IMAGING OF THE UROGENITAL TRACT

A) URINARY TRACT

There are many methods of imaging the urinary tract but plain abdominal X-ray and ultrasound scan are usually done first in most cases, especially in a third world setting.

Methods of imaging:
1. Plain films
2. Ultrasound
3. Intravenous urogram (pyelogram) - (IVU, IVP; excretion urography)
4. Micturating cystogram or cystourethrogram (MCUG)
5. Cystogram
6. Urethrogram (ascending urethrogram)
7. Retrograde pyelogram
8. Antegrade pyelogram
9. Radionuclide studies:
10. Computed tomography (CT)
11. Magnetic Resonance Imaging (MRI)
12. Angiography

Ultrasound should be performed before other investigations such as intravenous urography for the following reasons:
- it is cheap and readily available
- it is safe – no danger of contrast reactions
- no radiation
- the renal outlines are clearly seen
- no interference from bowel gas
- renal size can be easily assessed. Cortical loss can be measured.
- renal texture can be assessed e.g. echogenic in acute nephritis
- particularly good for renal failure, when IVP is contraindicated
- renal masses are seen, even if only small (earlier than on IVP)
- the bladder is well seen as is the bladder wall
- the prostate can be assessed
- residual urine can be measured fairly accurately
- other pelvis abnormalities may be visualised e.g. ovarian mass or fibroids

Disadvantages are:
- the ureters cannot be seen unless dilated.
- calyceal detail cannot be seen which is necessary for assessment of chronic pyelonephritis, papillary necrosis and tuberculosis
- uroendothelial (transitional cell) tumours of the renal pelvis/calyces are not visualised until large.

COMMON URINARY TRACT PROBLEMS:
1. Haematuria
2. Prostatism
3. Renal angle pain - infection; calculi.
4. Renal mass
5. Obstruction of the urinary tract –
   - Uretero-pelvic junction obstruction (UPJ)
   - ureteric stone, sloughed papilla, ureteric stricture
   - ureteric or bladder tumour,
   - pelvic malignancy e.g. carcinoma cervix.
   - prostatic hypertrophy
   - retroperitoneal mass or fibrosis
6. Renal trauma
7. Trauma to the bladder and urethra e.g. pelvic fractures.
8. Renal cysts
9. Ureteric reflux
10. Urethral stricture
11. Posterior urethral valve
12. Vesicovaginal fistula
13. Renal, ureteric, bladder stones
14. Schistosomiasis – ureteric strictures, bladder masses
15. Congenital lesions: duplex systems, polycystic disease, absent or pelvic kidney
1. PLAIN FILMS:

Some information about the urinary tract may be obtained from plain films. Bladder distension, opaque calculi, and bladder wall calcification may be seen. Calcified fibroids, prostatic calcification and calcification of the seminal vesicles is readily seen. In the presence of severe pain, excess gas in the bowel limits the value of the plain film and calculi are usually shown more easily on ultrasound examination or intravenous urography.

Features which may be seen on plain film

- **Calcification**
  - **Kidney**
    - Calculus. Shown to be lying within the kidney by taking an oblique film, when it maintains a constant relationship to the kidney. Usually forms in a calyx and may be single or multiple. Often bilateral. Small fragments may break off passing down the ureter producing colic.
    - Staghorn calculus - large calculus occupying much of the pelvi-calyceal system.
    - Nephrocalcinosis - multiple calcifications in the parenchyma, not the pelvicalyceal system, most commonly associated with:
      ... Renal tubular acidosis
      .... Hyperparathyroidism
      ... Medullary sponge kidneys

Plain film showing opacity on the L side at the level of L2. This was due to a ureteric stone, which was confirmed on an intravenous urogram/pyelogram

Plain film showing 3 opacities overlying the L kidney. The upper one is assuming the shape of a calyx as they are lying within the calyces. Eventually when very large they will produce the typical appearance of a staghorn calculus. They can be shown to be lying within the kidney by taking an oblique film. They will maintain a constant relationship to the renal outline.

Nephrocalcinosis. Multiple calcifications in the R kidney, clustered in the papillary regions (this was taken after contrast which faintly outlines the renal pelvis- white arrow). In this patient due to medullary sponge kidneys. These calculi are not within the pelvicalyceal system but may be passed into the calyces producing renal colic if they enter the ureter.

b) **Ureter**
   - Wall of ureter in schistosomiasis
   - Calculus

Plain film showing opacity on the L side at the level of L2. This was due to a ureteric stone, which was confirmed on an intravenous urogram/pyelogram

c) **Bladder**
   - Wall in Schistosomiasis
   - Calculus - may be small, large, laminated or just calcified around periphery
d) Fibroids, prostate, seminal vesicles
Mesenteric lymph nodes, pleboliths & calcified costal cartilages may also be seen and need to be distinguished from urinary tract calcification. Phleboliths are usually multiple and rounded with a central darker ring. Most are within the pelvis. Calcified nodes show uneven calcification and can lie anywhere within the abdomen. They change position and their relationship to other structures with change in position of the patient.

2. GAS IN THE URINARY TRACT
Gas in the bladder lumen may be seen in vesico-intestinal fistula and cystitis due anaerobic infection, usually associated with diabetes. A round dark shadow is produced by the bulb of an indwelling catheter. Gas in the bladder wall is seen in emphysematous cystitis due to anaerobic infection.

3. INTRAUTERINE CONTRACEPTIVE DEVICE may be seen in the pelvis

4. DERMOID cyst is occasionally recognised as a low density structure which may contain recognisable teeth
2. ULTRASOUND:

NORMAL FINDINGS:
1. Kidneys of fairly equal size: 9-11cm in bi-polar length measured from upper to lower pole along the renal axis. A 1.5cm difference in size is significant.
2. Renal outlines should be smooth
3. Renal texture: the echogenicity of the cortex is the same or slightly darker than a normal liver
4. Renal calyces: are well seen & show as a bright echogenic cluster centrally, easily differentiated from the cortex
5. Renal cortex is of even thickness throughout - around 2cm
6. Normal ureters are not seen
7. Bladder wall should be smooth & even with a mucosal thickness of not greater than 5mm
8. Prostate size is normally less than 20ml in volume and confined within its capsule
9. Prostate echogenicity should be fairly even
10. No measurable residual urine following micturition

ABNORMALITIES on Ultrasound:

1. Increased echogenicity: diffuse disease of the renal cortex usually causes the kidneys to become brighter in appearance, more echogenic than the liver and the cortex may equal the brightness of the central calyceal complex of echoes which cannot be differentiated. This occurs in acute and chronic nephritis. In acute nephritis the kidney is either normal in size or enlarged whereas in chronic nephritis the kidney is reduced in size.

![Ultrasound scan showing a normal L kidney. The calyces are brighter than the renal cortex & can be easily distinguished. The calyceal echo complex does not contain a dark area within it indicating that they are not distended with urine. The kidney measures 9.5 cm in length (between the crosses).](image1)

![Ultrasound scan showing a bright kidney, much brighter than the liver above it. The calyceal complex cannot be distinguished indicating that the renal cortex is echogenic. Both kidneys appeared the same indicating bilateral renal disease. The kidney measured 9cm, within the normal range, indicating that the disease is not of long standing.](image2)

2. Hydronephrosis:
In the presence of hydronephrosis the calyceal echoes are separated by urine which appears as a dark area centrally. If the ureters are dilated they may be seen distended with urine proximally or distally appearing as dark tubular structures on the longitudinal scan or round dark circles on the transverse scan. The mid parts of the ureters are obscured by bowel and other structures. The cause can sometimes be seen on ultrasound but if the obstruction lies in the mid part of the ureter an intravenous pyelogram (IVP) will be needed to demonstrate the site and cause.
A general guide is:
- Hydronephrosis in kidney but ureters not dilated - probably obstruction at the ureteropelvic junction.
- One ureter dilated proximally but not distally - ureteric obstructing lesion
- Whole ureter dilated – bladder/pelvic mass (carcinoma cervix common cause)
- Both ureters dilated down to the bladder - bladder outlet obstruction, thick walled bladder as in severe cystitis or large bladder tumour obstructing both ureters.
- Consider the possibility that hydronephrosis is not due to an obstruction but secondary to infection, or reflux if a child.

A complication of obstructive hydronephrosis is infection leading to pyonephrosis. In pyonephrosis the urine is no longer anechoic but contains echoes (turbid urine). In severe cases the calyces become filled with debris and are difficult to distinguish. They may be mistaken for a renal mass. Hydronephrosis, especially on the R side, is seen commonly in pregnancy after 14 weeks and is usually without significance unless there are associated urinary tract symptoms.
The thickness of the renal cortex is important. If the obstruction is of long standing the renal cortex atrophies and appears narrow on ultrasound. In severe, long-standing, obstruction the cortex may be completely destroyed and no longer visible. In these cases an intravenous pyelogram will usually be unhelpful as the kidney is often non-functioning.

Ultrasound scan showing separation of the calyces by urine which appears as a dark serpiginous area centrally. The renal cortex appears normal. This was a patient admitted with acute pain radiating from the loin to the groin suggestive of renal colic. The scan confirmed the presence of hydronephrosis & a plain film demonstrated an opacity at the level of L3 consistent with a ureteric calculus.

Renal ultrasound scan showing more marked hydronephrosis. The calyces & renal pelvis are quite markedly dilated. The renal cortex is very thin and barely visible (white arrow). This indicates that the obstruction has been present for some time.

Renal ultrasound in a child admitted with loin pain and fever. The scan shows hydronephrosis but the calyces contain echogenic urine. The debris has sunk to the lowest level producing the appearance of a fluid level. This was a case of pyonephrosis.

Renal scan on a young woman who presented with a large R sided abdominal mass. This had been present for several months, associated with pain and intermittent fever. An ultrasound scan done elsewhere had not demonstrated the R kidney. This repeat scan shows large dark rounded areas in the region of the kidney (white arrows). They are very dilated calyces filled with echogenic material (pyonephrosis). Just below the calyces centrally is a bright rounded structure casting a shadow (dark arrow). This was a calculus lying at the ureteropelvic junction resulting in obstruction. Secondary infection developed resulting in pyonephrosis. A plain film confirmed the presence of the calculus.
3. Renal infections

Renal infections are best assessed by ultrasound. In acute pyelonephritis the kidney may be swollen and darker than the other kidney. In the presence of pyonephrosis the calyces will be distended and contain echogenic urine (turbid urine or pus). In perinephric abscess pus will be seen as a dark collection in relation to the kidney. An intravenous pyelogram will show diminished or absent function. Occasionally a renal abscess may develop appearing as a hypoechoic renal mass.

4. Renal cysts: Ultrasound easily distinguishes cysts from solid masses. Cysts are anechoic (no internal echoes) and show acoustic enhancement (increased brightness behind the lesion). Simple cysts are very common in older patients & without clinical significance. They are quite different from congenital polycystic disease in which the renal architecture is distorted by the presence of multiple cysts of varying sizes & the kidneys are usually very large in size & palpable.

Cysts may be:
- multiple
- single
- due to polycystic disease which may also be associated with liver and pancreatic cysts
- calyceal diverticulae (calyceal cysts)
- parapelvic in location when they may be confused with hydronephrosis
- cystic tumour but this does not have the appearances of a simple cyst and there are usually strands or solid elements within it.

5. Solid renal mass: A space occupying lesion in the kidney is well shown on ultrasound. A cyst is readily distinguished from a solid mass. Malignant tumours are usually dark or hypoechoic and heterogeneous (uneven) in texture. If a suspicious mass is seen on ultrasound other features to look for are:
- involvement of the renal vein or inferior vena cava by tumour
- enlarged nodes
- liver metastases
- local spread outside the kidney
- tumour in the contralateral kidney- this is not uncommon

6. Calculi: These are usually demonstrated by plain film. A plain film + intravenous pyelography has been the recommended investigation in the past. However, low density or very small calculi are often seen on ultrasound before they are visualised on plain films. They show as bright structures, which cast a dark shadow due to attenuation of the beam. An ultrasound scan + plain film is helpful as an initial imaging method in suspected renal colic. The plain film will demonstrate calculi and ultrasound will demonstrate any

Ultrasound scan showing the appearance in polycystic renal disease. The normal renal structure is destroyed, the renal outline is difficult to recognise and the calyceal complex is lost as the kidney is replaced by cysts of varying sizes.

Renal scan showing a dark clear structure in the lower pole centrally (white arrow) which was a simple cyst. The normal echogenic calyces can be seen in the upper pole (dark arrow)
Hydronephrosis. An intravenous pyelogram may be needed for confirmation or further assessment.

Bladder calculi are well shown on ultrasound. On plain films they may be hidden by bowel contents.

7. **Large kidney(s):** One kidney may be larger than the other. If the kidney measures over 11cm in length it is enlarged. It may otherwise be of normal appearance or it may show features such as hydronephrosis. Sometimes both kidneys are enlarged. Some of the causes of a large kidney are:
   - Acute infection – acute pyelonephritis or pyonephrosis
   - Tumour of the kidney – a hypoechoic mass is usually obvious within the kidney.
   - Tumour infiltration - lymphoma; leukaemia – the cortex is thickened but otherwise there may be little change. It may be bilateral
   - Duplex kidney - may be difficult to detect on ultrasound but careful scanning will reveal two separate calyceal clusters.
   - Obstruction – calyces will be dilated and filled with urine
   - Compensatory hypertrophy – other kidney will be absent or small
   - Cystic kidney – the cysts will be apparent
   - Trauma - haematoma or urinoma – dark collection in the kidney
   - Amyloid – large kidneys usually bilateral. May otherwise look normal.
   - Acute interstitial nephritis - bilateral, often show increased echogenicity but may not
   - Renal vein thrombosis
   - Acute papillary necrosis
   - Medullary Sponge kidneys – calculi visible

8. **Small kidney(s):** One or both kidneys may be reduced in size. If unilateral think of chronic pyelonephritis or post obstructive atrophy. If bilateral chronic renal disease such as chronic glomerulonephritis.
   - Post obstructive atrophy - some residual dilatation of the pelvi-calyceal system may be evident
   - Ischaemia – reduced renal blood supply. Difficult to demonstrate even with doppler ultrasound
   - Congenital hypoplasia – the kidney has not developed normally. Unilateral with a smooth outline
   - Chronic glomerulonephritis – bilateral with smooth renal outlines
   - Chronic pyelo-nephritis - unilateral or bilateral. The kidneys show scarring and are irregular in outline
   - Chronic papillary necrosis - focal, bilateral – difficult to diagnose on ultrasound.

9. **Absent or ectopic Kidney:** This is not that uncommon. If a kidney is not found in the normal position look in the pelvis which is the commonest place for an ectopic kidney. If absent the opposite kidney will usually show compensatory hypertrophy.

10. **Bladder**
    The bladder is well seen on ultrasound. On intravenous pyelography it is often obscured by bowel gas.
    The thickness of the bladder wall can be measured, trabeculation and diverticulae are well shown. Diverticulae show as outpouchings from the bladder wall containing urine. The neck of the diverticulum is usually seen which helps in diagnosis. They show best on post micturition films. Asymmetrical thickening of the bladder wall is a feature of schistosomiasis while generalised thickening is seen in bladder outlet obstruction or chronic cystitis.

    Bladder tumours show well except for tumours arising from the anterior wall which are often difficult to see due to artefact as the bladder wall lies just below the anterior abdominal wall. Low lying posterior tumours commonly obstruct one or both ureters. Granulomas in schistosomiasis look like bladder tumours and cannot be distinguished. Cystoscopy is needed for assessment.
11. Prostate
The assessment of the prostate is part of a routine scan of the renal tract in males as is assessment of the pelvic organs in the female patient. The normal prostatic size (volume) is between 10-20 cubic cm. The texture can be difficult to assess but should be fairly homogenous, the capsule smooth and intact. There should be no more than a few ccs of residual urine following micturition.

12. Renal trauma:
Ultrasound is good as a first test for renal trauma. If the examination is completely normal there is unlikely to be significant damage to the kidney. It is limited by the fact that renal function is not assessed. Haematomas show as hypoechoic masses bulging the renal outline. If the capsule is torn there may be a dark collection of urine or blood around the kidney. Computed tomography is more sensitive for detecting renal damage following trauma.

INTRAVENOUS PYELOGRAM (IVP)

Intravenous pyelogram is interchangeable with intravenous urogram and is indicated in suspected urinary tract pathology when ultrasound has failed to make a diagnosis. It is particularly good for assessment of renal colic, to prove that an opacity seen on the plain film is actually lying within the ureter. Intravenous urography is not indicated in hypertension as it is an insensitive test. If imaging is considered necessary on clinical grounds an ultrasound scan is done as an initial screen. Narrowing of the renal artery may be suspected if one kidney is 2 cm smaller than the other. Renal artery stenosis can then be assessed by radionuclide scanning or angiography.

Intravenous pyelography is necessary for the assessment of early ureteric involvement in schistosomiasis and is undertaken for the assessment of any suspected ureteric problem.

Main indications for intravenous pyelography:
- suspected ureteric disease, unexplained loin pain
- haematuria with a negative cystoscopy and ultrasound scan
- dilated ureter on ultrasound when the cause has not been demonstrated
- renal colic with a normal scan
- abnormal scan which is difficult to interpret
- to show the position of ureters for planning surgery or X-ray therapy
- suspected renal disease that is likely to cause calyceal deformity such as tuberculosis, papillary necrosis and chronic pyelonephritis
- to exclude or prove that an abdominal mass is involving the kidney if computed tomography is not available and ultrasound was inconclusive.
- trauma – ultrasound and computed tomography have generally taken over from intravenous urography but if these imaging modalities are not available or ultrasound is inconclusive IVP may be necessary.

Carcinoma of the cervix is a common reason given for intravenous urography, however ureteric involvement can often be seen on ultrasound as can involved iliac nodes.

If the blood urea is more than a little elevated, IVP will seldom be of value, especially if the standard amount of contrast is used. If an IVP is considered to be necessary an increased amount of contrast should be used. If the urea is very high IVP will not be diagnostic and may be harmful. Ultrasound should be used in these patients. In the presence of a raised blood urea the patient should be well hydrated before performing an intravenous pyelogram.

Intravenous urography involves an intravenous injection of a water soluble iodinated contrast agent. These agents are classed as IONIC (HIGH OSMOLAR) and NON-IONIC (LOW OSMOLAR). The non-ionic contrast agents are safer to use and cause less severe reactions than those encountered with the cheaper ionic agents. In particular, they cause less vomiting and hot flushing. Unfortunately these safer non ionic agents are more difficult to obtain in Ghana and are
expensive. As there is a risk of producing a severe reaction even with non-ionic contrast, an IVP should only be performed if there is a valid clinical indication. The standard dose of contrast for an adult is 50cc but this can be increased to 100cc in very large patients or patients with an elevated blood urea. In children a guide to dosage is 1ml per kg of body weight up to age 15yrs. There should always be adrenaline & hydrocortisone immediately available in case of a severe reaction.

Intravenous pyelography is not indicated in:
- Advanced renal failure – use ultrasound
- Prostatism
- Polycystic renal disease – better seen on ultrasound
- Vague abdominal pain
- Acute urinary tract infection
- Not diagnostic for renal artery stenosis

Intravenous pyelography should be performed with caution in:
- diabetic patients
- very small children
- renal failure
- patients with a previous reaction to the dye. If the reaction was severe this is a contraindication.
- myelomatosis
- patients with sickle cell disease

In these cases non ionic contrast should be used if at all possible.

REACTIOnS TO INTRAVENOUS CONTRAST:
- Urticaria
- Laryngeal oedema
- bronchospasm
- Vascular collapse
- Cardiac Arrest

Severe reactions are rare but dangerous, requiring immediate treatment. For this reason intravenous pyelography should not be performed unless medical assistance is immediately available. Most reactions are mild and usually do not require any treatment. For example, mild urticaria, itching and vomiting.

PROCEDURE:
A plain film is always taken before injection of the dye. This is because calculi are masked by the contrast and would not be seen once the kidneys have started to excrete it. This film should be carefully checked for any opacity, which may be lying in the renal tract. Further views (e.g. oblique) may be necessary.

Following injection there are several different protocols depending on the clinical indication and the ultrasound report. Clinical details should always be provided. As ultrasound will usually already have been performed an immediate film is no longer necessary and usually the first film is taken at 5-10mins. An immediate film shows contrast in the tubules. This causes the whole kidney to be slightly denser and the renal outlines easier to see. This is called the nephrogram phase. The length of the kidney is normally the distance of 3.5 vertebral bodies.

The 5-10min film is usually a full-length film to show early ureteric filling before the lower ureters become obscured by contrast in the bladder. At this stage the calyces, renal pelvis and parts of the ureters are outlined with contrast. This is called the pyelogram phase.

The calyces may be different on the two sides as there is considerable variation anatomically but they should be reasonably symmetrical and the kidneys excreting at the same rate with equal fading of the nephrogram.

Normal 10 min film showing the pelvicalyceal systems, ureters and bladder outlined with contrast.
The nephrogram phase has faded equally on the two sides with most of the contrast having been excreted into the calyces.

Normal calyces, cup shaped and of similar distance from the outer margin of the kidney.
If this film shows the pelvicalyceal systems, ureters and bladder to be perfectly normal, further films may not be necessary and the examination can be ended. Usually however further films will be necessary.

If the kidneys are excreting normally, ureteric compression is applied, if this is available, to distend the calyces. This will help to demonstrate any calyceal abnormality. A film of the renal areas is taken at 15 minutes to show calyceal detail.

If this is satisfactory, compression is released and a full-length film taken to show the ureters and bladder. If the ureters have not been well demonstrated a prone film at this stage may be helpful.

If bladder pathology is suspected, a separate full bladder & post micturition films are taken.

A post micturition film is now seldom necessary as bladder emptying is best assessed by ultrasound but if the lower ureters are dilated and obscured by contrast in the bladder a post micturition film should be taken as this may demonstrate the cause of the ureteric dilatation. Also, a bladder lesion is often better demonstrated on a post micturition film when the bladder is “collapsed”. The sequence and number of films will depend on the clinical indications. If cystoscopy is readily available bladder films may not be necessary.

Other films may be indicated. If the kidneys are obscured by bowel gas tomograms may be necessary. If there is doubt about a kidney an oblique film may be taken. If the ureters are not outlined well and the renal pelvis is full, a prone film may be helpful. If there is delay in function it is necessary to prolong the examination and take films at intervals, sometimes up to 24 hours after the injection.

ABNORMALITIES ON INTRAVENOUS PYELOGRAPHY

1. “Missing” kidney(s)

It not uncommonly happens that either one or both kidneys are not seen. If neither kidney is seen it is often due to insufficient contrast being used. If contrast is seen in the bladder then at least one kidney must be functioning normally and the cause may be technical. More contrast should be injected and a film taken after 10 minutes. Tomograms may be necessary to show the kidneys. If contrast is not seen in the bladder it may be that both kidneys are obstructed or non functioning.

Causes of a missing kidney:
• Absent
• Displaced or ectopic
• Non functioning or poorly functioning

10 minute IVP film showing absence of the L kidney in its normal position. However, it is visible in the L side of the pelvis. This is the commonest place to find an ectopic kidney.

10 minute IVP film coned to the renal areas. The L kidney is absent from its normal position. The R kidney however is very large and shows 2 separate collecting systems. Further films did not reveal a pelvic kidney and this was a case of crossed ectopia, the L kidney being fused with the R.
Causes of a non functioning kidney:
- Infection, acute or chronic
- Long standing obstruction with destruction of the renal cortex
- Kidney completely replaced by tumour
- Renal artery thrombosis

2. Hydronephrosis: dilatation of the urinary tract may be due to:
- Ureteric obstruction. If unilateral think of a stone, stricture, sloughed papilla, blood clot or bladder tumour close to the ureteric orifice. Also pelvic malignancy. If bilateral think of: bladder mass, prostatic enlargement with bladder neck obstruction, posterior urethral valves (if a child), or urethral stricture. Irregular dilatation at the lower ends bilaterally is usually due to schistosomiasis.
- Infection: acute pyelonephritis or tuberculosis may cause ureteric dilatation.
- Ureteric reflux: due to malfunction of the ureterovesical junction. Usually in a young child with recurrent urinary infections.
- Congenital megaureter
- Neurogenic bladder : commonly is associated with dilated ureters as is ureteric transplantation into the bowel.
- Pregnancy : common on the R side after the first trimester, persisting after birth for 2-3 months.

It is important to realise that a dilated urinary tract is not necessarily an obstructed tract.

An obstructing ureteric lesion shows all or some of the following signs:
- delayed uptake of contrast by the involved kidney
- persistent contrast outlining the renal cortex (delayed nephrogram)
- delayed appearance of contrast in the collecting system
- dilated collecting system above the lesion
- leakage of contrast with severe acute obstruction (calculus)
- increased pain following injection of contrast

20 minute IVP film. This shows distension of the calyces with contrast. They have lost their normal cup shape and now appear “clubbed” in shape. The upper ureters are dilated. The lower ureters are not well demonstrated & a prone film would be helpful here. However, a stricture can be seen involving the R lower ureter. The L lower ureter is also affected by a stricture but is obscured by bowel gas on this film. This patient had schistosomiasis.

This is a full length post micturition film. On assuming the erect position contrast normally drains down the ureters and the kidneys empty of dye. In this patient the R kidney has drained normally but there is still considerable contrast retained in the L renal pelvis which appears dilated. There is just a little contrast outlining a normal sized L upper ureter (arrow). This indicates obstruction at the uretero pelvic junction.

A full length post micturition film is sometimes useful to demonstrate an obstructing lesion.

Note the spine is abnormal with congenital spina bifida & there is a dermoid cyst with a tooth lying in the pelvis (white arrows)
3. Renal masses

These are easier to detect on ultrasound and may not be seen on IVP unless very large. They can be easily missed if not affecting the calyces. If large enough, they displace and distort the calyces or may replace the kidney completely with little or no renal function. A feature sometimes seen is the “drooping flower” appearance. This is usually due to a space occupying lesion in the upper pole displacing the renal pelvis and calyces downwards like a drooping flower. There may be an obvious soft tissue mass in the region of the kidney or there may just be bulging of the renal outline. A cyst is best distinguished from a solid lesion by ultrasound. A space occupying lesion may not be due to a cyst or tumour but be caused by hydronephrosis of part of the calyceal complex, most commonly in a duplex kidney.
4. **Acute pyelonephritis** may show no changes on IVP. Sometimes the kidney is larger than the contralateral kidney and shows decreased concentration of the dye. There may be a focal abnormality if there is an inflammatory mass or abscess. IVP is not indicated in acute infection. A plain film and ultrasound are sufficient.

IVP in a patient with acute L pyelonephritis. The L kidney is a little larger than the R and the contrast is not as dense indicating poorer function.

Space occupying lesion in the lower pole causing bulging of the renal outline & no function in the affected area.

Very large L sided abdominal mass showing as an area of increased density. The calyces in the L kidney are distorted & widely separated indicating that it is involving the kidney. This was a child with a Wilms tumour of the L kidney. The appearances at times can look quite bizarre.

This patient had a large R renal mass but the only feature on IVP was a little displacement of the calyces which show a concave appearance.

A CT scan shows a very large R sided renal mass, easily seen. It was a malignant tumour.

IVP in a patient with acute L pyelonephritis.
4. **Chronic pyelonephritis** – results in renal scarring. It can affect any part of the renal cortex but most commonly the renal poles. It is often unilateral secondary to ureteric reflux as a child but may be bilateral when it is usually asymmetrical. Scarring is distinguished from foetal lobulation by the fact that the renal cortex is pulled in towards a distorted calyx.

Renal scarring in chronic pyelonephritis. The calyces are deformed and the renal cortex pulled inwards towards them.

Normal kidney

Normally cupped calyx

Calyx has lost its normal shape due to parenchymal scarring. It is now club shaped

This is a tomogram. In chronic renal disease function is reduced & the kidneys difficult to assess without topography. The R upper pole calyx is deformed & the cortex overlying it narrowed. There is deformity also of the L upper pole calyces with narrowing of the cortex. This patient had bilateral chronic pyelonephritis.

An oblique film of the R kidney in a patient with renal tuberculosis. The calyces are deformed & there is a rounded cavity in the mid part.

5. **Tuberculosis**: Any part of the renal tract may be affected, kidneys, ureters, bladder, prostate, seminal vesicles or epididymis. A plain film may show calcification in the kidneys or seminal vesicles. This may be just a few flecks or calcification of the whole kidney in advanced disease. If the kidney is grossly disorganised it will show no function on intravenous pyelography. The following features may be seen on IVP:

- Calyceal deformity with cavity formation and cortical scarring. Scarring may involve a calyceal stem causing focal dilatation of a calyx.
- The ureter may be dilated without obstruction due to ureteritis or there may be ureteric strictures.
- Cystitis will cause mucosal oedema in the bladder. The bladder on IVP will appear small and the wall thickening may be visible. Later the bladder contracts with marked thickening of the wall and small capacity. It may be irregular in outline.

“Amputation” of a calyx in renal tuberculosis due to stricture of the calyceal stem. There is dilatation of the calyx. This may be an early appearance in renal tuberculosis.
6. **Duplex kidneys and double ureter** are the commonest congenital variant seen on IVP. The ureters may be double on one or both sides. The ureters may re-join at any level or remain divided to the bladder with two separate openings into the bladder. Sometimes the ureter from the upper part drains into the vagina or male urethra instead of the bladder. It causes urinary incontinence. Often a duplex system is asymptomatic but there is an increased incidence of urinary infection, reflux and obstruction due to ureterocoele. The ureter draining the upper moiety may be obstructed by ureterocoele or it may have an ectopic insertion. The ureter draining the lower moiety commonly exhibits reflux resulting in scarring of the lower pole.

![Duplex system with otherwise normal appearances.](image)

![Duplex system with hydronephrosis in the upper pole. There is loss of renal cortex in the upper pole and a “drooping flower” appearance of the lower pole calyces. This would be an appearance in the presence of a ureterocoele.](image)

![Bilateral duplex kidneys. The L kidney is smaller than the R and shows scarring with loss of renal cortex in the lower pole. This was secondary to ureteric reflux involving the lower ureter only.](image)

Other congenital malformations may be present such as horseshoe kidney and crossed ectopia.

7. **Schistosomiasis**: May show calcification of the bladder wall or ureters on the plain film. On IVP the earliest sign is hold up of urine in the lower ureters, best shown on a post micturition film. Later the ureters will dilate proximally and lower ureteric strictures become more obvious. The appearances are seldom symmetrical but often more marked on one side than the other. Filling defects may be seen in the bladder due to granulomas or tumours. The bladder wall is often irregular in appearance due to focal thickening.

8. **Papillary necrosis**: shows varying appearances depending on the stage of the disease. It usually shows calyceal deformity. Contrast may track round the papillae or a sloughed papilla may obstruct the ureter resulting in hydronephrosis. It is a complication of diabetes and sickle cell disease, also excessive paracetamol intake.
9. **Tumours of the renal pelvis or ureter:** These present with haematuria and are usually transitional cell tumours unless associated with schistosomiasis when they are squamous cell. They show on IVP as lobulated or plaque-like filling defects in the pelvicalyceal system. When small they are easily missed if the calyces are not adequately filled with urine. Blood clots or sloughed papilla may mimic a tumour. They are not usually seen on ultrasound unless very large. They can be confirmed by a retrograde pyelogram or computed tomography.

10. **Bladder tumours** commonly present with haematuria. They show as irregular filling defects in the contrast filled bladder or an irregular mucosal pattern on the post micturition film. Sometimes difficult to differentiate from gas in the rectum they are often seen better on a post micturition film. They are more easily seen on ultrasound when even very small tumours can be visualised. IVP should not be performed for diagnosis of bladder lesions, ultrasound combined with cystoscopy is the recommended investigation. Bladder tumours and granulomas are common in schistosomiasis and appear identical on imaging. They are best assessed with cystoscopy.

11. **Bladder calculi:** are masked by contrast and difficult to see once contrast has entered the bladder, unless very large when they show as a filling defect. IVP is not indicated for assessing bladder calculi which are best seen on ultrasound. They occur as the result of stasis, commonly secondary to bladder neck obstruction in prostatic hypertrophy but also occur secondary to infection. They may be multiple, small, solitary or very large. They may be extremely dense and laminate in appearance on plain film or very low density and difficult to see. Intravenous pyelography is not
indicated for assessment of prostatism or other causes of bladder outlet obstruction. If there is long standing bilateral back pressure hydronephrosis IVP will seldom show good function and is usually unhelpful.

The bladder may be displaced by pelvic haematoma following trauma, by pelvis masses such as ovarian tumours and fibroids or displaced upwards by prostatic hypertrophy or carcinoma.

12. **Ureteric displacement:** One or both ureters may be displaced from the usual position. This may be due to a retroperitoneal tumour mass, enlarged nodes, retroperitoneal collection, or retroperitoneal fibrosis. IVP is needed to show the ureters and they are more likely to be seen if a larger amount of contrast is injected (50-100cc). The ureters may be obstructed as well as displaced. Retroperitoneal fibrosis displaces the ureters medially whereas enlarged para-aortic nodes displace them laterally.

**Not only are the ureters displaced laterally in this patient but also the kidneys. This was due to massive para-aortic lymphadenopathy in lymphoma.**

**This 45 minute IVP film shows bilateral hydronephrosis with a persistent nephrogram on the L side. The upper ureters only are shown. The R ureter is seen to be deviated medially towards the spine showing no filling beyond this point. This patient had retroperitoneal fibrosis with bilateral ureteric obstruction.**

13. **Trauma:** this may involve the kidney, ureter, bladder or urethra. Renal trauma is best assessed by computed tomography if available but ultrasound will demonstrate most significant injuries. If trauma is severe with damage to the blood supply IVP will show a non functioning kidney. Renal haematoma will displace the calyces as does any other renal mass. A calyceal tear will show leakage of contrast outside the pelvi-calyceal system. In ureteric tear contrast will be seen to be lying outside the ureter, which may be displaced by a surrounding collection of urine.

**MICTURATING CYSTOGRAPHY - cystourethrography – (descending study)**

A micturating cystogram is a study of bladder emptying after water soluble contrast has been inserted into the bladder, usually by catheter. The contrast needs to be of lesser concentration than that for IVP and should be diluted 50:50 if weaker contrast is not available.

Its main use is to show:
- Ureteric reflux
- Abnormality of the posterior urethra – urethral valves or stricture.
- Vesico-vaginal fistula (usually just a cystogram is adequate)

The examination is most commonly performed in children. Fluoroscopy is used. Contrast is inserted through a urethral catheter until the bladder is very full or the patient begins to micturate spontaneously if a very young child. If looking for ureteric reflux the bladder is screened intermittently by fluoroscopy during bladder filling as reflux may occur at this stage. The patient is then encouraged to micturate and films taken as appropriate using fluoroscopic guidance. If the examination is performed for posterior urethral abnormality films are taken of this area in the oblique position

Posterior urethral valves will only be demonstrated by a descending study, the urine causes them to balloon out on micturition. On an ascending study (urethrogram) they flatten against the wall of the urethra and will not be demonstrated.

A simple cystogram is now seldom performed except in detecting vesico-vaginal fistula and rupture of the bladder following trauma. The bladder is filled with contrast and images obtained. Fluoroscopy is not necessary. If there is
severe trauma involving bladder and urethra it may be possible to obtain enough detail by injecting contrast intravenously and performing a cystogram following IVP.

Vesico-vaginal fistula, a common problem in Africa, is often difficult to assess. If the fistula is very large the bladder will not distend with contrast, most of the contrast passing immediately into the vagina. As the fistulae are nearly always posterior the bladder can be filled in the prone position and the patient then turned to demonstrate the fistula if very large. When trying to demonstrate a small vesico vaginal fistula a lateral film is taken with the patient lying supine, as the leak is invariably on the posterior aspect of the bladder wall. It will not be seen on the AP projection as the contrast in the bladder will obscure it.

URETHROGRAPHY.- urethrogram (ascending study)

This is only performed in males. Indications are:
- urethral stricture
- trauma.
- congenital abnormalities
- fistulae or false passages due to previous catheterisation

It is contraindicated in:
- acute urinary infection
- recent instrumentation

Approximately 10mls of water soluble contrast is instilled into the anterior urethra through a small catheter with the bulb inflated in the navicular fossa (about 1cm from the meatus). A film is taken in the supine oblique position. If satisfactory the anterior urethra will be outlined and there will be a little contrast in the bladder. Adequate filling of the posterior urethra is prevented by the external sphincter. If the posterior urethra needs to be imaged this has to be done.
via contrast instilled into the bladder and films taken of the urethra during voiding. If a marked stenosis is demonstrated and contrast fails to outline the length of the stricture a descending study may also be necessary.

**RETROGRADE PYELOGRAM**

Since the advent of computed tomography and ultrasound, retrograde pyelography is performed less frequently but is still occasionally necessary when detail of the pelvi-calyceal system or ureter is not adequately demonstrated by intravenous contrast. This is especially so when there is suspicion of a transitional cell tumour of the renal pelvis or ureter. If there is ureteric obstruction and the cause has not been demonstrated on IVP a retrograde examination is indicated.
Indications for retrograde pyelogram:

- Demonstration of the site, length, and if possible the nature of an obstructive lesion
- Demonstration of the pelvicalyceal system after an unsatisfactory IVP e.g. if the kidney is non-functioning.
- Suspected tumour of the renal pelvis or ureter

It is contra-indicated in acute urinary infection.

A catheter is placed in the ureter after cystoscopy and contrast injected. Fluoroscopy is desirable but not essential. A plain film is taken before injection of contrast to check the position of the catheter, which may be lying too low in the ureter to outline the renal pelvis. If the catheter looks satisfactory low density contrast is injected until the patient experiences discomfort, about 7-10ml, to outline the renal pelvi-calyces and upper ureter. If there is adequate filling oblique films can be taken as necessary.

Complications include:
- damage to the ureter or perforation
- infection

ANTEROGRADE PYELOGRAM

If a retrograde fails for technical reasons and there is dilatation of the renal pelvis contrast can be injected through a fine needle introduced percutaneously into the pelvi-calyceal system. Ultrasound can be used for guidance but fluoroscopy is useful if available. It accurately shows the site & cause of an obstruction.

This is contraindicated in acute infection.

Antegrade pyelography is often combined with percutaneous nephrostomy in order to relieve obstruction as a temporary measure.
RADIONUCLIDE TECHNIQUES(Scintigraphy) - gamma camera studies

There are 2 basic types of scans commonly performed, each for different indications. One is a static scan showing radioactivity in the renal substance resulting in good images of the size and outline of each kidney. The second is a dynamic scan, a measure of the excretion of radioactive isotope by the kidneys and clearance down the ureters.

1. Static scan.
This is called a DMSA scan and is performed by injecting dimercaptosuccinate labelled with technetium 99m intravenously. This becomes fixed in the tubule cells with a very slow excretion rate producing images of the renal parenchyma. Imaging is performed after one hour and anytime up to 6 hours post injection. Posterior-anterior (PA) images and both obliques are obtained.

The normal renal image is formed by the functioning cortical tissue and corresponds well with the radiographic renal outline. Hence cortical scarring is well demonstrated. The collecting system is not opacified and although differential function can be assessed total renal functional assessments are not possible.

The most widespread use of DMSA scanning is in the assessment and follow up of patients with diseases that are liable to destroy the cortex progressively. These include chronic pyelonephritis, tuberculosis, reflux and obstructive nephropathy. In practice, the main indication in Europe is in the assessment of renal scarring in children with suspected ureteric reflux.

2. Renogram (functional study)
The most widely used compound for this is technetium 99m –DTPA, which is excreted by the glomeruli (glomerular filtration). It produces information on renal blood flow and renal function.
Images are taken of the aorta and kidneys in rapid sequence following intravenous injection.

The first phase consists of a sharp rise in activity over the renal areas due to vascular radioactivity in the vessels. This is followed by a slower rise due to accumulation within the nephrons. The slope is steep when there is a diuresis but decreased in renal tubular failure and impaired perfusion due to renal artery stenosis. Following the peak, activity falls as the isotope is excreted in the urine. The function curve is therefore one of rapid rise followed by a more gradual fall. In the presence of obstruction the curve does not fall normally but continues to rise or remains elevated.
If obstruction at the uretero-pelvic junction is suspected a diuretic is often given along with the radiopharmaceutical to increase the urine flow and enhance the abnormality.

Clinical applications:
• Suspected uretero-pelvic obstruction is the main indication
• Hypertension in order to detect renal artery stenosis. The renogram curve is lower due to diminished function and the transit time prolonged. The isotope in the vascular phase shows a slight delay on the affected side.
• Acute tubular necrosis. There is normal delivery of isotope to the kidney but as there is no excretion the isotope gradually diffuses into the extracellular space and the renal activity disappears.
• Renal transplantation. The commonest complication is acute tubular necrosis or ischaemia. Infarction is readily shown by its avascularity during all phases of the investigation. Rejection cannot be reliably diagnosed by imaging.
COMPUTED TOMOGRAPHY.
This aids assessment of renal masses, obstruction, retroperitoneal disease, renal and bladder neoplasms and trauma.

One of the main indications for CT scanning of the renal tract is to stage malignancies of the bladder and kidney. Contrast is usually given intravenously. The features assessed are:
- Further characterisation of a solid mass
- Assessment of spread into the perinephric fat and local structures
- Venous invasion
- Lymphadenopathy
- Liver metastases
- Lung metastases
- Contralateral tumour

CT is the imaging method of choice in renal trauma. It is used for two purposes:
1. To delineate the nature of renal injuries
2. To detect pre-existing abnormalities

Intravenous contrast is usually given:
- provides anatomical as well as functional information
- gives good definition of renal lacerations, haematoma and urinoma
- shows whether a non functioning kidney is due to massive parenchymal damage vascular pedicle injury obstructed collecting system
- provides assessment of adjacent organs e.g. liver, spleen, pancreas which may also be traumatised.

Curves of the vascular phase of a renogram showing the uptake of the isotope by the renal arteries. One artery has a slightly delayed & lower curve than the other. On ultrasound the kidney measured 2 cm shorter and the patient was hypertensive. These appearances suggest renal artery stenosis.

Renogram curves of the same patient. Again one curve is lower than the other and the peak activity (arrow) is a little delayed consistent with renal artery stenosis.

Computed tomography scan at the level of the kidneys which are enhanced by intravenous contrast. The aorta and renal vessels are highlighted by contrast. This is the nephrogram phase, the contrast not yet having entered the collecting system. The kidneys appear normal on this slice. The L renal vein is seen passing anterior to the aorta to join the inferior vena cava (dark arrow & the L renal artery lying behind it (white arrow),

CT scan at the level of the kidneys following intravenous contrast. There is a dark well defined lesion of low attenuation in the L kidney. Appearances suggest that it is benign. It can be characterised by measuring the attenuation (Hounsfield units). In this patient the attenuation was that of fat, the lesion being a benign angiomylipoma.
ANGIOGRAPHY:
The use of ultrasound and CT have reduced the need for diagnostic renal angiography. It remains useful for the following:
- if the evidence from other imaging methods is conflicting
- prior to interventional techniques e.g. angioplasty
- to diagnose renal artery stenosis
- vascular lesions such as arterio-venous fistula, angioma, aneurysm
- anatomical detail prior to renal transplant or suspected vascular occlusion following surgery

All urogenital angiography is performed via the femoral artery.

MRI SCANNING:
The main use of MR in urinary tract imaging is pathology of the bladder and prostate. It is used mainly for staging bladder and prostatic tumours.

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Notes compiled for the medical students of Kumasi by Genny Scarisbrick October 2002