly to antibiotics and no imaging is required.

In many instances imaging is not required. Situations in which imaging is indicated include:

- exclude obstructed kidney
- high risk patients: diabetics, elderly, immunocompromised
- those with mixed clinical picture
- previous renal pathology

Radiographic features:

On Ultrasound:

Ultrasound is insensitive to the changes of acute pyelonephritis, with most patients having 'normal' scan, and abnormalities only identified in ~25% of cases. Possible features include pus in the collecting system, gas bubbles, and abnormal echogenicity of the renal parenchyma (focal hypoechoic regions or mass-like changes)

On CT:

CT is the most sensitive modality for the renal tract, able to assess for renal calculi, gas, perfusion defects, collections and obstruction.

Non-contrast CT: often the kidneys appear normal, affected parts may appear swollen and of lower attenuation. Renal calculi or gas within the collecting system may be evident.

Post-contrast CT: regional swelling and demonstrate reduced enhancement, a striated nephrogram, persistent enhancement after 3-6 h

***On MRI*:**

MRI is usually reserved for patients who are pregnant, and findings mirror those seen on CT.

The kidney demonstrates wedge shaped regions of altered signal:

- **T1:** affected region(s) appear hypointense compared to normal kidney parenchyma
- **T2:** hyperintense compared to normal kidney parenchyma
- **T1 C+:** reduced enhancement

Contrast enhanced CT scan in patient with fever and flank pain shows ill-defined linear enhancement abnormality in the left mid pole anteriorly (arrows) known as "striated nephrogram" which is a finding seen in acute pyelonephritis

5. Renal abscess

Renal abscesses are typically seen as a complication of acute pyelonephritis. They often occur as the result of untreated or incompletely treated pyelonephritis or ascending urinary tract infections. Less commonly, renal abscesses may be caused by hematogenous seeding in patients with bacteremia.

Immunocompromised, pregnant, and diabetic patients have an increased risk for abscess formation.

Clinical presentation

The most common signs or symptoms are:

- fever
- flank/abdominal pain
- chills
- dysuria

Radiographic features:

On ultrasound:

- a renal abscess appears as a well-defined hypoechoic area within the cortex or in the corticomedullary parenchyma

- it demonstrates internal echoes within and an associated diffusely hypoechoic kidney due to acute pyelonephritis may be seen

- perinephric collection may also be seen

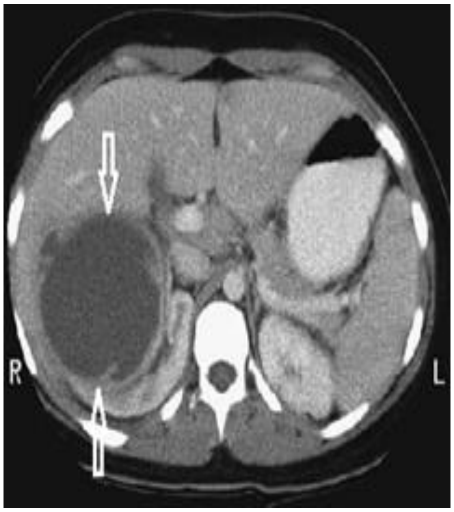
On CT:

- an abscess appears as a well-defined mass of low attenuation with a thick, irregular wall or pseudo capsule, which can be better visualized on contrast enhanced scans

- gas within a low attenuation/cystic mass strongly suggests abscess formation

- renal parenchyma around the abscess cavity may appear hypoenhancing in nephrogram phase, and may appear hyperattenuating in delayed images

- associated fascial and septal thickening is seen with obliteration of perinephric fat



On contrast-enhanced CT reveals: a huge fluid-filled structure at the superior pole of the right kidney (arrows).

6. Urolithiasis

Urolithiasis refers to the presence of calculi anywhere along the course of the urinary tracts. The lifetime incidence of renal stones is high, seen in as many as 5% of women and 12% of males. By far the most common stone is calcium oxalate, however the exact distribution of stones depends on the population and associated metabolic abnormalities (e.g. struvite stones are more frequently encountered in women, as urinary tract infection as more common).

Although some renal stones remain asymptomatic, most will result in pain. Small stones that arise in the kidney are more likely to pass into the ureter where they may result in renal colic. Hematuria, although common, may be absent in ~15% of patients.

The composition of urinary tract stones varies widely depending upon metabolic alterations, geography and presence of infection.

The more common composition of stones includes:

- calcium oxalate +/- calcium phosphate: ~75%

-struvite (triple phosphate): 15%

- pure calcium phosphate: 5-7%

- uric acid: 5-8%

- cysteine: 1%

Radiographic features:

On Ultrasound:

Ultrasound is frequently the first investigation of the renal tract, and it is often able to identify calculi Features include:

- echogenic foci
- acoustic shadowing
- twinkle artifact on color Doppler
- color comet-tail artifact

On plain abdominal film

Calcium containing stones are radiopaque

- calcium oxalate +/- calcium phosphate
- struvite (triple phosphate) - usually opaque but variable
- pure calcium phosphate

Lucent stones include

- uric acid
- cysteine
- indinavir stones
- pure matrix stones

On plain abdominal film: stone in the left kidney

On CT:

99% of renal tract calculi are visible on CT-KUB.

7. Hydronephrosis

Hydronephrosis is a dilatation of PCS secondary to distal obstruction.

Causes

ureteric stones

ureteric stricture

pyeloureteric junction obstruction

vesicoureteral reflux

bladder outlet obstruction

pregnancy

enlarged prostate gland

kidney, prostate, bladder, cervical, or ovarian cancer.

injury or infection

Radiographic features:

On IVU, US, CT, MRI**:**

Findings may vary with the duration and degree of the obstruction. Renal outline may be enlarged.

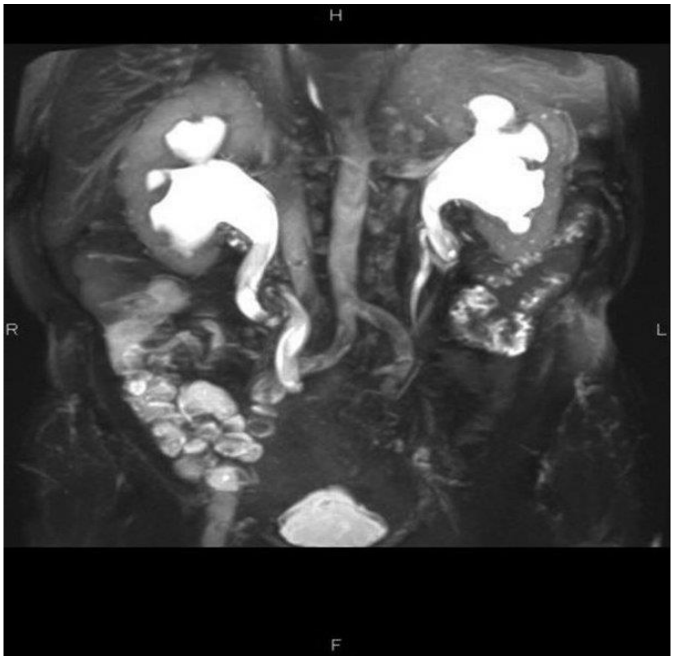
Grading

Grade1: minimal blunting of forniceal angle

Grade2: blunting of calyces with intact papillary markings

Grade3: loss of papillary markings

Grade4: ballooning of the calyces



https://www.quora.com/How-does-hydronephrosis-look-like-on-an-MRI
On MRI: hydronephrosis of the kidneys

8. Pelviureteric junction obstruction (PUJ)

This condition has a spectrum of severity from severe antenatal hydronephrosis with global cortical loss to radiologically demonstrable hydronephrosis in the adult without apparent symptoms or loss of renal function. The cause of this condition is still not entirely clear and has provoked much controversy. Possibilities include an intrauterine ischemic insult, excess collagen within the wall of the pelviureteric junction (PUJ) or the presence of aberrant blood vessels. Up to *20%* are associated with an accessory renal artery running across the PUJ, which may be visible on the IVU as a smooth indentation.

In some cases, however, the crossing blood vessels appear to be secondary to the development of the hydronephrosis and not the cause. The defining lesion is hydronephrosis that develops with a narrowed PUJ, which fails to relax and transmit the peristaltic wave to the ureter. Initially this is intermittent. In adult practice the typical presentation is of episodes of severe loin pain in a young adult, which may be related to the consumption of large quantities of fluid provoking a diuresis.

Radiographic features:

***On IVU*:**

- during the acute episode there are features on IVU of severe acute obstruction, which include a delayed, increasingly dense nephrogram and delayed appearance (sometimes up to 24 h or more) of contrast within the collecting system

- when opacification occurs it demonstrates clubbed calyces and a dilated pelvis - --prior to opacification of the pelvicalyceal system there may be a negative pyelogram, i.e. dilated calyces appearing as radiolucent areas surrounded by the denser areas of the nephrogram

- contrast may be seen with a curvilinear configuration just peripheral to the calyces; this appearance has been termed `crescents' and is thought to represent contrast stasis in collecting ducts displaced around distended calyces

- the PUJ is tightly closed and the ureter is often not opacified

On ultrasound:

- will demonstrate a hydronephrosis without a dilated ureter

On US: Pelviureteric junction obstruction

9. Tuberculosis of the urinary tract:

After pulmonary tuberculosis, the renal tract is the most common site of infection, usually due to haematogenous spread either from pulmonary or bone tuberculosis. Any part of the renal tract may be involved: kidneys, ureters, bladder, seminal vesicles and epididymis.

Patients with genitourinary tuberculosis typically have local symptoms including frequent voiding and dysuria. Hematuria can be either microscopic or macroscopic. Symptoms may also include back, flank, or abdominal pain. Constitutional symptoms such as fever, weight loss, fatigue, and anorexia are less common. There is often a long latency period (5–40 years) between initial infection and expression of genitourinary disease.

Radiographic features:

A chest film should be performed to exclude pulmonary tuberculosis

On plain abdominal films:

- renal calcifications are a common manifestation of tuberculosis at conventional radiography, occurring in 24%–44% of patients
- extensive parenchymal calcification in a nonfunctioning, autonephrectomized kidney (putty kidney) is characteristic of end-stage tuberculosis
- calcifications may also be amorphous, granular, or curvilinear, typically within the renal parenchyma
- focal globular calcification involving an entire renal lobe is frequently associated with a granulomatous mass
- triangular ring like calcifications within the collecting system are characteristic of papillary necrosis
- other extrapulmonary manifestations of mycobacterial disease, such as mesenteric lymph node and adrenal calcifications, as well as spinal abnormalities, may be visible on conventional radiographs

On IVU:

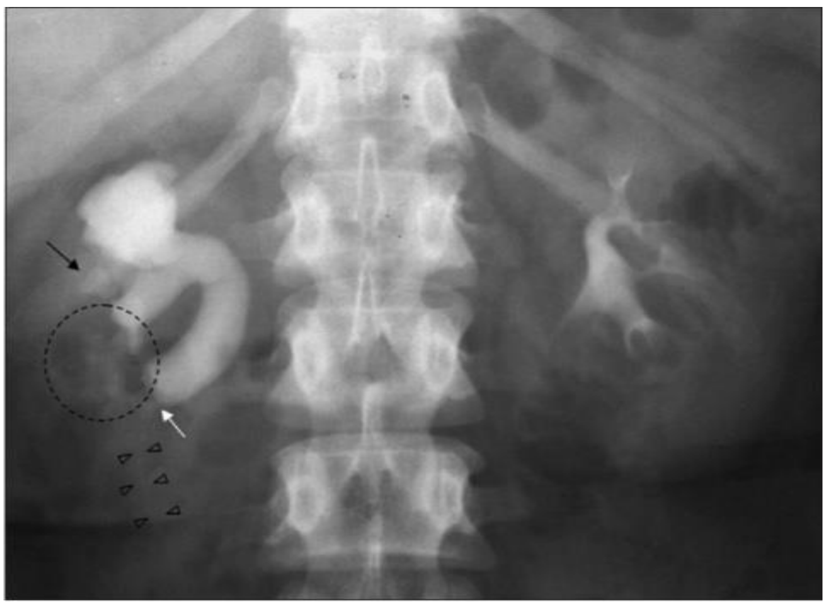
- approximately 10%–15% of patients who present with active renal tuberculosis will have normal urographic findings
- parenchymal scars are common, being seen in over 50% of patients

- irregularity of the papillary tips secondary to necrotizing papillitis ("moth-eaten" calices) is an early finding
- small cavities in the papillae can progress to become medullary cavities that communicate with the collecting system
- papillary cavitation results in the spread of infection to the urothelium and submucosa of the draining calyx
- a fibrotic reaction develops, which causes stenosis and strictures of the caliceal infundibula
- infundibular strictures can lead to localized caliectasis or incomplete opacification of the calyx (phantom calyx)
- some patients may present with generalized hydronephrosis
- scarring can cause sharp angulation of the renal pelvis (Kerr kink)
- ureteral involvement occurs due to the passage of infected urine
- such involvement first manifests as dilatation and mucosal irregularity (saw tooth ureter), which may progress, with advanced disease, to the formation of strictures and ureteral shortening (pipe-stem ureter)
- fusion of multiple strictures may create a long, irregular narrowing
- several no confluent strictures can produce a "beaded" or "corkscrew" ureter
- reduced bladder capacity is the most common finding in tuberculous cystitis
- the bladder may be diminutive and irregular with advanced disease (thimble bladder) deformities of calyces, strictures, irregular cavity formation and scarring of renal parenchyma

On CT:

- CT is helpful in determining the extent of renal and extrarenal spread of disease
- CT is the most sensitive modality for identifying renal calcifications, which occur in over 50% of cases of genitourinary tuberculosis
- coalesced cortical granulomas containing either caseous or calcified material are readily identified at CT

- calyces that are dilated and filled with fluid have an attenuation between 0 and 10 HU; debris and caseation, between 10 and 30 HU; putty-like calcification, between 50 and 120 HU; and calculi, greater than 120 HU
- parenchymal scarring is readily apparent at CT
- fibrotic strictures of the infundibula, renal pelvis, and ureters may be seen at contrast-enhanced CT and are highly suggestive of tuberculosis
- contrast-enhanced nephrographic-phase CT shows cortical thinning with markedly dilated calices that appeared to communicate with the globular high-attenuation areas
- the ureter is thickening and demonstrate abnormal mural enhancement



On IVU: revealing a (R) ureteric stricture (white arrow) with ureteric calcification (black arrowheads), pseudo-calculi (black arrow), and irregular calcification in the parenchyma (circled area)

10. Tumors

Renal cell carcinomas (RCC) are malignant tumors derived from the renal epithelium. It is the most common malignant renal tumor, with a variety of radiographic appearances.

Clear cell renal carcinoma (conventional): 70-80%

- arises from proximal convoluted tubules
- large uniform cells with clear cytoplasm
- highly vascular
- subtype: clear cell multinodular renal cell carcinoma

Papillary renal cell carcinoma: 13-20%

- arises from distal convoluted tubules
- can be multifocal and bilateral
- most common form in dialysis-associated RCC

  type I: sporadic, generally good prognosis

  type II: inherited, bilateral and multifocal

Chromophobe renal cell carcinoma: 5%

- arises from intercalated cells of collecting ducts
- similar histologically to renal oncocytomas
- best prognosis

Collecting duct renal cell carcinoma (Bellini duct): <1%

- often younger patients
- worst prognosis

Renal medullary carcinoma: rare

- seen primarily in patients with sickle cell disease or sickle cell trait

Sarcomatoid renal cell carcinoma (sRCC)

- advanced RCC may dedifferentiate into this highly aggressive subtype

Radiographic features:

On ultrasonography:

- it may appear solid or partially cystic
- may be hyper, iso, or hypoechogenic to the surrounding renal parenchyma
- the tumor pseudocapsule can sometimes be visualized with ultrasound as a hypoechoic halo

- contrast-enhanced ultrasound may typically show a lesion heterogeneously hypervascular in the arterial phase with early washout in the delayed phase

On CT:

Is frequently used to both diagnose and stage RCC:

- approximately 30% demonstrate some calcification
- variable enhancement, usually less than the normal cortex
- necrosis, renal vein and IVC involvement
- metastases and infiltration

On MRI:

- T1: often heterogeneous due to necrosis, hemorrhage and solid components
- T2: appearances depend on histology

    clear cell RCC: hyperintense

    papillary RCC: hypointense

- T1 C+ (Gd): often shows prompt arterial enhancement
- tumor pseudo capsule, essentially only seen in low-grade renal cell carcinomas, renal adenomas and oncocytomas appears as a hypointense rim between the tumor and the adjacent normal renal parenchyma

On CT: Renal cell carcinomas of the right kidney

11. Wilms tumors

Wilms tumors are the most common pediatric renal mass, accounting for over 85% of cases 1,8 and accounts for 6% of all childhood cancers. It typically occurs in early childhood (1-11 years) with peak incidence between 3 and 4 years of age.

Clinical presentation is typically with a painless upper quadrant abdominal mass.

Radiographic features:

On Plain radiograph:

- abdominal x-ray typically reveals a large soft tissue opacity displacing bowel.

On ultrasound:

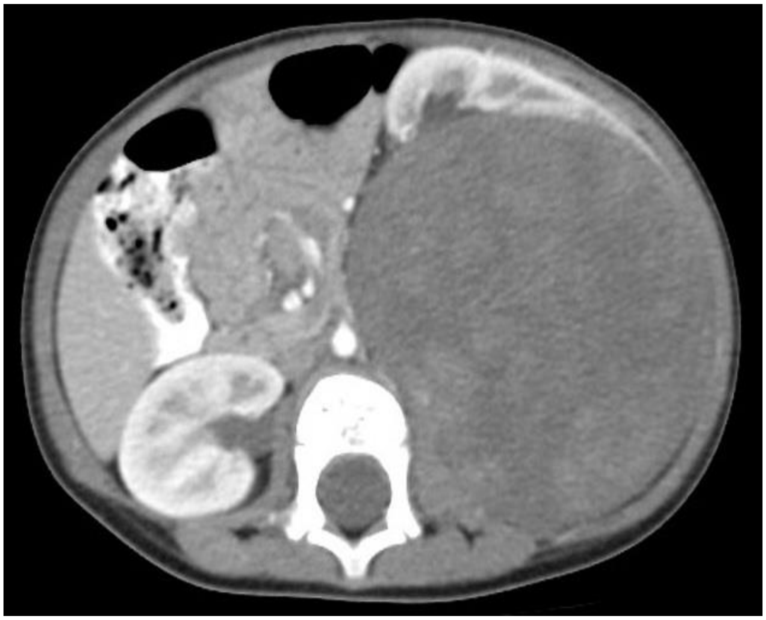
- large hypoechoic areas due to central necrosis and cyst formation
- hyperechoic areas may represent areas of fat, calcification or haemorrhage
- it may also appear less commonly as a solid spherical mass
- vessels are displaced rather than encased as the tumour directly displaces adjacent structures as it grows
- vascular invasion is estimated to occur in approximately 5-10% of cases

On CT:

- Wilms tumors are heterogeneous soft-tissue density masses with infrequent areas of calcification and fat-density regions
- enhancement is also patchy, and allows for better delineation of the relationship between the mass and kidney

On MRI:

- T1: hypointense
- T1 C+ (Gd): heterogeneous enhancement
- T2: hyperintense
- the non-cystic components of the Wilms mass typically show restricted diffusion on DWI.



CT: a large, heterogeneous mass arising from the left kidney

12. Renal metastases

Primary malignancies that most commonly metastasize to the kidney are lung, breast, gastrointestinal tumors and melanoma. Renal metastases usually occur late in the course of a known malignancy as part of widespread disease. In rare cases a renal metastasis may manifest as a solitary lesion and may be hard to differentiate from a renal cell carcinoma.

Radiographic features:

On CT:

- renal metastases are typically small, multifocal and bilateral, with an infiltrative growth pattern
- they show mild enhancement, much less than that of the normal renal parenchyma
- metastases can also be hypervascular however

CT scan: in a patient with a metastatic sarcoma shows ill-defined low density rounded lesions in the kidneys bilaterally (arrows) in this patient with a diffuse metastatic process.

Diffuse and multifocal renal parenchyma abnormalities

A number of pathological processes (some of which have already been discussed above) produce global or multifocal changes in the imaging appearances of one or both kidneys. These appearances include changes in the size and outline of the kidneys and the presence of multiple calcified areas.

13. Trauma

Renal trauma can result from direct blunt, penetrating and iatrogenic injury. Patients tend to present with microscopic or macroscopic hematuria and flank and/or abdominal pain. In more severe cases, hypotension and shock may be present.

Blunt trauma from motor vehicle collisions, falls and personal collisions are the major cause of renal injury (~85%) and the mechanism is from deceleration injuries from collision of the kidney with the vertebral column or thoracic cage. Iatrogenic injuries can result from surgery, percutaneous renal biopsy, nephrostomy and extracorpeal shock wave lithotripsy (ESWL).

The spectrum of renal injuries includes:

- contusion/hematoma

- laceration
- hemorrhage
- avulsion of the renal pedicle
- pseudoaneurysm
- AV fistula
- renal artery thrombosis, transection or dissection
- renal vein thrombosis

Renal injuries are graded as follows:

Grade 1 injuries are characterized by renal contusion without a parenchymal laceration, and a nonexpanding subcapsular hematoma.

Grade 2 injuries show superficial cortical lacerations that are < 1 cm deep (and thus do not involve the collecting system) and a nonexpanding perinephric hematoma.

Grade 3 injuries have deeper lacerations, > 1 cm deep, that do not extend into the collecting system, and nonexpanding perinephric hematoma.

Grade 4 injuries show lacerations that extend into the collecting system and injury to the main and segmental renal vessels. Grade 5 injuries show shattering of the kidney and dispersion of the avulsed portions, avulsion, laceration or thrombosis of the main renal vessels, hilar injury, and ureteropelvic junction (UPJ) avulsion.

Radiographic features:

On Plain film:

Plain film of urinary system is generally of poor quality due to distended coils of intestine obscuring retroperitoneal structures. Fracture of lower ribs, contraction of psoas muscles may take place. Affected side diaphragm may be elevated and there may be a secondary pleural effusion.

On IVU:

- intrarenal hematoma produces a localized defect in nephrogram with calyceal displacement

- laceration of the renal capsule produces enlargement of the renal outline and displacement of renal capsule

- compression of renal pelvis may produce hydronephrosis

- when laceration involves collecting system extravasation of contrast medium is seen

On CT:

- renal contusions are seen as areas of ill-defined decreased enhancement, whereas areas of segmental infarction due to laceration, thrombosis, or dissection of segmental arteries appear as sharply demarcated linear or wedge-shaped nonenhancing areas

- lacerations appear as irregular or linear parenchymal defects that may contain clot

- in a shattered kidney, foci of active arterial extravasation should be distinguished from islands of viable renal parenchyma that are still enhancing

- subcapsular hematomas are seen as round or elliptical high-attenuation (40–70 HU) collections of clotted blood

- segmental arterial injuries may cause areas of segmental infarction, pseudoaneurysms, or arteriovenous fistulae

- global infarction can be due to renal artery thrombosis related to intimal dissection from a deceleration injury, or to renal artery avulsion, in which case a perinephric hematoma should be present

- venous injuries with blunt trauma are rare and usually occur in association with arterial pedicle injuries and severe parenchymal injuries, although isolated renal venous injury without arterial or parenchymal injury has been reported with trauma sustained during martial arts

On CT: Subcapsular hematoma on the left kidney

Ureteral injuries

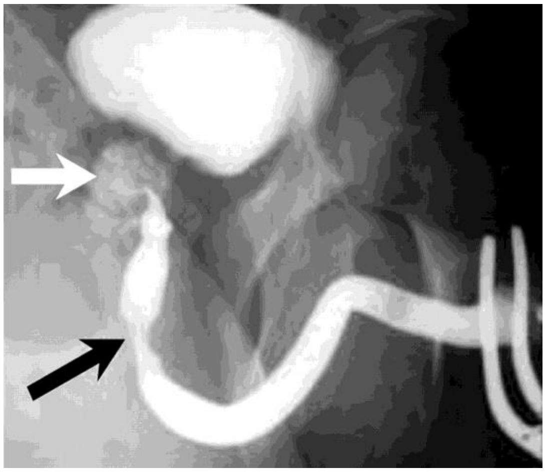
Iatrogenic ureteral injuries can occur during gynecologic, obstetric, urologic, colorectal, general, or vascular surgery; gynecologic surgery accounts for more than half of all iatrogenic injuries. Patients may present with flank or abdominal pain, elevated serum blood urea nitrogen and creatinine levels, vaginal urinary leakage, fever, or other nonspecific symptoms. Unfortunately, the diagnosis of an iatrogenic ureteral injury can be delayed for several weeks until the patient becomes symptomatic.

In patients with blunt trauma and suspected ureteral - pelvic junction (UPJ) injury, CT with excretory phase imaging is a reliable tool for evaluation.

Radiographic features:

On retrograde pyelography, CT:

- features that suggest UPJ injury include predominantly medial perirenal contrast extravasation in the absence of renal parenchymal injury
- if the UPJ is lacerated, contrast material will be present in the distal ureter; and with transection, the distal ureter will not be opacified
- in equivocal cases, retrograde pyelography can be helpful in distinguishing partial laceration from complete transection



On ascending urethrography: shows an area of contrast material extravasation (white arrow) indicative of injury to the posterior urethra, with an intact urogenital diaphragm (black arrow)

Urinary bladder trauma

Classification of bladder injury:

type 1 is bladder contusion

type 2 intraperitoneal rupture

type 3 extraperitoneal rupture

type 4 combined injury

The most frequent causes of bladder trauma are motor vehicle crashes (in which both seat belt compressions of the bladder and ejection injuries may be responsible), falls, crush injuries, and blows to the lower abdomen. Sixty percent to 90% (mean, 80%) of patients with bladder injuries due to blunt trauma have associated pelvic fractures, and approximately 30% of patients with pelvic fractures will have some bladder injury, including bladder contusion. Twenty-five percent of intraperitoneal bladder ruptures occur in patients without a pelvic fracture. Simultaneous ruptures of the bladder and prostatomembraneous urethra can occur in 10–29% of males undergoing trauma.

Intraperitoneal rupture occurs when there is a blow to or compression of the lower abdomen in a patient with a distended urinary bladder, causing a sudden rise in the intraluminal pressure of the bladder and rupture of the dome, which is the weakest portion of the bladder. The dome of the distended bladder is covered by peritoneum, so an injury at this site causes intraperitoneal extravasation.

Extraperitoneal ruptures are further classified into two groups, simple and complex, by Sandler et al.

In simple extraperitoneal rupture, contrast extravasation is confined to the pelvic extraperitoneal space; whereas in complex extraperitoneal rupture, extravasated contrast material can disperse widely into the anterior abdominal wall, the penis, the scrotum, and the perineum as a result of disruption of the fascial planes of the pelvis by the injury.

Radiographic features:

On cystography, conventional cystography:

- the identification of contrast material outside the confines of the urinary bladder confirms the diagnosis of bladder rupture
- with extraperitoneal leaks, the contrast agent remains confined to the pelvis
- with intraperitoneal leaks, contrast material may outline bowel loops and extend into the paracolic gutters and diffusely into the peritoneal cavity
- molar tooth sign' indicating extraperitoneal bladder rupture.

14. Diverticula of urinary bladder

Bladder diverticula are herniation of bladder mucosa between fibers of the detrusor muscle. Depending on the size of the muscular defect, the diverticula have either a narrow or a wide neck.

Bladder diverticula may be ***acquired or congenital***.

Acquired diverticula are usually multiple and associated with bladder trabeculation. They are the result of bladder outlet obstruction or infection or have iatrogenic causes.

Congenital diverticula most often are solitary, occur in a smooth wall bladder, and are more common in males. They are usually located in the lateral cornu of the trigone and the ureteral hiatus and can impinge on, engulf, or be separate from ureteral orifices. The cause is believed to be an inherent weakness in the detrusor musculature, in particular deficiencies of the Waldeyer fascial sheath.

Because of urinary stasis, diverticula predispose to infection and stone formation and tumors may, on occasion, arise within them.

Clinical Findings

- usually asymptomatic
- rarely a cause of bladder outlet obstruction

Radiographic features:

Most diverticula fill at urography (***IVU post-voiding film) and micturating cystography***. They are readily demonstrated at ***US, CT, and MRI***. When large, diverticula may deform the adjacent bladder or ureter

On IVU: diverticula of urinary bladder

15. Neurogenic bladder

Neurogenic bladder is a term applied to a dysfunctional urinary bladder that results from an injury to the central or peripheral nerves that control and regulate urination. Injury to the brain, brainstem, spinal cord or peripheral nerves from various causes including infection, trauma, malignancy or vascular insult can result in a dysfunctional bladder.

Clinical Presentation

Depending on the location of the injury in the nervous system, patients typically present with increased frequency, nocturia, urinary incontinence/urgency, urinary tract infection and urinary retention.

Bladder may be ***hyperreflexic, hyporeflexic or areflexic*** with impaired to no sensation.

Classification

A number of classification schemes exist for neurogenic bladders, including the Lapides classification which remains popular.

1. ***sensory neurogenic bladder:*** posterior columns of the spinal cord or afferent tracts leading from the bladder
2. ***motor paralytic bladder:*** damage to motor neurons of the bladder
3. ***uninhibited neurogenic bladder:*** incomplete spinal cord lesions above S2 or cerebral cortex or cerebropontine axis lesions
4. ***reflex neurogenic bladder:*** complete spinal cord lesions above S2 - may lead to pine cone bladder
5. ***autonomous neurogenic bladder:*** conus or cauda equina lesions

Radiographic features:

Generally, a markedly contracted or distended bladder.

On fluoroscopy, IVU:

Sensory neurogenic bladder

- inability to sense bladder fullness results in a large rounded and smooth bladder - - voiding is often preserved

Motor paralytic bladder

- atonic large bladder with inability of detrusor contraction during voiding

Uninhibited neurogenic bladder

- rounded bladder with a trabeculated appearance to the mucosa above the trigone from detrusor contractions
- on voiding large interureteric ridge is noted

Reflex neurogenic bladder

- results from detrusor hyperreflexia with a dyssynergic sphincter
- this leads to contrast extension to the posterior urethra and an elongated pointed urethra with pseudodiverticula

Autonomous neurogenic bladder

- intermediate between detrusor hyperreflexia (contracted) and dysreflexia (atonic)

On ultrasound:

- detailed images of the bladder often demonstrate a thick wall with a small contracted or large atonic bladder
- a large post void residual is often noted

On IVU: neurogenic bladder

16. Bladder cancer

Transitional cell carcinoma (TCC)

Transitional cell carcinoma is the most common primary neoplasm of the urinary bladder, and bladder TCC is the most common tumor of the entire urinary system. Presentation includes hematuria, ureteral obstruction and hydronephrosis, flank pain, bladder outlet obstruction and urinary retention.

Diagnosis and local tumor staging is usually achieved with cystoscopy and full thickness biopsy.

Invasive tumors account for only 20-30%.

Imaging serves to exclude infiltration and metastasis.

Radiographic features:

On IVU:

Because transitional cell carcinoma is a multifocal disease, excretory urography may identify synchronous lesions.

- a primary tumor may appear as a small-capacity, thick-walled bladder or as a focal mass
- it may also appear as a filling defect or as a stricture along the course of the ureters
- if severe, obstruction may result in hydroureteronephrosis and a delayed nephrogram

On US:

- it often appears as a polypoid or plaque like, hypoechoic lesion that may project into the bladder
- calcifications or fibrosis produce an increase in echogenicity
- blood flow can be shown in tumors on Doppler sonography

On CT:

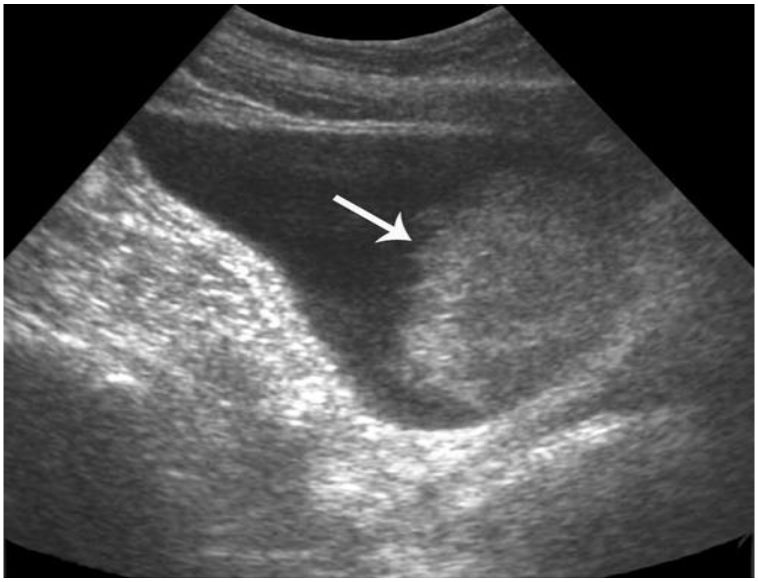
CT is the primary imaging modality for cancer of the urinary bladder.

- optimally, rapid scanning is performed in the nephrographic phase before excreted IV contrast material reaches the bladder
- the enhancing tumor can be visualized against a background of low-attenuation urine within the bladder
- on delayed scanning, the lesion appears as a mural nodule against a background of high-attenuation contrast material within the bladder
- the mass may appear plaque like or papillary
- calcifications may also be noted
- mucinous adenocarcinoma such as urachal carcinomas can have either pattern
- as the tumor grows, circumferential wall thickening may also be seen

- in addition, the mass may invade the ureteral orifice, resulting in hydroureteronephrosis

On MRI:

- on T1-weighted sequences, the tumor has an intermediate signal and contrasts with the high signal in fat
- urine in the bladder has a lower signal than the tumor
- T1-weighted sequences are optimal for detection of extravesical infiltration, nodes, and bone metastases
- on T2-weighted images, contrasting with the high signal intensity of urine and low signal intensity of muscle
- T2-weighted sequences are optimal for evaluation of tumor depth and differentiating tumor from fibrosis and for detection of invasion of surrounding organs and marrow metastases
- cancer of the urinary bladder enhances after gadolinium injection
- peak enhancement is earlier than that of the bladder wall, which may be helpful if dynamic imaging is performed
- gadolinium contrast enhancement can obscure discrimination of tumor invading into the adjacent high-signal fat; fat-saturated images can be helpful in this regard
- enhancement with or without fat saturation can show invasion into adjacent organs
- coronal and sagittal planes can also be useful in identifying perivesical invasion, particularly at the dome and at the base of the bladder
- synchronous or metachronous lesions in the ureters may also be detected on MR imaging



Urothelial carcinoma. Longitudinal US image of the bladder shows a large, hypoechoic urothelial carcinoma (arrow) within the bladder.

17. Prostatic enlargement

The term benign prostatic hypertrophy (BPH) was formerly used for this condition, but since there is actually an increase in the number of epithelial and stromal cells in the periurethral area of the prostate, not an enlargement of cells, the more accurate term is hyperplasia.

Although the term prostatomegaly is often used interchangeably with BPH, strictly speaking prostatomegaly may refer to any cause of prostatic enlargement. Prostatic enlargement is very common in elderly men. It is usually due to benign prostatic hypertrophy but may be due to carcinoma.

Radiographic features:

On transrectal ultrasound (TRUS):

- can show the overall size of the prostate and can diagnose relatively small masses within its substance
- TRUS-guided biopsy is used for the diagnosis of prostatic carcinoma

On transabdominal ultrasound:

- there is an increase in volume of the prostate with a calculated volume exceeding 30 mL (width x height x length x 0.52)

- the central gland is enlarged, and is hypoechoic or of mixed echogenicity
- calcification may be seen both within the enlarged gland as well as in the pseudocapsule (representing compressed peripheral zone)
- post-micturition residual volume is typically elevated
- associated bladder wall hypertrophy and trabeculation due to chronically elevated filling pressures

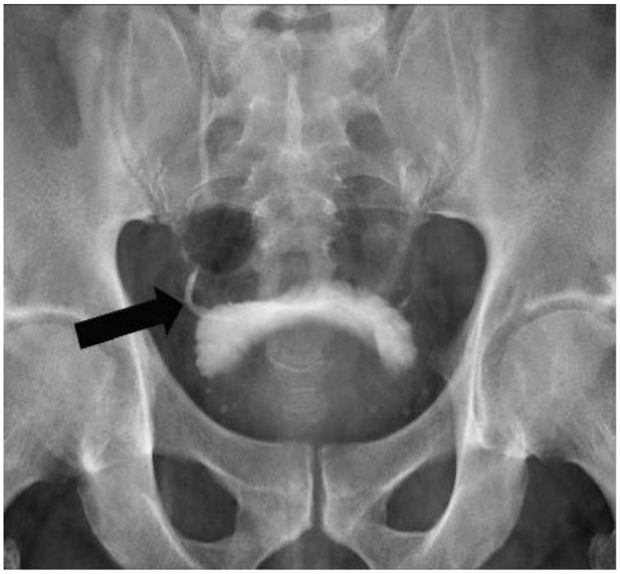
measurement of post voiding residual urine volume and determine if there is associated development of hydronephrosis

On IVU:

- enlarged prostate may cause round central filling defect at the bladder base and hooking of the distal ureters due to elevation of the bladder base

On MRI:

- in T2 images, the peripheral zone (the most common origin of tumors) is of high signal intensity and the tumor is of low signal intensity
- MRI is used to assess early stage prostatic cancer in patients being considered for radical surgery or radiotherapy
- MRI is also used to demonstrate extracapsular tumor spread, to show invasion of the seminal vesicles, and to demonstrate possible metastases



On IVU: benign prostatic hypertroph

Recommended literature

Basic

1. Kravchuk S. Yu. Radiology: textbook for student and interns of medical institutions of higher education / S. Yu. Kravchuk. - Kyiv: AUS Medicine Publ, 2021. - 224 p.

2. Radiological features of the urinary system pathology: навч. посібник/ E.G. Nordio, N.V. Tumanskaya, S.A. Myagkov – Запоріжжя, ЗДМУ, 2020. - 74с.

Additional literature

1. Radiological investigations: навч. посібник/ E.G. Nordio, N.V. Tumanskaya, S.A. Myagkov – Запоріжжя, ЗДМУ, 2021. - 84с.

2. Kovalsky O. V. Radiology. Radiotherapy. Diagnostic imaging: textbook higher medical educational establishments of IV th accred. level / O. V. Kovalsky, D. S. Mechev, V. P. Danylevych. - 2nd ed. - Vinnytsya : Nova Knyha, 2017. - 504 p.