Intravenous urography and imaging of the urinary tract

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This article briefly reviews the commonly used radiological investigations of the renal tract. The intravenous urogram (IVU) is a widely available imaging technique and one of the first-line investigations, yet is often poorly understood by junior medical teams. This article therefore discusses the IVU in detail, and reviews the common pathologies seen using this technique.

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There are a number of techniques used in the evaluation of the urinary tract, including plain radiography, the intravenous urogram (IVU), ultrasound (US) and computed tomography (CT). Recently, magnetic resonance imaging has also been used. This article will discuss each of these techniques in turn, and then review some of the more common pathologies as demonstrated by IVU.

IMAGING OF THE RENAL TRACT

The simplest imaging modality remains the plain radiograph of the abdomen which has been localized (coned) to the area of the urinary tract in order to reduce exposure to the peripheral soft tissues. This examination is referred to as the KUB (kidneys, ureters, bladder).

The KUB is widely used as a first-line investigation of the urological tract, predominantly in the diagnosis of calcified (and therefore radio-opaque) stones (*Figure 1*). This simple investigation will detect 90% of such calculi (Sutton, 2003), but its evaluation can be made difficult if there are large quantities of bowel gas or calcified costochondral cartilages, which may obscure small calculi. Similarly, calcified pelvic phleboliths (calcification within the walls of perivesical veins) can be confused with calculi at the vesicoureteric orifices. Phleboliths may be discriminated by their round smooth outlines, and sometimes a central lucency corresponding to the vein lumen. Consequently, an IVU may be needed to confirm this distinction. The KUB may also demonstrate the renal outlines although, as described below, the renal parenchyma is better seen on US. Despite its limitations the KUB remains an important initial examination, particularly for diagnosis of urinary tract calculi.

Figure 1. Film of kidney, ureters, bladder (KUB) showing multiple well-defined calculi within the bladder. Incidental calcification is also seen within the prostate.

Intravenous urogram

The IVU is also a commonly used investigation. The IVU aids in the diagnosis of many urinary tract pathologies, including calculi, malignancy, obstruction and anatomical variants. The IVU will be discussed in detail below.

Ultrasound

US has a very important role in renal tract imaging. It is excellent for evaluating the soft tissues of the renal parenchyma (Warshauer et al, 1988). In addition, US is used to diagnose renal obstruction (hydronephrosis) in cases of renal failure. US is not commonly used in the evaluation of the ureter but may be used in the evaluation of the bladder, both for bladder volumes and prostate size, as well as the detection of bladder tumours. Bladder tumours are usually subsequently confirmed by cystoscopy.

Computed tomography

The use of CT has increased as it has become more widely available. CT may be used for detailed analysis of small intraparenchymal lesions, as well as for the staging of renal tumours.

CT KUB is increasing in popularity in the investigation of renal colic (Lui et al, 2000; Spencer et al, 2000). This technique involves performing a fine slice, non-contrast-enhanced, prone scan from the kidneys to the pubic symphysis. The absence of contrast means that this will identify calculi, but will also indicate whether the upper tracts are obstructed, as well as further evaluating perirenal and other intra-abdominal pathology. It has the advantage of not using intravenous water-soluble contrast medium, and thus avoiding risk associated with this. It is also rapidly performed, but involves a slightly higher radiation dose than IVU.

Magnetic resonance imaging

Magnetic resonance imaging has been used increasingly in the abdomen and pelvis, particularly in staging tumours within the pelvis (MacVicar, 2000).

PERFORMING THE IVU

The IVU is a relatively simple and non-invasive investigation. A preliminary or control film is initially performed to exclude renal calculi. This is identical to the standard KUB examination, and does not need to be repeated if a KUB has recently been performed. A water-soluble iodine-containing contrast medium is then injected intravenously. Over the subsequent 20–25 minutes a series of films are taken as contrast passes through the kidneys into the ureters and bladder. Compression is often applied to the mid abdomen, to help distend and thus opacify the upper tracts. Compression is avoided if there has been recent surgery, trauma or abdominal aortic aneurysm, or in pregnancy.

There are few absolute contraindications to performing an IVU, although contrast allergy remains the most important despite the use of modern contrast media (*Figure 2*). As with all radiographic procedures using ionizing radiation, these procedures should be avoided in pregnancy. There is variation in how different departments perform IVUs but a common IVU protocol is shown in *Figure 3*.

INTERPRETATION OF THE IVU

Initially, the control films must be evaluated to identify any calcification within the urinary tract. Such calcification would be obscured after contrast medium injection.

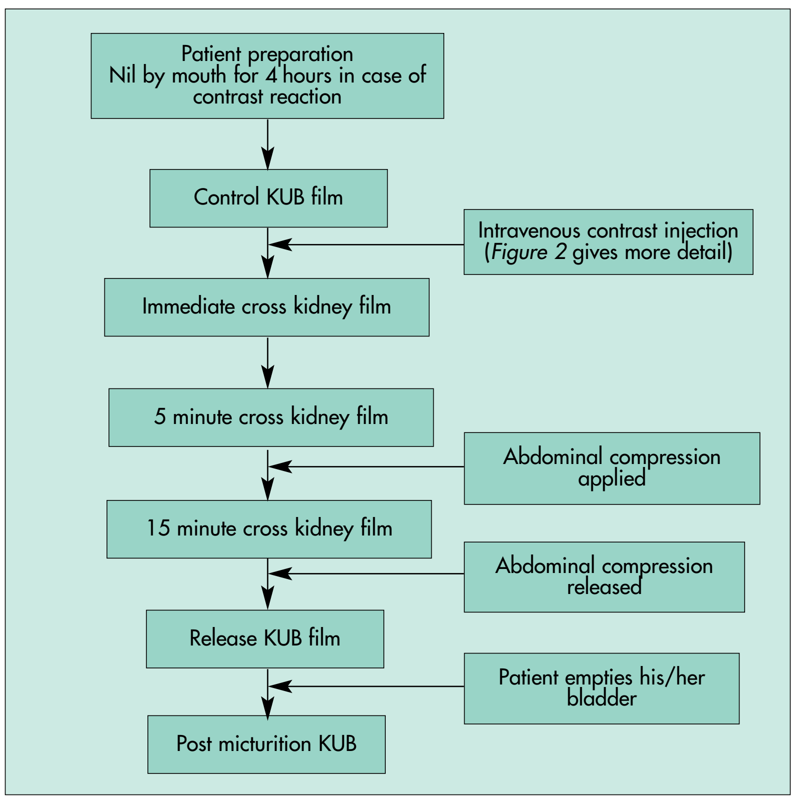
The post contrast films are then evaluated, paying particular attention to the renal position, size and outline, and if there is distortion of the renal parenchyma. The right kidney usually lies a little lower than its left-sided counterpart as a result of inferior displacement beneath the liver. Renal size is usually measured at between three and four vertebral bodies in length. The pelvicalyceal system is scrutinized for symmetry, normal filling and any evidence of extrinsic compression. The ureters should drain normally, and even if they are not seen in their entirety, should not be more than 1–2 mm in diameter.

Normal renal function will result in near complete excretion of contrast 20–25 minutes post injection. If contrast is still being excreted 35–40 minutes after injection, this suggests either poor renal perfusion, poor renal function or obstruction. Finally, the bladder is assessed for normal filling and post micturition emptying.

> Water-soluble contrast medium is widely used in radiology. It are safe but there are a few contraindications to its use, for example previous allergic reaction to contrast medium or iodine, renal failure and severe asthma. Water-soluble contrast medium can very rarely react with metformin, causing lactic acidosis. Patients are advised to stop taking metformin for 48 hours after the intravenous urogram and have their renal function checked; if these results are normal they can restart metformin.
>
> The major side effects of water-soluble contrast medium are anaphylactic hypersensitivity reactions. These are rare but can very rarely lead to death, cardiovascular compromise as a result of the high osmotic potential of the contrast medium, or contrast-induced nephropathy. The minor side effects, which frequently occur, are nausea, vomiting, warm feeling and metallic taste in mouth (Bettmann et al, 1997).

Figure 2. Intravenous contrast agents.

Figure 3. A flow diagram of a commonly used protocol for an intravenous urogram. A limited series of films may be performed to limit radiation dose if the patient has had many radiological procedures, pregnant or is a child. KUB = kidney, ureters, bladder.



Careful examination for any filling defects should be performed.

After reviewing the IVU film series for renal tract pathology, the remainder of the films must be reviewed to exclude alternative pathology. In particular, the bowel gas pattern must be reviewed, and calcified gallstones or aortic aneurysm may be seen. The bones must be examined for degenerative change or metastases. The bases of the lungs are often seen and a lung lesion may occasionally be identified.

In view of the importance of the IVU, this article will now concentrate on a pictorial review of the common pathologies and appearances seen using this imaging technique.

COMMON FINDINGS ON AN IVU

Calculi

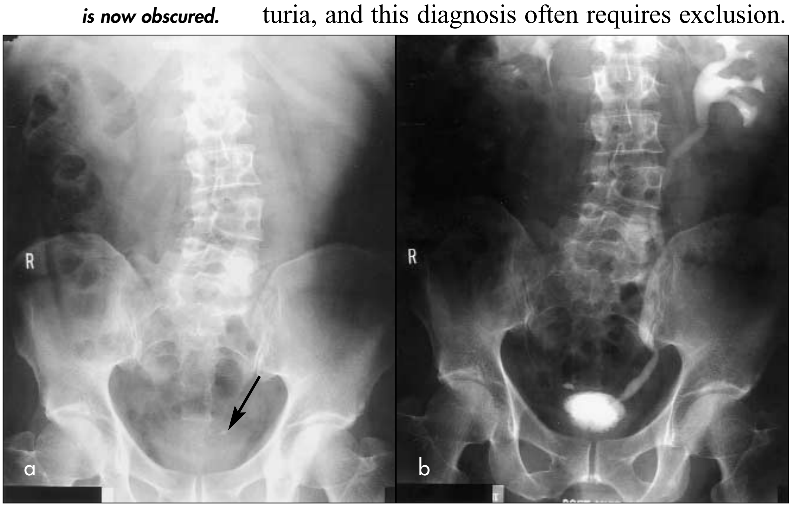
As already stated, 90% of renal tract calculi are visible on the plain control radiograph. The importance of the preliminary film cannot be overemphasized, since small non-obstructing calculi may be completely obscured after contrast is given. The IVU is often performed in cases of suspected renal colic, both to confirm the presence of a calculus and to assess whether there is obstruction to the renal tract, since this has implications for patient management. The commonest sites of obstruction are the pelvic ureteric junction and the vesicoureteric junction (Grainger et al, 2001).

Obstruction of the renal tract results in dilation and a standing column of contrast in the ureter (*Figures 4a* and *b*). In complete obstruction, no contrast is seen distal to the obstruction and because of the high pressures created there may be extravasation of contrast from the kidney into the retroperitoneal space (*Figure 5*).

Urinary tract malignancy

Malignancy of the kidney or renal tract is a serious cause of macroscopic or microscopic haematuria, and this diagnosis often requires exclusion.

Figure 4. a. Control film from intravenous urogram (IVU) series showing calculus at left vesicoureteric orifice (arrow). b. Post micturition film from same IVU series, showing a standing column of contrast within the left ureter as a result of obstruction. The calculus is now obscured.



A mass within the kidney is manifested on IVU by distortion of the renal outline and/or pelvicalyceal system (*Figure 6*). This may represent a primary renal cell carcinoma, metastasis (from lung, breast, lymphoma or contralateral kidney; Dähnert, 2003), cyst, abscess or benign mass. An US is usually performed to exclude simple cyst as a cause, but CT may be needed in further evaluation and/or staging of a carcinoma (*Figure 7*).

Figure 5. Intravenous urogram 35 minutes after injection of contrast medium showing left hydronephrosis and extravasation. The calculus is not visible.

Figure 6. Intravenous urogram showing distortion of the pelvicalyceal system on the right as a result of a renal mass.

Transitional cell carcinomas (TCC) commonly occur within the bladder and ureter, and these result in irregular filling defects within these structures (*Figure 8*). Depending on the size and position of the TCC they may obstruct the renal tract causing hydronephrosis or hydroureter.

Rare filling defects

Two of the commonest causes of filling defects in the urinary tract have been mentioned, i.e. renal calculi and TCC. Other causes include other malignancies (squamous cell carcinoma, metastasis), blood clot, sloughed papilla, fungus balls and gas bubbles.

Gas in the urinary tract is an uncommon but important diagnosis (*Figure 9*). Gas bubbles are seen as a filling defect in the urinary tract on IVUs. Small lucencies may be visible on the control film which may only be differentiated from bowel gas by their configuration within the collecting system. The differential diagnosis for such gas includes infections (gas-forming organisms such as *Escherichia coli*), fistulae (as a result of diverticular disease, carcinoma of the bowel or Crohn's disease), iatrogenic (urinary diversion, instrumentation) and penetrating wounds. If this has occurred as a result of infection, gas may also be seen in the renal parenchyma (emphysematous pyelonephritis) extending into the retroperitoneal tissues. There may also be gas in the bladder wall (emphysematous cystitis).

Figure 7. Contrast-enhanced computed tomograph showing mixed density mass of renal cell carcinoma involving entirety of the right kidney (black arrow). There is involvement of the inferior vena cava (white arrow), and local lymph nodes.

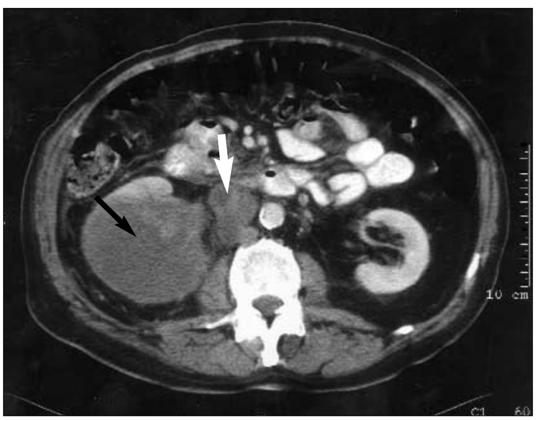


Figure 8. Intravenous urogram showing irregular filling defects in the left pelvicalyceal system, caused by transitional cell carcinoma.

Congenital abnormalities of the renal tract

Complete or incomplete duplication of a ureter is not uncommon (*Figure 10*). About 1 in 500 of the population have complete duplication of the ureter, the incidence of incomplete duplication being even higher (Dähnert, 2003). Duplication of the ureter is often an incidental finding on an IVU but this can be complicated by vesicoureteric reflux or recurrent infections.

An ureterocele is a submucosal dilation of the intravesical ureter. Ureterocele occurs in the asymptomatic population at a frequency of 1 in 5000 to 1 in 12 000. It is often associated with a duplex ureteric system. On IVU it is seen as smooth-walled contrast-filled structure surrounded by a radiolucent rim which itself is surrounded by contrast in the bladder. This has been called the cobra's head sign (*Figure 11*). Ureteroceles are often asymptomatic incidental findings but can be associated with calculi, infections or obstruction.

Figure 9. 30-minute intravenous urogram showing low density filling defects within the pelvicalyceal systems and bladder. These appearances were the result of gas from **Escherichia coli** ***infection.***

Extrinsic mass lesions

The IVU sometimes provides information on pathologies outside the renal tract. A mass outside the renal tract may distort the normal position of the renal tract. A pelvic mass, for example, can distort the normal shape of the bladder. This could be caused by a large pelvic haematoma (*Figure 12*), abscess, ovarian mass or enlarged prostate.

***Figure 10.** Intravenous urogram showing a duplex collecting system and ureter.*

***Figure 11.** Post micturition film from intravenous urogram series showing typical cobra's head sign (arrow) as a result of ureterocele.*

KEY POINTS

- The control films must be reviewed for renal tract calcification. This may be obscured after contrast has been given.
- The kidneys must be examined for position and outline.
- The pelvicalyceal system must be seen to fill normally and ureteric drainage confirmed. Filling defects may be subtle.
- If the collecting system is obstructed, the site and the degree of obstruction must be assessed.
- Other important pathologies may be present on the radiographs.

CONCLUSION

There are a wide range of techniques used in the imaging of the renal tract. The IVU is an important and useful investigation for evaluating the kidneys and renal tract. It is often the investigation of choice in the diagnosis of renal calculi, obstruction and malignancy. The IVU also provides useful anatomical information in the detection of congenital anomalies of the renal tract. Occasionally pathologies unrelated to the renal tract are detected on the IVU radiographs. **HM**

Conflict of interest: none.

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***Figure 12.** Intravenous urogram showing distortion of the bladder as a result of pelvic haematoma (arrow) – in this case caused by a displaced right acetabular fracture.*