

# Renal imaging

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## Abstract

The renal tract is investigated in the assessment of abnormal renal function, hypertension, renal colic or haematuria. Increasing use of ultrasonography and computed tomography (CT) has limited the role of plain radiographs, but these are still used in the initial assessment of abdominal colic to evaluate potential renal or bowel abnormalities. Intravenous urography – radiological examination of the urinary tract performed after the intravenous injection of iodinated contrast – is the classical means of assessing the kidneys and ureters. Ultrasonography is often the first imaging modality used to interrogate and follow up renal abnormalities. CT can be useful to evaluate renal masses and determine the site of ureteric obstruction by calculi. Magnetic resonance imaging (MRI) is primarily used to assess the renal arteries in patients with suspected renal artery stenosis. CT and MRI can provide images of exceptional detail and resolution beyond the capability of other modalities, and are thus often used to characterize and follow up renal masses; in addition, images can be obtained in multiple planes. Radionuclide scans can be helpful in evaluating renal tract obstruction and providing a functional assessment of the renal tract.

**Keywords** Computed tomography; kidney–ureter–bladder radiography; magnetic resonance imaging; MRCP; renal angiography; renal biopsy; renal imaging

## Indications

Abnormal renal function is the most common indication for renal imaging. Other indications include renal colic, haematuria and the investigation of hypertension with a suspected renal vascular cause (renal artery stenosis).

## Plain abdominal radiographs

The increasing use of ultrasonography (US) and computed tomography (CT) has limited the use of plain radiographs, but they still have a role in the management and surveillance of renal calculi. Kidney–ureter–bladder (KUB) radiographs may demonstrate urinary stones. However, approximately 10% of urinary stones are undetectable by plain radiography because they are not radio-opaque, and some urinary stones are also obscured by overlying bowel gas. In the pelvis, phleboliths (calcified venous thrombosis) can be mistaken for ureteric

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## Key points

- Ultrasonography is often the first useful test in assessing renal failure to detect hydronephrosis
- Computed tomography is the most useful test to detect renal calculi, assess renal trauma and confirm and stage renal cancers

stones, although phleboliths typically have a relatively radiolucent centre, which helps to differentiate them. If it is difficult to differentiate between a phlebolith and a ureteric calculus, intravenous urography (IVU) or CT can help.

## Intravenous urography

IVU is performed after intravenous injection of iodinated contrast medium, with serial radiographs taken to follow the progress of contrast within the urinary tract. The initial nephrographic phase (when contrast is in the renal parenchyma) confirms that the glomeruli are filtering blood (and hence excreting contrast). This phase can help to confirm the intra-renal location of a calculus projected over the renal outline on the KUB image. Focal lesions, such as cysts and tumours in the renal parenchyma, may be apparent during this phase.

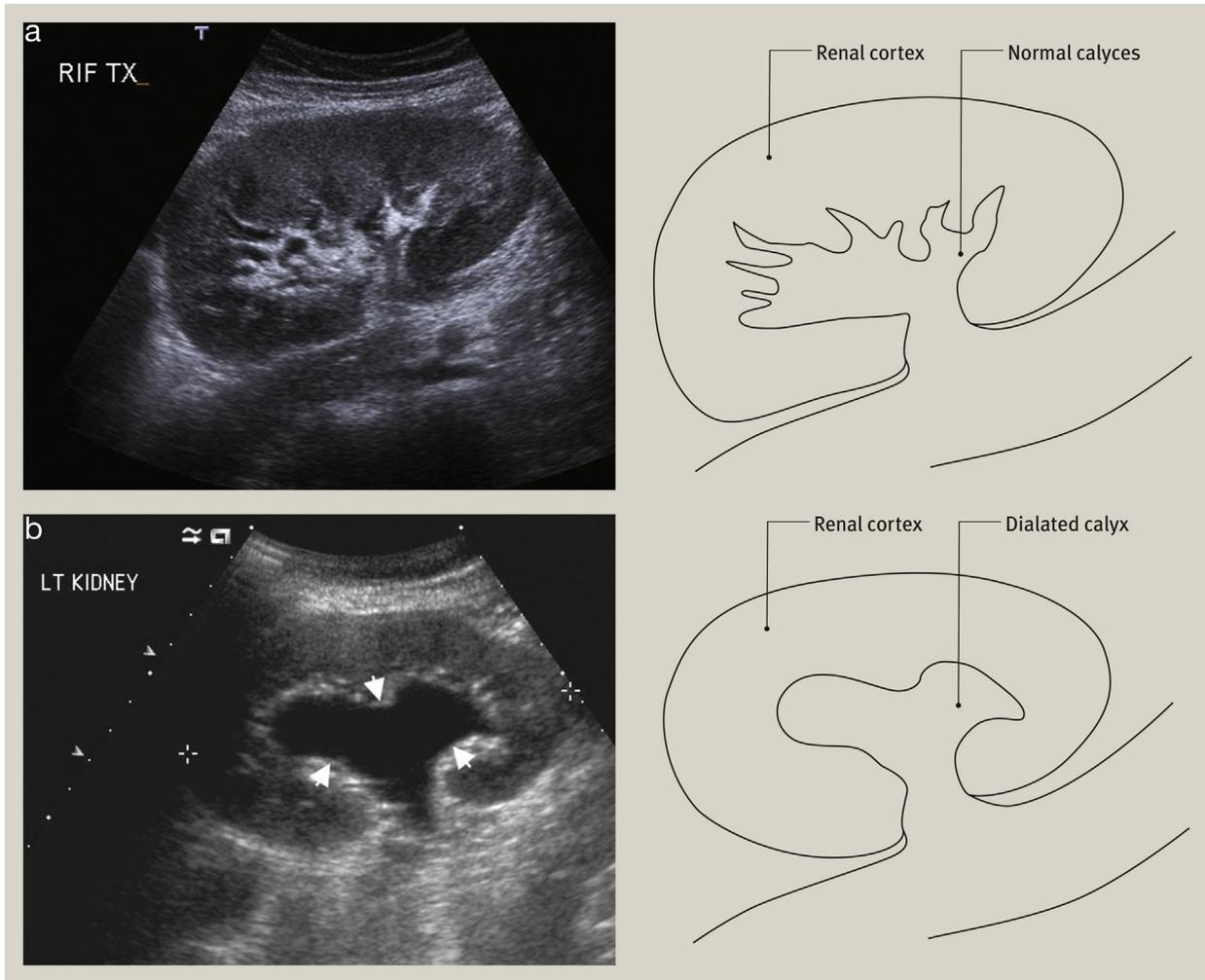
The subsequent urographic phase identifies calculi or urothelial tumours in the renal pelvis and ureters, and helps in assessing urinary obstruction. The delay in passage of contrast into the renal pelvis and ureter (persistent nephrographic phase) is, if unilateral, a sign of obstruction; bilateral delay implies a systemic cause, such as poor kidney perfusion or function. IVU also aids in the detection of congenital abnormalities of the urinary system, such as horseshoe kidney, ureteric duplication and ureteroceles. IVU is contraindicated in patients with contrast allergy and in pregnant women. Adequate visualization of the renal pelvi-calyceal system and upper ureters often requires abdominal compression during the IVU examination, and this is contraindicated in patients with abdominal pain or an abdominal aortic aneurysm.

**Advantages** – IVU can help distinguish a collecting system dilated because of current obstruction from one showing residual dilatation as a result of previous obstruction.

**Disadvantages** – IVU requires administration of intravenous contrast, and the radiation dose is 2.5 times that of a chest radiograph. In addition, it may not be possible to delineate the specific nature of a space-occupying lesion of the renal tract demonstrated on IVU. US can be required to differentiate a renal cyst from a tumour. A non-radio-opaque calculus can produce a negative filling defect within the contrast-filled collecting system, similar to a urothelial tumour.

## Ultrasonography

The use of US in the assessment and follow-up of renal disease has become widespread chiefly because of the absence of exposure to radiation and its easy availability. An urgent US examination is indicated in the assessment of new-onset renal failure to exclude urinary obstruction (Figure 1), especially in the context of sepsis. If urinary obstruction is detected as hydronephrosis and/or



**Figure 1** Ultrasound scans. (a) Normal appearance of kidney with undilated pelvi-calyceal systems. (b) Dilated pelvi-calyceal system in a kidney, caused by ureteric obstruction.

hydronephrosis, image-guided nephrostomy is often appropriate to relieve urinary obstruction and preserve renal function (Figure 2).

In chronic renal failure, the kidneys can be small (normal size 10–12 cm) and hyperechoic. Asymmetry in renal size can suggest renal artery stenosis, and Doppler investigation of the renal artery may confirm this. Focal renal scarring could be evidence of previous pyelonephritis or focal renal ischaemia. Renal stones can be visualized even if they are not radio-opaque. Simple renal cysts can be confidently diagnosed with US, whereas alternative imaging, such as CT or magnetic resonance imaging (MRI), is required to exclude malignancy in atypical cysts (cysts other than thin-walled, unilocular fluid-filled cysts, such as multi-loculated cysts and cysts containing solid components). Further assessment of suspicious renal lesions is now also possible with contrast-enhanced renal US. In cases of renal trauma, a perinephric haematoma can be demonstrated. The presence of such extra-renal fluid should be a stimulus to further investigation with CT to exclude significant renal parenchymal or vascular injury. Renal colour Doppler examination can be used to assess the patency of the renal artery and vein.

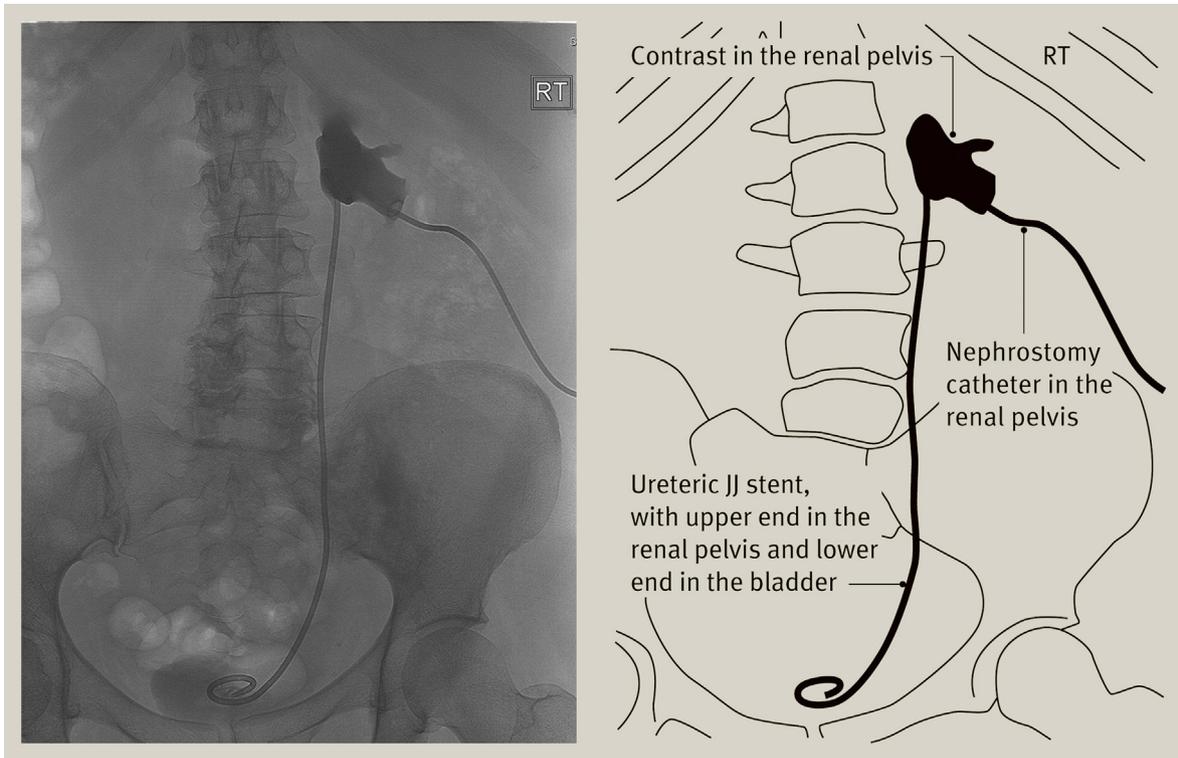
**Advantages** – US can be used for bedside assessment and for real-time guidance during renal intervention. The patient is not exposed to radiation.

**Disadvantages** – these include operator dependence and suboptimal image quality in obese patients.

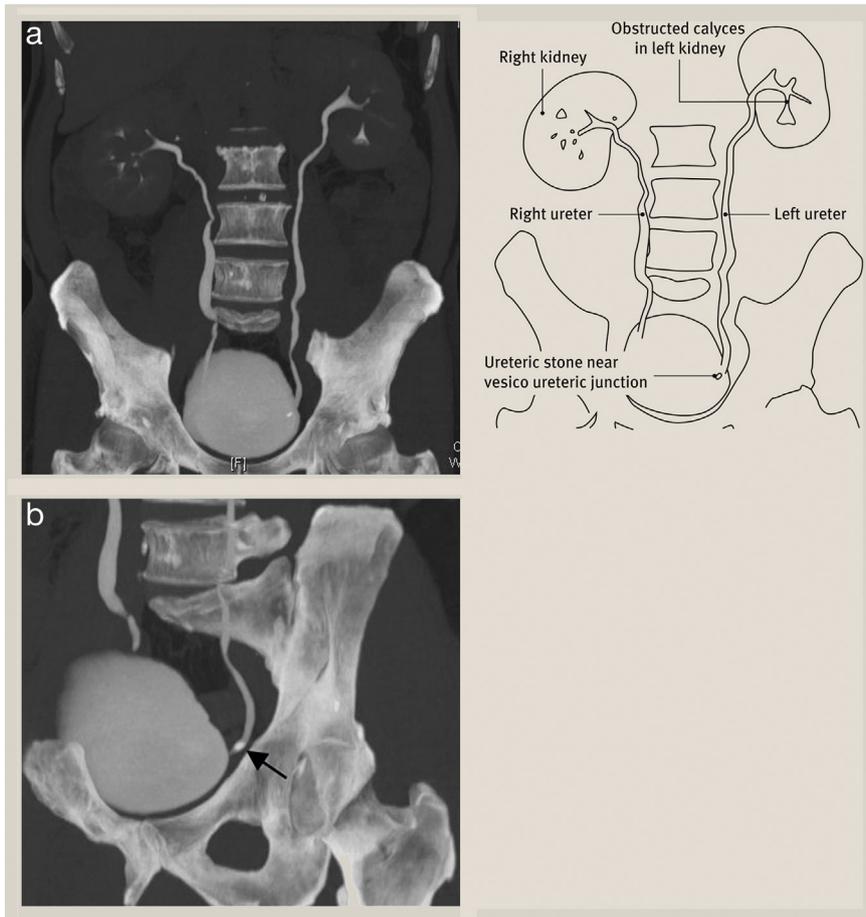
### Computed tomography

In many centres, CT has replaced IVU as the preferred imaging modality for the diagnosis of urinary calculi (Figure 3). It is usually performed without intravenous contrast enhancement. Modern multi-detector CT scanners allow coverage of the whole abdomen in a few seconds during a single breath-hold, and dedicated work stations allow multi-planar interrogation of the data acquired.

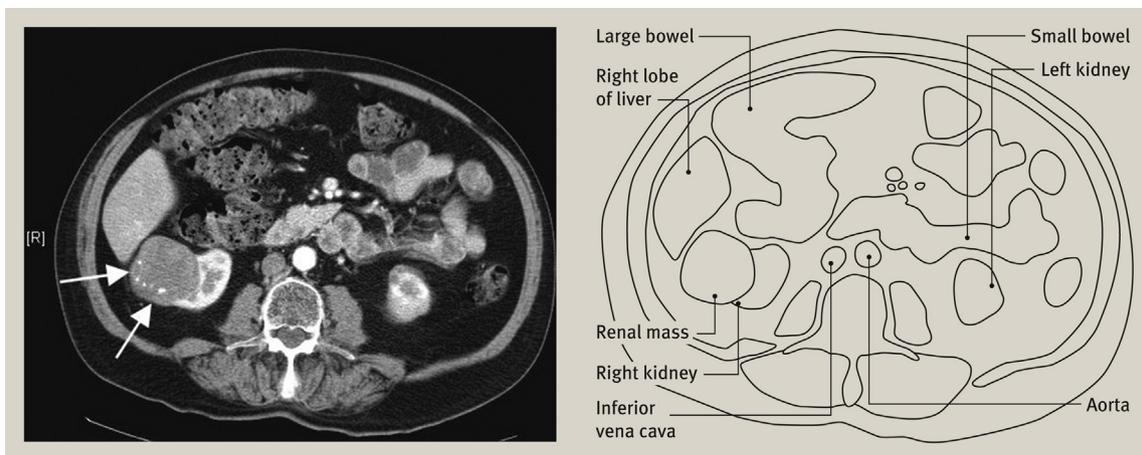
If urolithiasis is not the cause of the patient's symptoms, this examination can help to identify other abdominal causes. Renal masses can be assessed by a triple-phase CT scan (unenhanced, arterial and delayed-phase acquisitions). Unenhanced scans demonstrate soft tissue calcification or fat in renal tumours (angiomyolipoma). Subsequent scans assess the response of the lesion to contrast and, if malignant, stage the lesion with regard to vascular involvement, lymph node and metastatic spread (Figure 4). Relatively new CT scanner technology using dual energy is capable of detecting the chemical composition of renal stones,<sup>1</sup> but use of these scanners is currently limited (Figure 5).



**Figure 2** Nephrostogram performed by contrast injection through the nephrostomy catheter shows contrast reaching the bladder through the ureteric stent.



**Figure 3** Coronal reformatted images from a CT urogram show a stone (arrowed) in the distal left ureter.



**Figure 4** CT scan of the abdomen with intravenous contrast enhancement shows a mass (arrowed) in the right kidney.

In patients with haematuria and suspected urothelial malignancy, a CT urogram (scan performed 20 minutes after intravenous contrast injection) can show upper tract urothelial cancers.

**Advantages** – CT scans have high spatial resolution and the ability to assess all the other abdominal viscera. Image quality is relatively independent of body habitus and bowel gas.

**Disadvantages** – radiation exposure is 10 times that of a chest radiograph. When patients with renal impairment (especially if associated with diabetes mellitus) are given intravenous contrast agents, there is a small risk of contrast-induced nephropathy. Adequate hydration before the scan can reduce this risk.

### Magnetic resonance imaging

MRI scans are obtained by interrogating the patient's body with radiofrequency pulses while in a magnetic field. The main role of renal MRI is assessment of the renal arteries by magnetic resonance angiography (MRA). Atherosclerotic disease, which most commonly affects older men, typically involves the proximal third of the main renal artery. Fibromuscular dysplasia, more common in younger women, usually affects the distal two-thirds of the renal artery and its branches. MRI can overestimate the severity of renal arterial stenosis. In young individuals with hypertension, it is

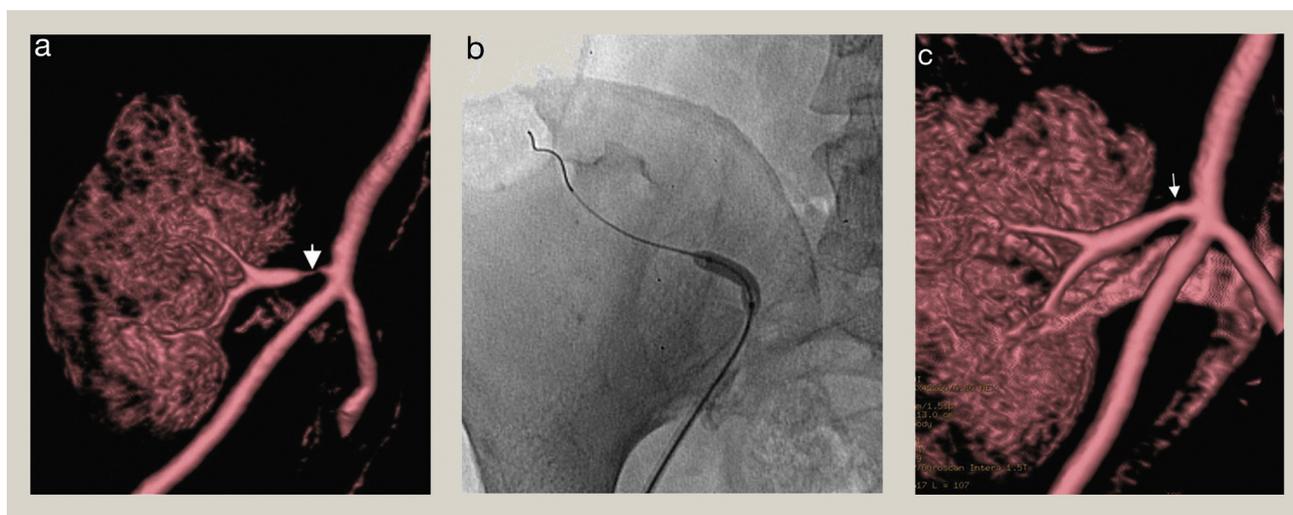
possible, while assessing the renal arteries for stenosis, for the magnetic resonance scan to also exclude other causes of hypertension, for example coarctation of aorta and adrenal masses. MRI can be used to evaluate potential live renal donors before renal transplantation. The renal parenchyma, collecting system and vascular anatomy can all be assessed. Multiple renal arteries can be identified in such potential donors.

**Advantages** – images of supreme contrast resolution can be obtained in multiple planes. No X-rays are involved.

**Disadvantages** – scans are relatively lengthy and therefore susceptible to disruption by patient movement. The individual may also become claustrophobic within the scanner and be unable to complete the examination. When patients with renal impairment are given gadolinium contrast agents, there is a risk of nephrogenic systemic fibrosis. However, renal MRA can be performed using techniques that do not use intravenous gadolinium contrast agents. Some patients have contraindications to MRI, for example a permanent pacemaker or intracranial surgical clips.

### Digital subtraction angiography (DSA)

DSA is usually performed to confirm the findings of non-invasive techniques before proceeding to endovascular treatment; in the



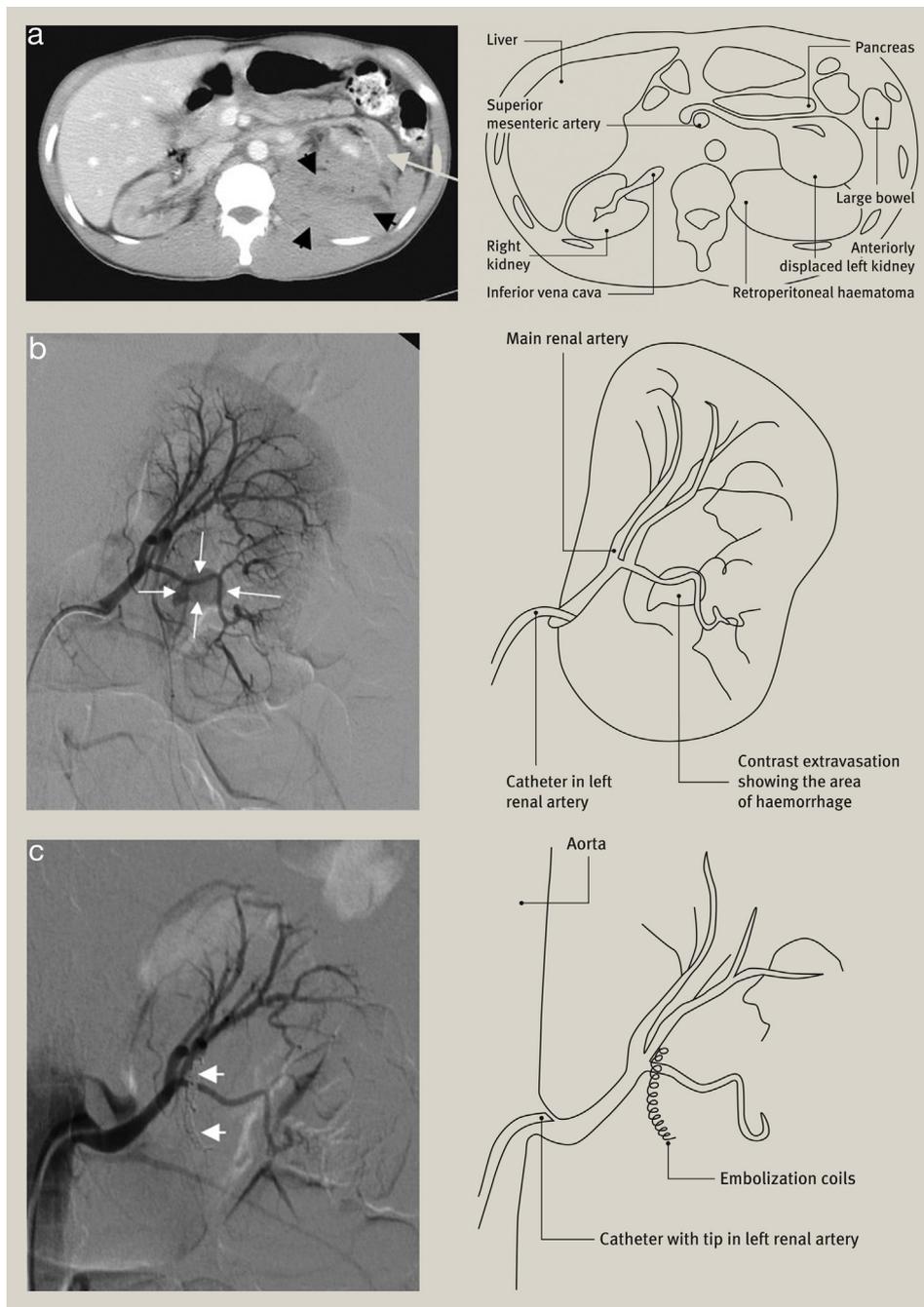
**Figure 5** (a) Reformatted image from CT angiography shows stenosis (arrow) in the renal artery of a renal transplant patient. (b) Balloon angioplasty of renal artery stenosis. (c) CT angiography shows resolution (arrow) of the renal artery stenosis after angioplasty.

case of renal artery stenosis, this takes the form of balloon catheter angioplasty and, if appropriate, insertion of a renal artery stent. In cases of haematuria, DSA can be used to identify the source of bleeding, which can be renal tumours (e.g. renal cell carcinoma, angiomyolipoma) or iatrogenic arterial injury after renal biopsy. Life-threatening bleeding in these instances can be controlled by selective embolization while preserving the function of the rest of the kidney (Figure 6).

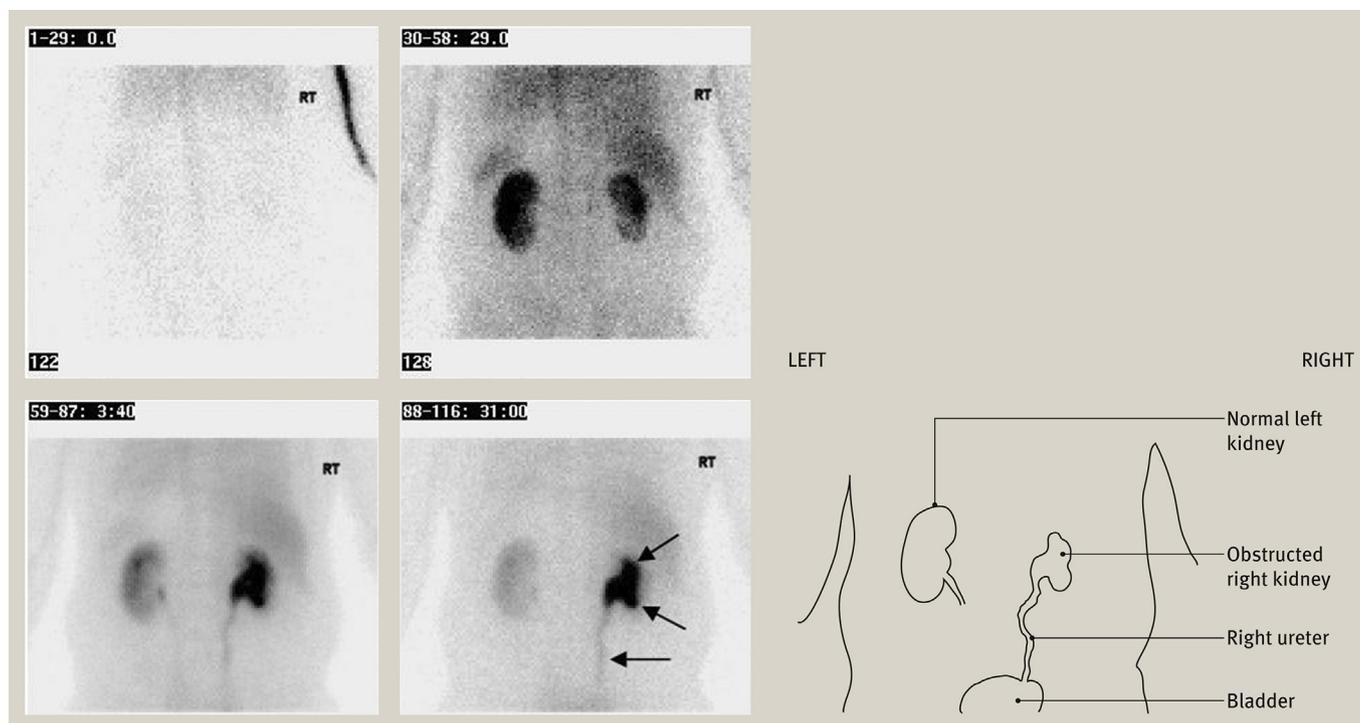
### Isotope studies

Radionuclide investigations provide functional and quantitative information to supplement the structural information provided

by other imaging techniques. There are two broad categories: dynamic and static renal scans. A dynamic renal scan can be used to measure total function, differential blood flow and differential renal function, giving a quantitative evaluation of the rate of transit through the urinary tract. This is useful when assessing whether chronically dilated collecting systems are obstructed (Figure 7). A static renal scan can be used to assess divided renal function and is helpful in detecting renal cortical scars in children with urinary tract infections; further investigation here would involve micturating cystography (a dynamic contrast X-ray examination of the bladder) to look for vesico-ureteric reflux. The radiopharmaceuticals used in static scans



**Figure 6** (a) CT with contrast enhancement shows a haematoma (arrow) behind the left kidney. (b) Catheter angiography shows the site of haemorrhage (arrow) from the left kidney. (c) Catheter angiography after selective embolization (arrow) of the renal artery branch shows cessation of bleeding.



**Figure 7** Sequential images from a dynamic radionuclide scan show delayed emptying with a dilated pelvi-calyceal system in the right kidney and a dilated right ureter (arrow). There is normal emptying of the left kidney.

are taken up by the renal parenchyma with no significant excretion.

### Renal transplant assessment

Renal transplants are placed in the right or left iliac fossa, and as they are relatively superficial compared with native kidneys, they are readily assessed using US. In the immediate postoperative period, colour Doppler US can be used to assess kidney perfusion and measure the intra-renal resistive index. The resistive index is a measure of resistance to arterial flow in the renal vascular bed; values  $<0.8$  are normal, but values  $>0.9$  suggest transplant dysfunction. In addition to measuring the flow in the main transplant artery, the patency of the renal vein can also be confirmed. In addition, the presence of extra-renal collections (haematomas, lymphoceles, urinomas) can be identified. Dilatation of the collecting system can indicate obstruction (Figure 7).

### Image-guided biopsy and treatment

US can be used to provide real-time guidance during renal biopsy. A renal biopsy is usually performed for evaluation of renal diseases, which can present as acute kidney injury or chronic kidney disease (e.g. glomerulonephritis, interstitial nephritis), and to diagnose graft rejection in cases of transplant

dysfunction. Biopsy of focal renal masses is not usually performed if the lesion is to be surgically removed. However, biopsy can be indicated if the patient is to be treated non-surgically with chemotherapy or there is a suspicion that the lesion might be a renal metastasis or lymphoma.

Image-guided ablative therapies, such as radiofrequency ablation and cryotherapy, can be used to treat focal renal lesions including tumours, thereby avoiding the need for surgical nephrectomy and preserving renal function. This form of treatment is minimally invasive and associated with less morbidity than open surgery. ◆

### KEY REFERENCES

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### FURTHER READING

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## TEST YOURSELF

To test your knowledge based on the article you have just read, please complete the questions below. The answers can be found at the end of the issue or online [here](#).

**Question 1**

A 30-year-old man presented with hypertension that was not well controlled with three different medications.

**What is the best imaging test for further assessment?**

- A. Ultrasound scan of the kidneys
- B. CT angiogram of the renal arteries
- C. MR angiogram of the renal arteries and thoracic aorta
- D. Radio-isotope scan with dimercaptosuccinic acid (DMSA)
- E. Micturating cystourethrogram (MCU)

**Question 2**

A 25-year-old man presented acutely with lethargy and reduced urine output. Blood tests indicated acute renal failure.

**What is the first imaging test that should be performed urgently?**

- A. Ultrasound scan of the kidneys and bladder
- B. CT angiogram
- C. MR renal angiogram
- D. Plain abdominal radiograph
- E. Renal biopsy

**Question 3**

A 35-year-old woman presented for assessment as a donor for a renal transplant.

**What is the best imaging test to assess her suitability?**

- A. Renal ultrasound scan
- B. Non-contrast renal CT scan
- C. MR scan of the kidneys including MR angiogram
- D. Plain abdominal radiograph
- E. Radio-isotope scan