from other possible cystic masses near the splenic hilum, such as pancreatic pseudocysts.

They are usually asymptomatic and are associated with pregnancy or liver disease with portal hypertension. Surgical resection or ligation is performed to prevent rupture, although smaller aneurysms may be safely monitored with ultrasound.\(^{12}\)

**Pseudoaneurysm**

Pseudoaneurysm in the spleen occurs in a minority of cases following splenic trauma. An echo-free or ‘cystic’ area may be observed, which demonstrates flow on colour Doppler.

In rare cases, pseudoaneurysm is also a complication of splenic infarct, infiltration of the spleen by malignancy, inflammatory disease such as pancreatitis, or infection\(^ {13}\) and usually occurs in association with non-traumatic splenic rupture.

**Splenic trauma**

(*See also Chapter 10.*) Splenic laceration may be particularly difficult to detect on ultrasound, particularly in the immediate post-trauma phase. The presence of free fluid in the abdomen of a trauma victim should alert the sonographer to the strong possibility of organ injury. The laceration may appear as a subtle, hyperechoic line within the spleen immediately after the injury. A frank area of haemorrhage, easily identifiable on ultrasound, may not develop until later.

CT is normally performed following the identification of free fluid on ultrasound in order to assess the extent of organ injury. Intrasplenic pseudoaneurysm is a recognized, but rare complication of splenic trauma, which can be demonstrated on colour Doppler.

In rare cases, spontaneous splenic rupture may be encountered, most usually associated with massive splenomegaly of the sort seen in infectious mononucleosis.

**LYMPHATICS**

Traditionally, normal lymph nodes are difficult or impossible to demonstrate on ultrasound. However, with good-resolution equipment, and using a suitable acoustic window, such as normal liver tissue, normal lymph nodes can be demonstrated in the hepatoduodenal ligament at the porta hepatitis (Fig. 6.9A), particularly in younger patients.\(^ {14}\)

The search for lymphadenopathy should include the para-aortic and paracaval regions, the splanchnic vessels and epigastric regions, and the renal hila (Fig. 6.9). Ultrasound has a low sensitivity for demonstrating lymphadenopathy, in the retroperit.
toneum, as bowel contents frequently obscure the relevant areas.

CT or MRI is better able to define the extent of lymphadenopathy, particularly in the pelvis.

The presence of lymphadenopathy is highly non-specific, being associated with a wide range of conditions including malignancy, infections and inflammatory disorders.

Benign lymphadenopathy is commonly seen in conjunction with hepatitis and other inflammatory disorders such as pancreatitis, cholangitis and colitis.
Nodes of 1.5 cm or over are generally considered pathological. Enlarged nodes are most often hypoechoic, rounded or oval in shape and well-defined. Larger nodes display colour or power Doppler flow.

Less frequently nodes are hyperechoic, or may combine to form large, lobulated masses. There is some evidence that colour Doppler may assist in differentiating benign from malignant superficial nodes (Fig. 6.9E), the latter displaying a significantly higher resistance on spectral analysis.16,17

Lymphadenopathy at the porta may occasionally cause obstructive jaundice due to compression of the common bile duct.

**Lymphangioma**

These are benign tumours of the lymphatic vessels, usually diagnosed in the neonatal period or on prenatal sonography. They are predominantly cystic, frequently septated, and may be large (Fig. 6.10). They can compress adjacent organs and vessels and their severity depends to a large extent upon their location. They are most common in the neck (cystic hygroma) but can be found in various locations, including the abdomen,18 and are occasionally found in adults after a long asymptomatic period.

**References**

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# Chapter 7

## The renal tract

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THE NORMAL RENAL TRACT

Ultrasound technique

The right kidney is readily demonstrated through the right lobe of the liver. Generally a subcostal approach displays the (more anterior) lower pole to best effect, while an intercostal approach is best for demonstrating the upper pole (Fig. 7.1).

The left kidney is not usually demonstrable sagittally because it lies posterior to the stomach and splenic flexure. The spleen can be used as an acoustic window to the upper pole by scanning coronally, from the patient’s left side, with the patient supine or decubitus (left side raised), but, unless the spleen is enlarged, the lower pole must usually be imaged from the left side posteriorly.

Coronal sections of both kidneys are particularly useful as they display the renal pelvicalyceal system (PCS) and its relationship to the renal hilum (Fig. 7.2A). This section demonstrates the main blood vessels and ureter (if dilated).

Figure 7.1  (A) Sagittal section through the normal right kidney (RK), using the liver as an acoustic window. The central echoes from the renal sinus are hyperechoic due to the fat content. The hypoechoic, triangular, medullary pyramids are demonstrated in a regular arrangement around the sinus. The cortex is of similar echogenicity to the liver. (B) TS through the hilum of the RK, demonstrating the renal vein (arrow) draining into the inferior vena cava (IVC) (arrowhead). (C) Left kidney (LK) in coronal section. The renal hilum is seen furthest from the transducer (s = spleen). (Compare this with the sagittal section of the RK in which cortex is seen all the way around the pelvicalyceal system.) (D) The renal cortex lies between the capsule and the lateral margin of the medullary pyramid (arrowheads).
As with any other organ, the kidneys must be examined in both longitudinal and transverse (axial) planes. This usually requires a combination of subcostal and intercostal scanning with anterior, posterior and lateral approaches. The operator must be flexible in approach to obtain the necessary results.

The bladder should be filled and examined to complete the renal tract scan. An excessively full bladder may cause mild dilatation of the PCS, which will return to normal following micturition.

**Normal ultrasound appearances of the kidneys**

The cortex of the normal kidney is slightly hypoechoic when compared to the adjacent liver parenchyma, although this is age-dependent. In young people it may be of similar echogenicity and in the elderly it is not unusual for it to be compara-

---

**Figure 7.2** (A) Coronal section through the RK demonstrating fetal lobulations (arrows). The pelvicalyceal system (PCS) is mildly distended due to a full bladder. (B) TS through the base of the bladder, demonstrating a left ureteric jet. (C) 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.
tively hyperechoic and thin. The medullary pyramids are seen as regularly spaced, echo-poor triangular structures between the cortex and the renal sinus (Fig. 7.1). The tiny reflective structures often seen at the margins of the pyramids are echoes from the arcuate arteries which branch around the pyramids.

The renal sinus containing the PCS is hyper-echoic due to sinus fat which surrounds the vessels. The main artery and vein can be readily demonstrated at the renal hilum and should not be confused with a mild degree of PCS dilatation. Colour Doppler can help differentiate.

The kidney develops in the fetus from a number of lobes, which fuse. Occasionally the traces of these lobes can be seen on the surface of the kidney, forming fetal lobulations (Fig. 7.2A); these may persist into adulthood.

**Normal ultrasound appearances of the lower renal tract**

When the bladder is distended with urine, the walls are thin, regular and hyperechoic. The walls may appear thickened or trabeculated if the bladder is insufficiently distended, making it impossible to exclude a bladder lesion.

The ureteric orifices can be demonstrated in a transverse section at the bladder base. Ureteric jets can easily be demonstrated with colour Doppler at this point and normally occur between 1.5 and 12.4 times per minute (a mean of 5.4 jets per minute) from each side1 (Fig. 7.2B).

It is useful to examine the pelvis for other masses, e.g. related to the uterus or ovaries, which could exert pressure on the ureters causing proximal dilatation. The prostate is demonstrated transabdominally by angling caudally through the full bladder (Fig. 7.2C). The investigation of choice for the prostate is transrectal ultrasound; however an approximate idea of its size can be gained from transabdominal scanning. When prostatic hypertrophy is suspected, it is useful to perform a postmicturition bladder volume measurement to determine the residual volume of urine (see Measurements below).

**Measurements**

The normal adult kidney measures between 9 and 12 cm in length. A renal length outside the normal range may be an indication of a pathological process and measurements should therefore form part of the protocol of renal scanning. The maximum renal length can often only be obtained from a section which includes rib shadowing. A subcostal section, which foreshortens the kidney, often underestimates the length and it is more accurate to measure a coronal or posterior longitudinal section.

The cortical thickness of the kidney is generally taken as the distance between the capsule and the margin of the medullary pyramid (Fig. 7.2D). This varies between individuals and within individual kidneys and tends to decrease with age.

The bladder volume (Fig. 7.2C) can be estimated for most purposes by taking the product of three perpendicular measurements and multiplying by 0.56:

\[
\text{Bladder volume (ml)} = \text{length} \times \text{width} \times \text{anteroposterior diameter (cm)} \times 0.56
\]

**Haemodynamics**

The vascular tree of the kidney can be effectively demonstrated with colour Doppler (Fig. 7.3). 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 [Fig. 7.3D].

The normal adult renal vasculature is of low resistance with a fast, almost vertical systolic upstroke and continuous forward end diastolic flow. Resistance generally increases with age.² The more peripheral arteries are of lower velocity with weaker Doppler signals, and are less pulsatile than the main vessel.
Assessment of renal function

Blood and urine tests can be useful indicators of pathology. Frequently, the request to perform ultrasound is triggered by biochemical results out-with the normal range. Raised serum levels of urea and creatinine are associated with a reduction in renal function. However, any damage is usually quite severe before this becomes apparent. The creatinine clearance rate estimates the amount of creatinine excreted over 24 h, and is a guide to the glomerular filtration rate (normal glomerular filtration rate 100–120 ml/min). A poor rate of clearance (ml/min) is indicative of renal failure.

Figure 7.3  (A) Colour Doppler of the RK in coronal section demonstrates normal global intrarenal perfusion throughout the kidney. (B) TS through the LK demonstrates the main renal vein (blue) draining into the IVC. The main renal artery can be seen in red alongside. (C) The waveform from the main renal artery at the hilum of the kidney is of low resistance with good end-diastolic flow. The spectrum from the adjacent vein can be seen below the baseline. (D) Coronal section through the aorta (AO) showing the origin of the left renal artery. The blue colour in the proximal section of the artery is an aliasing artefact due to the strong Doppler signal from this part of the vessel, which is parallel to the beam. (Compare this with the aorta, which, because of its relatively perpendicular angle with the beam, has a poor Doppler signal, despite its high velocity in reality.)
Blood in the urine is a potentially serious sign which should prompt investigation with ultrasound. Frank haematuria may be a sign of renal tract malignancy. Microscopic haematuria may reflect inflammation, infection, calculi or malignancy. The urine can be easily examined for protein, glucose, acetone and pH using chemically impregnated strips.

Radioisotope scans

Although the ultrasound scan is invaluable in assessing the morphology of the kidneys, it is not able to assess function. The administration of a radioactive tracer, however, reveals valuable information regarding renal function and an isotope scan may often be performed in addition to ultrasound.

A diethylene triaminepenta-acetic acid (DTPA) scan, in which the isotope is intravenously injected as a bolus, can assess renal perfusion, with further data reflecting renal uptake, excretion and drainage during later images.

A dimercaptosuccinic acid (DMSA) scan shows uptake of isotope which is proportional to functioning renal tissue. Relative renal function can be determined between kidneys and localized areas of poor or absent function, such as scars, are clearly demonstrated.

Normal variants

Duplex kidneys

These occur in a spectrum of degrees, from two separate organs with separate collecting systems and duplex ureters, to a mild degree of separation of the PCS at the renal hilum (Fig. 7.4A). The latter is more difficult to recognize on ultrasound, but the two moieties of the PCS are separated by a zone of normal renal cortex which invaginates the kidney, a hypertrophied column of Bertin (see below).

If duplex ureters are present (a difficult diagnosis to make on ultrasound unless dilatation is present) then a ureterocoele related to the upper moiety should be sought at or adjacent to the bladder. This may cause dilatation of the affected moiety.

The main renal artery and vein may also be duplicated, which can occasionally be identified using colour or power Doppler.

Ectopic kidneys

The kidney normally ascends from the pelvis into the renal fossa during its course of development. During this ‘migration’ it rotates inwards so that the renal hilum faces medially. A failure of this mechanism causes the kidney to fall short of its normal position, remaining in the pelvis, that is, a pelvic kidney. Usually it lies on the correct side, however occasionally it can cross to the other side, lying inferior to its normally placed partner—crossed renal ectopia. Frequently it may fuse with the lower pole of the other kidney, crossed fused renal ectopia, resulting in what appears to be a very long, unilateral organ.

Horseshoe kidneys

In the horseshoe kidney, the kidneys lie one on each side of the abdomen but their lower poles are fused by a connecting band of renal tissue, or isthmus, which lies anterior to the aorta and IVC (Fig. 7.4). The kidneys tend to be rotated and lie with their lower poles medially.

It may be difficult to visualize the isthmus due to bowel gas anterior to it but a horseshoe kidney should always be suspected when the operator is unable to identify the lower poles of the kidneys confidently.

When the isthmus can be seen, it is important not to confuse it with other abdominal masses, such as lymphadenopathy. CT is occasionally performed because of this but normally clarifies the findings.

Extrarenal pelvis

Not infrequently, the renal pelvis projects outside the kidney, medial to the renal sinus. This is best seen in a transverse section through the renal hilum. It is frequently ‘baggy’, containing anechoic urine, which is prominently demonstrated on the ultrasound scan (Fig. 7.4E).

The importance of recognizing the extrarenal pelvis lies in not confusing it with dilatation of the PCS, or with a parapelvic cyst or collection.

Hypertrophied column of Bertin

The septum of Bertin is an invagination of renal cortex down to the renal sinus. It occurs at the
junctions of original fetal lobulations and is present in duplex systems (see above), dividing the two moieties. Particularly prominent, hypertrophied columns of Bertin may mimic a renal tumour. It is usually possible to distinguish between the two as the column of Bertin does not affect the renal outline and has the same acoustic characteristics as the adjacent cortex (Fig. 7.4F).

Colour or power Doppler can be helpful in revealing the normal, regular vascular pattern (as opposed to the chaotic and increased blood flow pattern of malignant renal tumours). If doubt persists, particularly in a symptomatic patient, CT will differentiate tumour from a prominent column of Bertin; an isotope scan can also be helpful in demonstrating normally functioning renal tissue.

Figure 7.4  (A) Duplex kidney showing two separate intrarenal collecting systems (arrows). These drained into a single ureter on intravenous urogram (IVU). (B) TS through the abdomen demonstrating the fused lower poles of the horseshoe kidney anterior to the spine. (C) Coronal section through a horseshoe kidney with the isthmus of the kidney (i) anterior to the aorta and IVC. (D) MAG3 scan demonstrating a horseshoe kidney with a poorly functioning LK and isthmus. Differential function is 86% on the right and 14% on the left.

(Continued)
Renal humps

These are areas of renal cortex, which form a bulge in the renal outline. Like the hypertrophied column of Bertin, a hump may mimic a renal mass. Careful scanning can usually solve the dilemma as the cortex remains constant in thickness. The most usual manifestation is the splenic hump on the left kidney, which is a flattening of the upper pole with a lateral prominence just below the margin of the spleen. Humps are basically a variation in the shape of the kidney rather than an area of hypertrophied tissue.

RENAL CYSTS AND CYSTIC DISEASE

Cysts

The most common renal mass is a simple cyst which can be found in up to 50% of the population, the incidence increasing with age. Most cysts are asymptomatic and may be solitary or multiple. Generally they are peripheral but may occur within the kidney adjacent to the renal pelvis. A parapelvic cyst may be difficult to distinguish from pelvic-lyceal dilatation, a calyceal diverticulum or an extra-

renal pelvis and careful scanning is required to differentiate. A parapelvic cyst may be the cause of a filling defect on intravenous urogram (IVU) and CT can differentiate a cyst from a diverticulum if necessary, as the latter will fill with contrast.

Occasionally cysts can haemorrhage causing pain. Large cysts, particularly of the lower pole, may be palpable, prompting a request for an ultrasound scan.

Ultrasound appearances

Like cysts in any other organ, renal cysts display three basic characteristics: they are anechoic, have a thin, well-defined capsule and exhibit posterior enhancement. It can be difficult to appreciate the posterior enhancement if the hyperechoic perirenal fat lies distal to the cyst; scanning from a different angle (Fig. 7.5) may be helpful. Haemorrhage or infection can give rise to low-level echoes within a cyst and in some cases the capsule may display calcification.

Whilst a solitary, simple cyst can almost certainly be ignored, cysts with more complex acoustic characteristics may require further investigation,
for example CT. A calcified wall may be associated with malignancy.

**Autosomal dominant (adult) polycystic kidney disease (APKD)**

This autosomal dominant disease has a wide spectrum of presentation. It is normally associated with progressive renal failure. A renal transplant offers a successful cure for many patients. Although in some cases APKD may cause renal failure in early life, it is also possible to achieve a normal life span with no appreciable symptoms.

In about 50% of cases, cysts are present in the liver; they are also found in the spleen and pancreas in a small proportion of patients.

Ultrasound screening for APKD is performed in families with a positive history, as patients may then be monitored and treated for hypertension. A negative scan does not entirely exclude disease, especially in the younger patient, and multiple examinations over years may need to be performed.

**Ultrasound appearances**

The disease is always bilateral, causing progressively enlarging kidneys with multiple cysts of various sizes, many having irregular margins (Fig. 7.6). There is often little or no demonstrable normal renal tissue and the kidneys may become so large that they visibly distend the abdomen.

APKD predisposes the patient to urinary tract infections and some of the cysts may contain low-level echoes as a result of infection or haemorrhage.

The liver, spleen and pancreas should also be examined on ultrasound for associated cysts. A small but recognized increased incidence of tumour is recorded in patients with APKD.
Autosomal recessive (infantile) polycystic kidney disease (PCKD)

This autosomal recessive condition may often be diagnosed prenatally on ultrasound. The disease carries a high mortality rate in early childhood, and is therefore rarely seen on ultrasound in children.

Tiny cysts replace both kidneys, giving them a hyperechogenic appearance due to the multiple reflections from the cyst walls and the overall increased through-transmission.

Acquired cystic disease

This condition tends to affect patients on long-term dialysis who may already have shrunken, end-stage kidneys. Its frequency increases with the duration of dialysis.

Multiple cysts form in the kidneys, which may, like adult PCKD, haemorrhage or become infected. The disease tends to be more severe the longer the patient has been on dialysis. The proliferative changes which cause acquired cystic disease also give rise to small adenomata and the ultrasound appearances may be a combination of cysts and solid, hypoechoic nodules. In particular, acquired cystic disease has the potential for malignancy and it is therefore prudent to screen native kidneys, even after renal transplantation has been performed (Fig. 7.7).

Multicystic dysplastic kidney (MCDK)

This is a congenital malformation of the kidney, in which the renal tissue is completely replaced by cysts. It is frequently diagnosed prenatally (although it is naturally a lethal condition if bilateral).

The MCDK may shrink with age and, by adulthood, may be so small that it is difficult to detect and may be mistaken for an absent kidney. Contralateral renal hypertrophy is often present. MCDK can be associated with contralateral pelvi-ureteric junction obstruction, which is also frequently diagnosed in utero.

It is thought that MCDK occurs as a result of severe early renal obstruction during development in utero. Obstructed calyces become blocked off, forming numerous cysts which do not connect.

BENIGN FOCAL RENAL TUMOURS

Angiomyolipoma

This is a homogeneous, highly echogenic, usually rounded lesion in the renal parenchyma containing blood vessels, muscle tissue and fat, as the name suggests. They are usually solitary, asymptomatic lesions, found incidentally on the scan, although the larger lesions can haemorrhage, causing haematuria and pain. Angiomyolipomas are also associated with tuberose sclerosis, when they are often multiple and bilateral (Fig. 7.8).

Because the contrast between the hypoechoic renal parenchyma and the hyperechoic angiomyolipoma is so great, very small lesions in the order of a few millimetres can easily be recognized.

It may be difficult confidently to differentiate an angiomyolipoma from a malignant renal neoplasm, particularly in a patient with haematuria. Angiomyolipomas tend to be smaller and more echogenic than renal cell carcinomas, and sometimes demonstrate shadowing, which is not normally seen in small carcinomas. When doubt persists, CT is often able to differentiate in these cases by identifying the fat content of the lesion.

Adenoma

The renal adenoma is usually a small, well-defined hyperechoic lesion, similar in appearance to the
Angiomyolipoma. It is felt that adenomas are frequently early manifestations of renal carcinoma as distinct from a benign lesion and the two may be histologically indistinguishable.

Renal adenomas are often found in association with a renal cell carcinoma in the same or contralateral kidney, although these are radiologically indistinguishable from metastases.

Because of the controversy surrounding the distinction between adenomas and small renal cell carcinomas, the management of patients with these masses is uncertain. Most incidentally discovered, small (less than 3 cm), parenchymal renal masses are slow-growing and may be safely monitored with CT or ultrasound, particularly in the elderly.

**MALIGNANT RENAL TRACT MASSES**

*Imaging of malignant renal masses*

Ultrasound, as one of the first-line investigations in patients with haematuria, is highly sensitive in detecting large renal masses above 2.5 cm in diameter and in differentiating them from renal cysts. Smaller masses may be missed with ultrasound however, as they are frequently isoechoic (in 86% of cases); CT is more sensitive in small lesion detection.

MRI also detects small renal masses more frequently than ultrasound but is generally reserved for patients with equivocal CT scans as it is less widely available. IVU is also known to miss small renal masses and normally requires further characterization of any detected mass with ultrasound or CT.

**Renal cell carcinoma (RCC)**

Adenocarcinoma is the most common type of renal malignancy (referred to as renal cell carcinoma) occurring less commonly in the bladder and ureter. RCCs are frequently large at clinical presentation; they may occasionally be identified as an incidental finding in an asymptomatic patient.

*Ultrasound appearances*

The RCC is a (usually) large, heterogeneous mass which enlarges and deforms the shape of the kidney (Fig. 7.9). The mass may contain areas of cystic degeneration and/or calcification. It has a predilection to spread into the ipsilateral renal vein and IVC (see also Chapter 8).

Colour Doppler usually reveals a disorganized and increased blood flow pattern within the mass with high velocities from the arteriovenous shunts within the carcinoma.

Smaller RCCs can be hyperechoic and may be confused with benign angiomyolipoma. The latter
has well-defined borders whilst an RCC is ill-defined: differentiation may not be possible on all occasions and biopsy or interval scan may be required.

A chest X-ray and/or CT will demonstrate if metastases are present in the lungs. Liver, adrenal and lymph node metastases can be demonstrated on ultrasound but CT is used for staging purposes as ultrasound generally has a lower sensitivity for distant disease detection.

Transitional cell carcinoma

Transitional cell carcinoma is the most common bladder tumour, occurring less frequently in the collecting system of the kidney and the ureter. It usually presents with haematuria while still small. It is best diagnosed with cystoscopy. Small tumours in the collecting system are difficult to detect on ultrasound unless there is proximal dilatation. Depending on its location it may cause hydronephrosis, particularly if it is situated in the ureter (rare) or at

Figure 7.9  (A) The RK is almost completely replaced by a large renal carcinoma (T). The main renal vein contains tumour thrombus which has spread into the IVC. The main renal artery is seen alongside. (B) Colour Doppler of the tumour reveals vigorous, multidirectional blood flow within it. (C) Recurrence of carcinoma (between calipers) in the right renal bed of a patient following right nephrectomy for renal carcinoma. (D) CT demonstrating a large left renal carcinoma.
the vesicoureteric junction (VUJ). IVU, retrograde cystography and CT are methods of diagnosis.

**Ultrasound appearances**

Situated within the collecting system of the kidney, the transitional cell tumour is usually small (compared to the RCC), homogeneous and relatively hypoechoic (Fig. 7.10A). Proximal renal tract dilatation may sometimes be present. These tumours are easy to miss on ultrasound unless the kidney is scanned very carefully, and often are, unless the case is highlighted by clinical symptoms or a high clinical index of suspicion. They can mimic a hypertrophied column of Bertin (see above); CT may differentiate in cases of doubt.

Once large, they invade the surrounding renal parenchyma and become indistinguishable from RCC on ultrasound. They frequently spread to the bladder and the entire renal tract should be carefully examined.

In the bladder they are potentially easier to see as they are surrounded by urine (Fig. 7.10B). Invasion of the bladder wall can be identified on ultrasound in the larger ones but biopsy is necessary to determine formally the level of invasion.

IVU or a retrograde cystogram are the methods of choice for demonstrating a filling defect in the PCS (Fig. 7.11) or ureter; CT may be useful and is also used for staging purposes.

**Lymphoma**

Renal involvement of non-Hodgkin’s or Hodgkin’s lymphoma is not uncommon and depends upon the stage of the disease. The ultrasound appearances are highly variable and range from solitary to multiple masses, usually hypoechoic but sometimes anechoic, hyperechoic or mixed.

The masses may have increased through transmission of sound and may mimic complex fluid lesions such as haematoma or abscess. The clinical history should help to differentiate these cases. Occasionally diffuse enlargement may occur secondary to diffuse infiltration.

**Metastases**

Renal metastases from a distant primary are usually found in cases of widespread metastatic disease and are frequently multiple.
In such cases, the primary diagnosis is usually already known and other abdominal metastases, such as liver deposits and/or lymphadenopathy, are commonly seen on ultrasound.

Rarely, a single metastasis is seen in the kidney without other evidence of metastatic spread, making the diagnosis difficult (as the question arises of whether this could be a primary or secondary lesion). CT may identify the primary and frequently picks up other, smaller metastases not identified on ultrasound.

**Physiological dilatation**

Mild dilatation of the renal collecting system is a common finding, most commonly secondary to an over-distended bladder. Following micturition, the collecting system decompresses and returns to normal. An external renal pelvis (see above) is a non-obstructive ‘baggy’ dilatation of the pelvis and can be regarded as a normal variant. The intrarenal collecting system is normal in this situation (Fig. 7.4, D, E).

Pregnancy is another common cause of mild PCS dilatation, more frequently on the right, particularly in the second and third trimester. This is thought to be due partly to pressure on the ureters from the advancing pregnancy and partly hormonal. It is however wrong to assume that the kidney is not obstructed just because the patient is pregnant. If symptomatic, the suspicion of obstruction in a dilated system is increased, particularly if echoes are present in the PCS.

**Obstructive uropathy**

Renal obstruction, particularly if long-standing, can irreversibly damage the kidney or kidneys, leading eventually to renal failure. If diagnosed early enough, renal function can be preserved and therefore ultrasound plays a prominent role as one of the first-line investigations in patients with loin pain, renal colic or micturition disorders (Table 7.1).

In the vast majority of cases, urinary tract obstruction causes dilatation of the collecting system proximal to the site of obstruction (Fig. 7.12). Whether the hydronephrosis is bilateral or unilateral and whether or not it involves the ureter(s) depends on the cause and site of the obstructing lesion.

Dilatation of the collecting system may be localized. Sometimes only one moiety of the kidney may be obstructed by a stone or tumour, whilst the rest of the kidney remains normal. In a duplex kidney, dilatation of the upper pole moiety is a common occurrence due to an anomaly at the VUJ, that is, a ureterocoele.

If the obstruction is long-standing the renal cortex may atrophy, becoming thin. Normal thickness of cortex is a good prognostic indicator. Function may be assessed with a nuclear medicine (DTPA) scan prior to further management.
Further management of renal obstruction

In the majority of cases the exact level and cause of obstruction are difficult to identify on ultrasound. Confirmation of the cause and identification of the exact level is traditionally best established on IVU, however CT IVU is becoming a rapidly universally adopted first-line investigation.

A plain abdominal X-ray is useful in confirming the presence of calculi in the renal tract, but ultrasound may demonstrate stones which are non-opaque on X-ray; CT is probably the best overall test for stone detection.

It is important to assess the function of the obstructed side, as a chronic, longstanding obstruction with no residual function cannot be treated, but a kidney which still has function is worth saving. A DTPA scan can assess the relative functions of the obstructed and non-obstructed side.

Percutaneous nephrostomy (the placing of a tube into the PCS to drain the urine) in the case of unilateral obstruction is performed to relieve the obstruction, minimizing damage to the kidney and maintaining renal function and drainage. This may be done under either ultrasound or fluoroscopic guidance or a combination of both. The decision of whether to proceed to nephrostomy or cystoscopic stent will depend upon patient presentation and local factors and policies.

Pyonephrosis

Pyonephrosis is a urological emergency. An obstructed kidney is prone to become infected. High fever and loin pain can suggest obstructive pyonephrosis. Pus or pus cells may also be detected in the urine.

Low level echoes can be seen within the dilated PCS on ultrasound, and may represent pus. Sometimes, however, the urine may appear anechoic, despite being infected. The clinical history should help differentiate pyo- from simple hydronephrosis (Fig. 7.13A). Percutaneous drainage by ultrasound or fluoroscopically guided nephrostomy is usually necessary, partly as diagnostic confirmation and partly as a therapeutic procedure.

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### Table 7.1 Causes of renal tract obstruction

<table>
<thead>
<tr>
<th>Source of obstruction</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intrinsic factors</strong></td>
<td></td>
</tr>
<tr>
<td>Stones</td>
<td>Accompanied by renal colic. May be situated anywhere along the renal tract.</td>
</tr>
<tr>
<td>Tumour</td>
<td>In the bladder, PCS or ureter.</td>
</tr>
<tr>
<td>Blood clot</td>
<td>From infection or trauma.</td>
</tr>
<tr>
<td>Papillary necrosis</td>
<td>Sloughed papillae can travel down the ureter, causing obstruction.</td>
</tr>
<tr>
<td><strong>Infective processes</strong></td>
<td></td>
</tr>
<tr>
<td>Stricture</td>
<td>Caused by chronic, repeated infection.</td>
</tr>
<tr>
<td>Fungal balls</td>
<td>Rare.</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>Usually unilateral. PCS dilation only.</td>
</tr>
<tr>
<td>Congenital</td>
<td>Usually unilateral. PCS dilation only.</td>
</tr>
<tr>
<td>Idiopathic PUJ</td>
<td>Entire renal tract dilatation.</td>
</tr>
<tr>
<td>Obstruction</td>
<td>Frequently diagnosed antenataly.</td>
</tr>
<tr>
<td>Posterior urethral</td>
<td>Unilateral hydronephrosis with hydroureter.</td>
</tr>
<tr>
<td>Valves</td>
<td>Unilateral hydronephrosis with hydroureter.</td>
</tr>
<tr>
<td><strong>Outflow obstruction</strong></td>
<td></td>
</tr>
<tr>
<td>Prostate enlargement</td>
<td>Benign or malignant.</td>
</tr>
<tr>
<td>Urethral stricture</td>
<td>May be iatrogenic, congenital or as a result of infection. Accompanied by disturbed micturition.</td>
</tr>
<tr>
<td><strong>Extrinsic pelvic mass</strong></td>
<td></td>
</tr>
<tr>
<td>Cervical carcinoma</td>
<td>Proximity to the ureters causes obstruction.</td>
</tr>
<tr>
<td>Endometriosis</td>
<td>Endometriotic lesions adhere to the peritoneal and/or ureteric surfaces, causing compression.</td>
</tr>
<tr>
<td><strong>Others: lymphadenopathy, inflammatory bowel masses, gynaecological masses</strong></td>
<td></td>
</tr>
<tr>
<td>Iatrogenic</td>
<td>Ligation of ureters in gynaecological procedures.</td>
</tr>
<tr>
<td>Postsurgical procedure</td>
<td>Can cause a stricture of the ureter or can cause the renal tract to be blocked by blood clot from damage to the kidney.</td>
</tr>
</tbody>
</table>

PCS = pelvicalyceal system; PUJ = pelviureteric junction.
Haemo-hydronephrosis

Blood within the dilated PCS may be due to trauma or other local or semilocal pathological processes such as infection or tumour. It is not usually possible to determine whether obstruction is caused by a blood clot or whether the blood is the result of an obstructing lesion which is also causing bleeding. Renal colic as a result of obstruction by a blood clot in the absence of trauma or blood dyscrasia must naturally be thoroughly investigated to exclude an underlying lesion.

Figure 7.12  (A) Hydronephrosis of the left kidney, secondary to a large circumferential bladder tumour. (B) A ureteric stent is noted within the renal pelvis of (A) (arrow); however, a moderate degree of hydrenephrosis is present and highly suggestive of partial or complete stent occlusion. (C) Moderate to marked hydrenephrosis of the right kidney secondary to a pelvic lesion. The cortical thickness is normal suggesting the obstruction is relatively recent and that relief of obstruction should produce a significant improvement in renal function. (D) Hydrenephrosis of the right kidney. The kidney however is small at 7.2 cm, the cortex echogenic and thinned, particularly at mid pole level. Appearances suggest this appearance is chronic. (E) TS of a left-sided hydrenephrosis. Echogenic material is present within the collecting system. The patient was pyrexial. Pus was drained.
Like pyonephrosis, low-level echoes may be seen on ultrasound within the collecting system (Fig. 7.13B). Although ultrasonically it is not possible to differentiate pyo- from haemohydronephrosis, the clinical picture can be suggestive of one or the other.

**Non-dilated renal obstruction**

Obstruction may occasionally be present in the acute stages before renal dilatation is apparent: beware—the finding of a non-dilated PCS on ultrasound does not exclude obstruction in any patient with symptoms of renal colic.

Spectral Doppler is useful in diagnosing acute, early renal obstruction, before PCS dilatation develops, because of the associated increase in blood flow resistance in the affected kidney (Fig. 7.14). This causes an increase in the resistance and pulsatility indices (RI and PI) on the obstructed side, due to a reduction in diastolic flow. A raised RI in itself is a non-specific finding, not necessarily indicating obstruction; it is known to be age-related or can be associated with extrinsic compression of the kidney (for example by a fluid collection or mass) or with some chronic renal diseases or vascular disorders. This can be overcome by analysing Doppler spectra from both kidneys and evaluating any difference between the two sides.

A marked difference in the RI between the kidneys in a patient with renal colic points towards obstruction of the kidney with the higher resistance. A difference in RI of greater than 6 is highly suspicious of obstruction in a patient with renal colic; a reduction in the RI on the affected side
can be observed when the obstruction has been relieved or after the renal PCS has become dilated. This effect often does not persist once the kidney dilates, presumably because the intrarenal pressure is relieved, which emphasizes the use of Doppler in acute cases, before dilatation has become established. Because of the vagaries of the stage of obstruction, renal pressure, etc., the interpretation of RI should be made cautiously. IVU will show delayed PCS opacification and is also more useful than ultrasound in assessing the level of obstruction. CT IVU, as mentioned previously, is more commonly fulfilling the role previously held by the IVU.

Vesicoureteric junction

The normal ureters may be identified on ultrasound with high-resolution equipment, as they enter the bladder. Jets of urine emerge into the bladder at these points and can be demonstrated with colour Doppler. An absent or reduced number of jets may indicate obstruction on that side; this finding again should be interpreted cautiously. Ureteric jet analysis is not routinely performed at most hospitals as a diagnostic test of renal obstruction.

Careful scanning at the VUJs can identify significant anomalies (Figs 7.12 D, E):

- Reflux can be seen to dilate the ureter intermittently (see below).
- A ureterocoele may be diagnosed as it dilates with the passage of urine; it may not be obvious until the operator has watched carefully for a few minutes.
- Stones may become lodged at the VUJ, causing proximal dilatation.

Non-obstructive hydronephrosis

Not all renal dilatation is the result of an obstructive process and the kidney may frequently be dilated for other reasons.

Reflux

This is the most common cause of non-obstructive renal dilatation, and is normally diagnosed in children. Reflux is associated with recurrent urinary tract infections and can result in reflux nephropathy, in which the renal parenchyma is irretrievably damaged.

Reflux can be distinguished from other causes of renal dilatation by observing the dilatation of the ureters at the bladder base, due to the retrograde passage of urine. For a more detailed consideration of the diagnosis of reflux, see Chapter 9.

Postobstructive dilatation

Dilatation of a once severely obstructed kidney may persist. The PCS remains baggy and dilated despite the obstruction having been relieved.

Papillary necrosis

The renal papillae, which are situated in the medulla adjacent to the calyces, are susceptible to ischaemia due to relatively low oxygenation in the region of the medullary junction. This is particularly associated with diabetic patients and those on long-term anti-inflammatory or analgesic medication.

The papillae tend to necrose and slough off, causing blunting of calyces on IVU. Sloughed-off papillae may lodge in the entrance to the calyces, causing obstruction.

Papillary necrosis is difficult to detect on ultrasound unless advanced. It appears as prominent calyces with increased corticomedullary differentiation. IVU is the imaging method of choice (Fig. 7.15).

Congenital megacalycæs

This is a congenital condition in which the PCS is dilated due to poor development of the papillae. The calyces are normally markedly enlarged but the cortex is normal and the ureters are of normal calibre and not dilated. Occasionally this is associated with congenital megaureter in which the muscular layer of the ureter is atonic. Differential diagnoses for fluid-filled renal masses are summarized in Table 7.2.

RENAL TRACT CALCIFICATION

Calcification within the kidney usually occurs in the form of stones. Smaller foci of calcium, which
do not shadow on ultrasound, are associated with conditions such as tuberculosis, xanthogranulomatous pyelonephritis, nephrocalcinosis or some neoplastic tumours.

### Renal tract stones

Renal calculi are a common finding on ultrasound. They may be an incidental discovery in an asymptomatic patient; alternatively they may be present in patients with acute renal colic and complete or partial obstruction of the ipsilateral renal tract. They may be the cause of haematuria and can also be associated with urinary tract infections. The composition of calculi can vary. The common types include:

- **Calcium stones** are the most common type and are frequently associated with patients who have abnormal calcium metabolism.
- **Struvite (triple phosphate) stones** have a different composition of salts and are associated with urinary tract infections. They may form large, staghorn calculi (see below).
- **Uric acid stones** are rare, and tend to be associated with gout.
- **Cystine stones** are the rarest of all and result from a disorder of amino acid metabolism—cystinuria.

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**Table 7.2  Differential diagnoses for fluid-filled renal masses**

<table>
<thead>
<tr>
<th>Solitary lesions</th>
<th>Simple cyst</th>
<th>Infected or haemorrhagic cyst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complex fluid lesions</td>
<td>Haemoptysis</td>
<td>Abscess</td>
</tr>
<tr>
<td>Pelvocalyceal system dilatation</td>
<td>Lymphoma</td>
<td>Necrotic primary or secondary tumour</td>
</tr>
<tr>
<td>Multiple cystic lesions</td>
<td>Tuberculosis</td>
<td>Xanthogranulomatous</td>
</tr>
<tr>
<td></td>
<td>Polyvesical</td>
<td>Pyelonephritis</td>
</tr>
</tbody>
</table>

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**Figure 7.15**  (A) Papillary necrosis. The calyces are mildly dilated with blunted, irregular margins and contain low-level echoes from sloughed papillae. (B) IVU of the same patient demonstrating the blunted calyces.
Ultrasound appearances

Most renal calculi are calcified foci located in the collecting system of the kidney. Careful scanning with modern equipment can identify over 90% of these. Most stones are highly reflective structures which display distal shadowing (Fig. 7.16). The shadowing may, however, be difficult to demonstrate due to the proximity of hyperechoic sinus echoes distal to the stone, or due to the relatively small size of the stone compared to the beam width.

The identification of reflective foci in the kidney is complicated by the fact that the normal renal sinus echoes are of similar echogenicity. This means that small stones may be missed on ultrasound. Differentiation of stones from sinus fat and reflective vessel walls is dependent upon careful technique and optimal use of the equipment. The operator must adjust the technique to display the distal shadow by using a variety of scanning angles and approaches and by ensuring that the suspected stone lies within the (narrowest) focal zone of the beam. The higher the frequency used, the better the chances of identifying the stone.

Clearly the identification of large calculi is normally straightforward; however, for many of the reasons above, identification of small calculi can be difficult, especially in a patient with pain. Both false-positive and false-negative studies are well recognized. Although traditionally the plain film, that is kidneys, ureters, bladder (KUB), is often the first-line investigation for patients with suspected calculi, it is now being accepted that CT IVU is the best and most reliable diagnostic test for calculi detection (Fig. 7.16 C and D).

Figure 7.16  (A) A calculus within the PCS of the RK. Distal acoustic shadowing is easily seen. (B) A staghorn calculus fills the entire PCS of the kidney. A sagittal section through the lateral aspect of the kidney gives the impression of several separate stones, although this is, in fact, a single calculus. (C) CT IVU through the renal area. The right renal pelvis is mildly dilated (arrow) and a small amount of perirenal stranding is noted, suggestive of obstruction (arrowheads). (D) CT scan through the bladder showing a small calculus on the right (arrow) at the right vesicoureteric junction.
Ultrasound still has a major role, however, not just in calculus detection but in identifying the secondary effects, that is, hydronephrosis, and where necessary, guiding renal drainage. The PCS may be obstructed proximal to the stone. Obvious hydronephrosis may be present and a dilated ureter may be apparent when the stone has travelled distally. The stone can sometimes be identified in the dilated ureter, but this is unusual as the retroperitoneum is frequently obscured by overlying bowel. Plain X-ray and/or IVU are traditional essential adjuncts to investigating renal colic in these cases; however CT IVU is rapidly becoming accepted as one of the mainstream investigations.17

Early obstruction occurs before the PCS can become dilated, making the diagnosis more difficult on ultrasound. Occasionally there will be mild separation of the PCS to give a clue, but sometimes the kidney appears normal. Doppler ultrasound can help to diagnose obstruction in a non-dilated kidney, as discussed previously; however this may not always be definitive.

**Staghorn calculi**

These large calculi are so called because they occupy a significant proportion of the collecting system, giving the appearance of a staghorn on X-ray (Fig. 7.16B). They may be less obvious on ultrasound than on X-ray, casting a dense shadow from the PCS which may obscure any associated dilatation and can, in small, atrophied kidneys, be misinterpreted as shadowing from bowel gas. Because of the lobulated shape of the calculus it may appear as several separate calculi on ultrasound. A coronal section may therefore be more successful in confirming a staghorn calculus than a sagittal section.

**Cystinuria**

This rare metabolic disease causes crystals of cystine to precipitate in the kidneys and be excreted in the urine (Fig. 7.17). Cystine stones form in the kidneys and may result in obstruction.

**Nephrocalcinosis**

This term is used to describe the deposition of calcium in the renal parenchyma. It is most often related to the medullary pyramids and is frequently associated with medullary sponge kidney (see below). It may also be seen in papillary necrosis and in patients with disorders of calcium metabolism, e.g. hyperparathyroidism.

**Ultrasound appearances**

Nephrocalcinosis may affect some or all of the pyramids. A regular arrangement of hyperechoic pyramids are seen which may shadow if large calcific foci are present, but not if the foci are numerous and tiny, as they are smaller than the beam width (Fig. 7.18).

Less frequently, calcification is seen in the renal cortex.

**Hyperparathyroidism**

The (normally) four parathyroid glands in the neck regulate calcium metabolism in the body. Patients with primary hyperparathyroidism (due to an adenoma or hyperplasia of one or more of the parathyroid glands) have hypercalcaemia, which makes them prone to nephrocalcinosis or stones in the kidneys.

Secondary hyperparathyroidism is associated with chronic renal failure; hypocalcaemia, which results from the chronic renal failure, induces
compensatory hyperplasia of the parathyroid glands. There is a high incidence of hyperparathyroidism secondary to chronic renal failure in patients on dialysis; scintigraphy may demonstrate the region of increased activity and ultrasound is particularly suitable for demonstrating the enlarged parathyroid, guiding a diagnostic aspiration and, if necessary, ablating the gland with ethanol as an alternative to surgical removal. Alcohol ablation is generally reserved for those patients deemed to be a poor surgical risk.

RENAL TRACT INFLAMMATION AND INFECTION

The most common urinary tract infections are bacterial in origin, with viral and fungal infections being comparatively rare. The diagnosis is made by urinalysis after the patient presents with symptoms of dysuria, haematuria and/or suprapubic or renal angle pain. The origin of the infection may be via the blood stream (haematogenous) or the urethra (ascending). Ascending infections are more common in women due to their short urethra.

Ultrasound is often requested, particularly in children, to identify any unsuspected renal pathology which may be associated with the infection, for example a duplex collecting system, pelvic kidney.

Common conditions which may be identified on ultrasound include renal cystic diseases, calculi, obstructive uropathy, reflux and anatomical variants.

The infection may be either acute or chronic. Ultrasound signs of renal infection may be absent altogether, and this is the commonest scenario as the infective episode has often been successfully treated with antibiotics by the time the ultrasound scan is performed.

The infection may be confined to the bladder, that is cystitis, in which case low-level echoes and/or hyperechoic debris may be identified, or may have progressed to the kidneys. Scarring and/or cortical thinning may be present in cases of repeated infections (see Chronic pyelonephritis below).

Pyelonephritis

Acute pyelonephritis

Acute inflammation of the kidney rarely results in any ultrasound abnormality. Occasionally the kidney may be enlarged and hypoechocic, the contrast between the kidney and the hepatic or splenic parenchyma increasing due to oedema, but the ultrasound changes are generally subtle.

The normally clear differentiation between the cortex and the medullary pyramids may become indistinct, but again may go unrecognized.
CT is useful for detecting subtle inflammatory changes within the kidney.

**Chronic pyelonephritis**

This chronic inflammatory state is usually the result of frequent previous inflammatory/infecive episodes.

The kidney may be small and often has focal scarring present. Scar tissue has the appearance of a hyperechoic, linear lesion which affects the smooth renal outline and crosses the renal cortex (Fig. 7.19A). (Do not confuse focal scarring with fetal lobulation: the latter is smooth, thin, continuous with the capsule and forms an indentation between the pyramids.)

The renal cortex is frequently thin in chronic pyelonephritis and may appear abnormally hyperechoic.

**Bladder diverticula** Repeated infections can cause the bladder wall to thicken and become trabeculated. In such cases, a bladder diverticulum may form, making treatment of subsequent infections particularly difficult. The diverticulum may harbour debris or stones and may fail to empty properly, often enlarging as the urine refluxes into it when the patient micturates (Fig. 7.19B).

**Focal pyelonephritis**

The presence of acute infection within the kidney may progress in focal regions of the renal parenchyma. This phenomenon is particularly associated with diabetics.

The ultrasonic changes are subtle, as in diffuse pyelonephritis, but it is possible to detect a slight change in echogenicity when it is surrounded by normal-looking parenchyma.

Focal pyelonephritis (sometimes called focal nephronia) may be either hypo- or hyperechoic compared with normal renal tissue. Depending on the size of the lesion, it may cause a mass effect, mimicking a renal tumour. The outline of the kidney is preserved, however (Fig. 7.19C).

The patient presents with fever and tenderness on the affected side and frequently has a history of urinary tract infection. A focal renal mass under these circumstances is highly suggestive of focal pyelonephritis and is also well demonstrated on CT. It usually responds to antibiotic therapy and resolution of the lesion can be monitored with ultrasound scans. Focal pyelonephritis can progress to form an abscess in the kidney, which can normally be treated by percutaneous drainage and antibiotics.

**Renal abscess**

A renal abscess is generally a progression of focal inflammation within the kidney (see above). The area liquefies and may enlarge to form a complex mass with distal acoustic enhancement. Low-level echoes from pus may fill the abscess cavity, giving it the appearance of increased echogenicity, but it may also be hypoechoic. The margins of the abscess may be ill-defined at first but may develop a more obvious capsule as the lesion becomes established (Fig. 7.19F), this capsule often has an easily identifiable thick rim. Flow may be seen in the inflammatory capsule with Doppler, but not in the liquefied centre.

A renal abscess may mimic a lymphoma as both may be hypoechoic on ultrasound, and both may have either single or multiple foci.

The abscess may be intrarenal, subcapsular or perirenal. Frequently, drainage under ultrasound guidance is the preferred treatment; gradual resolution of the abscess can also be monitored with ultrasound.

**Tuberculosis (TB)**

Renal TB is an uncommon finding and a difficult diagnosis to make on ultrasound. The subtle inflammatory changes which affect the calyces in the early stages are best demonstrated with CT.

In the later stages ultrasound may show calcific foci and obstructed calyces as a result of thickened inflammatory calyceal walls, calcification and debris.

TB frequently spreads to other adjacent sites in the abdomen, including the psoas muscle and gastrointestinal tract.

The differential diagnosis is xanthogranulomatous pyelonephritis, which is often indistinguishable from TB on ultrasound, or a necrotic renal neoplasm.
Figure 7.19  (A) Cortical scar tissue is demonstrated following repeated episodes of urinary tract infection.  
(B) A bladder diverticulum can be seen communicating with the bladder (arrow). The main bladder wall is trabeculated. 
(C) Focal pyelonephritis (arrow). This subtle area of altered echogenicity in the kidney slightly displaces the renal sinus 
echoes. (D) Another case of focal inflammation in an enlarged RK with an area of decreased echogenicity. (E) CT of 
case in (D) demonstrates the area with greater clarity. (F) Abscess in the LK containing low-level echoes from pus. The 
abscess capsule is irregular and thickened.
Xanthogranulomatous pyelonephritis (XGP)

This condition (which gets its name from the yellow colour of the kidney) is the result of renal obstruction by calculi in the pelvicalyceal system. Frequently, a staghorn calculus is responsible.

The kidney becomes chronically infected and the calyces enlarge and become filled with infected debris. The cortex may be eroded and thin (Fig. 7.20).

On ultrasound, these appearances are similar to TB or to a pyonephrosis. The latter is usually accompanied by a more severe, acute pain and fever whereas XGP or TB has a lower-grade, chronic pain.

CT may differentiate TB from XGP and is also more sensitive to extrarenal spread of disease.

Hydatid cysts

The Echinococcus parasite spends part of its life cycle in dogs. The larvae may be transmitted to humans through contact with dog faeces, finding their way to the lungs, liver and, less frequently, the kidneys.

The parasite forms a cyst which has a thickened wall, often with smaller, peripheral daughter cysts. Frequently the main cyst contains echoes.

The condition is rare in the UK, but may be diagnosed when small, grape-like cysts are passed in the urine.

DIFFUSE RENAL DISEASE AND RENAL FAILURE

Most diffuse medical renal conditions have non-specific appearances on ultrasound, the kidneys often appearing normal in the early stages of disease. Renal failure may be acute or chronic and its causes are numerous. If acute, an increase in overall renal size may be observed and there may be a diffuse alteration in the renal echogenicity, however this can be either hypo- or hyperechoic compared with normal. Either increased or decreased corticomedullary differentiation may also be observed (Fig. 7.21).

Although ultrasound is successful in detecting renal parenchymal disease, the acoustic changes are not specific and the cause must usually be diagnosed histologically, ultrasound being invaluable in directing the biopsy procedure.

In chronic renal failure the kidneys shrink and the cortex thins. The end-stage kidney can be quite tiny and hyperechoic and may be difficult to differentiate from the surrounding tissues (Fig. 7.21C).

Depending on the cause, either one but generally both of the kidneys are affected.

Acute tubular necrosis

Acute tubular necrosis is the result of ischaemia, which destroys the tubules of the kidney, resulting in acute renal failure. It occurs when there is a sudden decrease in renal perfusion as a result of a severely hypotensive episode, for example, cardiac arrest, massive haemorrhage, drug toxicity or septicemia.

Patients are treated temporarily by dialysis. Tubular damage is capable of regeneration once the blood supply and perfusion pressure return to normal, reversing the renal failure. If suspected, it is useful to perform a biopsy to determine the cause of renal failure, in order to plan further management.

On ultrasound the kidneys are normal in size or slightly enlarged. They may be completely normal in appearance, a not uncommon finding, although in some cases the echogenicity is altered,
sometimes having a hyperechoic cortex with increased corticomedullary differentiation.

Spectral Doppler can be normal or demonstrate increased arterial resistance with reduced or even reversed end diastolic flow.

**Glomerulonephritis**

Glomerulonephritis is an inflammatory condition which affects the glomeruli of the kidney. It may be either acute or chronic, and frequently follows prolonged infection.

Patients may present in acute renal failure, with oliguria or anuria, or with features of nephrotic syndrome such as oedema, proteinuria and hypoalbuminaemia.

Depending upon aetiology, acute renal failure may be reversible or may progress to chronic renal failure requiring dialysis.

Glomerulonephritis can be caused by numerous mechanisms:

- **Immunologic mechanisms**, for example in systemic lupus erythematosus (SLE) or acquired immune deficiency syndrome (AIDS)
- **Metabolic disorders**, for example diabetes
- **Circulatory disturbances**, for example atherosclerosis or disseminated intravascular coagulation (DIC).
As with acute tubular necrosis, the ultrasound appearances are non-specific. In the acute stages the kidneys may be slightly enlarged; changes in the echogenicity of the cortex may be observed. In the chronic stages the kidneys shrink, become hyperechoic, lose cortical thickness and have increased corticomedullary differentiation.19

**Medullary sponge kidney**

In medullary sponge kidney the distal tubules, which lie in the medullary pyramids, dilate. This may be due to a developmental anomaly but this is not certain. In itself it is usually asymptomatic and therefore rarely seen on ultrasound. However, the condition is prone to nephrocalcinosis, particularly at the outer edges of the pyramids, and stone formation (see above), which may cause pain and haematuria.

**Amyloid**

In amyloid disease, excess protein is deposited in the renal parenchyma, predominantly the cortex. This causes proteinuria and may progress to nephrotic syndrome (oedema, proteinuria and hypoalbuminaemia).

Amyloidosis can cause acute renal failure and is particularly associated with long-standing rheumatoid arthritis.

As with other diffuse renal diseases, the acute stage may cause renal enlargement and the parenchyma tends to be diffusely hyperechoic. By the time the chronic stage of disease has been reached, the kidneys become shrunken and hyperechoic, in keeping with all end-stage appearances.

**The renal biopsy**

*(See Chapter 11.*) Biopsy is rarely merited in end-stage renal failure, as the only treatment is dialysis or renal transplantation. Small kidneys, below 8 cm in length therefore, are almost never subjected to biopsy.

Histology is required when the kidney is potentially curable, such as in cases of acute disease, or when a specific knowledge of aetiology is paramount.

**RENAL VASCULAR PATHOLOGY**

**Renal artery stenosis (RAS)**

Stenosis of the renal artery is due to atherosclerotic disease in the vast majority of patients, or to fibromuscular dysplasia of the arterial wall in the younger, generally female patient. RAS may cause hypertension and may eventually cause renal failure. It is frequently bilateral, and is responsible for up to 15% of patients who require long-term dialysis. It is associated with aortic aneurysm, neurofibromatosis or can be traumatic in origin.

Stenosis generally affects the main vessel at its origin and involves the aorta (ostial) or occurs within 1 cm of its origin (non-ostial). It can occur in both native and transplanted organs. It is frequently bilateral.

**Ultrasound appearances of RAS**

If the stenosis is long-standing and/or severe, the kidney is likely to be small. Loss of renal mass is associated with a stenosis of 60% or greater.20 However, the ultrasound appearances are often normal with milder grades of RAS.

Ultrasound has traditionally had a limited role to play in the diagnosis of RAS and digital subtraction angiography is still considered the gold standard, although magnetic resonance angiography (MRA) is now regarded as the first-line imaging modality of choice. However, colour and spectral Doppler techniques have greatly enhanced the usefulness of ultrasound, particularly in experienced hands.21

At the site of a stenosis, an increase in peak systolic velocity may be found (greater than 1.5–1.8 m/s) with poststenotic turbulence. Although, it is often not technically possible confidently to examine and sample the whole main renal artery and thus make a definitive diagnosis, it nevertheless remains the best Doppler technique for diagnosis.

In addition, the intrarenal vessels may show changes on colour or power Doppler which are indicative of a downstream stenosis. Within the kidney, the perfusion may appear subjectively reduced in the number of vessels and velocity of flow and it may be necessary for the operator to use a low PRF value to detect blood flow. This is
very subjective and variable. The spectral waveforms of arteries distal to the stenosis also reflect changes which suggest a proximal stenosis; the normally fast systolic upstroke is replaced by a delayed parvus tardus pattern (Fig. 7.22), making the waveform less pulsatile with a rounded envelope.22

This type of waveform can be appreciated subjectively, but quantitative measurements may be used to support the diagnosis. The acceleration time (AT) or acceleration index (AI) is the most common; a normal AT is < 0.07s, and a normal AI > 3 m/s.

The actual value of these indices, however, does not reflect the severity of stenosis; unfortunately stenoses of < 70–80% narrowing do not normally demonstrate the parvus tardus effect (although these tend to be less clinically significant) and these spectral phenomena may be obscured altogether if the vessels are rigid and severely diseased23 or if a good collateral circulation has developed. In such cases the Doppler result is falsely negative and the operator should bear this in mind when attempting to exclude RAS.

Renal artery occlusion may occur as a result of further progression of the same disease process which causes stenosis. Doppler will confirm the lack of renal perfusion. The kidney is likely to be small as a result of gradually deteriorating arterial perfusion.

Management of RAS

Stenosis of the main renal artery is amenable to percutaneous angioplasty and/or stenting, which can effect a cure or more realistically stabilize or slow disease progression. A postangioplasty ultrasound scan can confirm vessel patency, and may play a role in monitoring the patient for disease recurrence. For those with deteriorating function, for whom percutaneous techniques have failed, renal failure will ultimately necessitate dialysis. Renal transplant is a viable option, particularly for those who have been treated in the long term.

Renal vein thrombosis

This can occur when chronic renal disease is already present or in cases of a coagulation disor-
der with increased tendency to thrombose, for example polycythaemia. It is frequently associated with nephrotic syndrome. Other associated factors include the oral contraceptive pill and the use of steroids.24

Tumour thrombus from RCC is also prone to invade the ipsilateral renal vein, and sometimes may extend into the IVC and even renal artery.

Thrombus in the renal vein, whether secondary to a malignancy or thrombocythaemia can travel up the IVC forming a source of emboli. If non-malignant, the thrombus may be successfully treated medically and the renal function can be preserved even if the vein is totally occluded.

**Ultrasound appearances**

It is often possible to see echo-poor thrombus within a dilated renal vein, running beside the renal artery in an axial section through the renal hilum (Fig. 7.9). Colour Doppler confirms absent venous flow.

Perfusion within the kidney itself is reduced and there may be a highly pulsatile arterial waveform with reversed diastolic flow (Fig. 7.23), although this is not commonly seen in the native kidney.

If the thrombus produces a total and sudden occlusion, the kidney becomes oedematous and swollen within the first 24 h. Eventually it will shrink and become hyperechoic.

Partially occluding thrombus is more difficult to diagnose as the changes in the kidney may not be apparent. However, a non-dilated renal vein with good colour Doppler displayed throughout has a high negative predictive value.

Incomplete thrombosis may still demonstrate venous flow within the kidney, although the arterial waveforms are of lower velocity than normal, with a marked reduction in the systolic peak.25 Forward diastolic flow may be preserved at this stage.

**Arteriovenous fistula**

These lesions can occur at the site of a biopsy and are recognized on colour and spectral Doppler by localized vessel enlargement with turbulent, sometimes high-velocity flow. A ‘pool’ of colour flow is often present. The vein may show a regular, pulsatile pattern and be dilated. These iatrogenic fistulae usually resolve spontaneously and are clinically insignificant. If bleeding is a clinical problem and is ongoing, recurrent and/or severe then embolization is the treatment of choice.

**Ultrasound in dialysis**

Patients with chronic renal failure may undergo either haemodialysis (in which a subcutaneous arteriovenous shunt is created, often in the wrist) or continuous ambulatory peritoneal dialysis (CAPD), in which a catheter is inserted through the abdominal wall. Ultrasound may be used to assess the patency of the shunt or catheter, and may identify localized areas of infection along the CAPD tract which can be drained under ultrasound guidance if necessary.
Ultrasound may also be used to diagnose acquired cystic kidney disease in long-term dialysis patients (see above).

RENAL TRAUMA

The severity of trauma to the kidney may vary significantly and therefore a range of findings can be seen with ultrasound. A direct injury can rupture the kidney. This will result in blood and/or urine leaking out into the perinephric space. The nature of the fluid can be determined by ultrasound guided aspiration. A large urinoma or haematoma may be drained percutaneously. The main renal vessels may also be damaged, causing lack of perfusion (see Chapter 10).

Causes of haematuria are listed in Table 7.3.

RENAL TRANSPLANTS

Although there are a number of treatment choices for patients with renal failure including peritoneal and haemodialysis, undoubtedly the treatment of choice is renal transplantation.

From the very early days of Carrel’s experimental attempts at transplantation in the 1900s (resulting in the Nobel Prize of 1912), to the un-immunosuppressed allografting of the 1950s, the more successful and encouraging outcome of twin to twin transplants, a better understanding of tissue rejection and the introduction of azathioprine and steroid in 1963, and more specifically ciclosporin A by Calne in the 1970s, have all contributed immensely to slow but positive progress in this field. Improvements in surgical technique, newer, more effective and less toxic anti-rejection therapy, the routine use of ultrasound in the 1970s and then Doppler a decade later, and the development of interventional radiology have all combined to make this the successful operation and clinical outcome we now take so much for granted.

Although many different imaging modalities are available, ultrasound is the single most useful investigation in the postoperative monitoring of the transplant. Amongst its many roles, it is sensitive to early PCS dilatation, can be used to guide biopsy procedures and to guide the drainage of fluid collections and placement of nephrostomy tubes.

An early, baseline scan is an essential part of the postoperative management, and serial scans are to be recommended.

Normal anatomy

Most renal transplants are heterotopic, that is they are placed in addition to the diseased, native kidneys, which remain in situ.

The transplanted organ is usually positioned in the iliac fossa anterior to the psoas and iliacus muscles. It lies outside the peritoneal cavity.

Within the UK the majority of transplanted kidneys are cadaveric, and are harvested with their main vessels intact, which are then anastomosed to the recipient iliac artery and vein.

Normal ultrasound appearances

The transplanted kidney is particularly amenable to ultrasonic investigation; its position relatively near to the skin surface allows a high frequency transducer (5 MHz) to be used for better detail. For visualization of the vasculature or origins of the transplant vessels a 3.5–4.0MHz probe is normally required.

The ultrasonic appearances of the transplant kidney are the same as expected for a native kidney, allowing for the higher resolution. The transplant kidney should be assessed in the same way as the native organ, that is in two planes. Features to be observed include:

<table>
<thead>
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<th>Table 7.3 Causes of haematuria</th>
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<tbody>
<tr>
<td>- Urinary tract infection</td>
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<td>- Stones</td>
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<td>- Neoplasm (renal cell or transitional cell carcinoma in the kidney, ureter or bladder)</td>
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<td>- Prostatic pathology (benign hypertrophy or carcinoma)</td>
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<td>- Renal cyst haemorrhage</td>
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<tr>
<td>- Papillary necrosis</td>
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<tr>
<td>- Glomerulonephritis</td>
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<td>- Trauma</td>
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<td>- Tuberculosis</td>
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<td>- Renal infarct</td>
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● **Morphological appearances** This should include an assessment of the relative echogenicity of the cortex, medulla and renal sinus and corticomedullary differentiation. Focal or diffuse changes in echogenicity may be observed, but are non-specific findings associated with inflammation, infection or infarction.

● **Size** Changes in renal size may be significant in transplanted organs; it is useful to calculate the renal volume, circumference or area, rather than just relying on the length.

● **PCS dilatation** Even mild PCS dilatation may be significant, as it may represent an early obstructive process. The bladder should be empty before assessing the PCS, to eliminate physiological dilatation. Any degree of hydronephrosis should be correlated with the clinical findings and biochemistry;

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(Figure 7.24) (A) Perfusion within the transplanted kidney is easily displayed. A higher frequency may be used, as the kidney is usually superficially situated in the iliac fossa. (B) Same kidney as (A). The Doppler sensitivity has been increased to demonstrate tiny arcuate vessels at the periphery of the kidney. (C) The increased sensitivity of power Doppler is valuable in demonstrating perfusion in the transplanted kidney. (D) Normal spectrum from the interlobar renal artery, demonstrating good end-diastolic flow (EDF) (low resistance) with a vertical systolic upstroke.

(Continued)
Figure 7.24 cont’d (E) i, large vessels at the hilum may mimic dilatation; ii, colour Doppler demonstrates this is the main renal vein.
hydronephrosis in isolation is not a reason for nephrostomy.

- **Vascular anatomy** The main transplant artery and vein are anastomosed to the recipient’s external iliac artery and vein respectively and can normally be visualized throughout their length. Overall global perfusion can be assessed with colour Doppler and the smaller vessels at the periphery of the kidney (Fig. 7.24) should be discernible. The normal spectral Doppler waveform is a low-resistance waveform with continuous forward end diastolic flow.

- **Perirenal fluid** A small amount of free fluid is not unusual postoperatively. This usually resolves spontaneously. Fluid collections around the kidney are a common complication. They may resolve on further scanning; drainage is only performed for good clinical reasons (see below).

### Postoperative complications

Ultrasound has an essential role in assessing the transplant and makes a significant contribution towards graft survival through the early recognition of postoperative complications. Complications are varied and include acute rejection, ureteric obstruction, vascular occlusions, perirenal fluid collections, renal dysfunction (of various aetiologies) and infection. Drug toxicity from the immunosuppressive therapy can also compromise graft function. Finally, in the long term, the original disease, for which transplantation was performed, may recur.

Complications can be divided into three main categories: immediate postoperative complications, primary and secondary renal dysfunction.

- **Immediate**
  - non-perfusion, normally the result of an occluded or twisted renal artery; correction is surgical
  - haematoma

- **Primary dysfunction**
  - non-perfusion (arterial occlusion), total or lobar
  - acute tubular necrosis
  - renal vein thrombosis
  - obstruction
  - acute or accelerated acute rejection

- **Secondary dysfunction**
  - acute rejection
  - ciclosporin nephrotoxicity
  - acute tubular necrosis
  - obstruction
  - RAS
  - postbiopsy fistula
  - infection
  - chronic rejection.

### Renal transplant dilatation

A mild degree of PCS dilatation is normal postoperatively, due to oedema at the site of the vesicoureteric anastomosis. This phenomenon is usually transient, and serial scans in conjunction with biochemistry (urea, creatinine) is normally all that is required. More severe dilatation may be indicative of obstruction, especially if the individual calyces are also dilated. A trend of increasing dilatation is a poor prognostic indicator. A ratio between the area of the PCS and the renal outline in two planes, the *dilatation index*, has been found to predict obstruction and differentiate obstructive from non-obstructive dilatation

The degree of dilatation of the PCS correlates well with the severity of obstruction.

Obstruction of the transplant kidney may be due to an ischaemic related stricture at the vesicoureteric anastomosis, or may be the result of a blood clot or infected debris in the ureter. Haematoma or debris within the PCS may appear echogenic but requires to be differentiated from fungal balls.

Percutaneous nephrostomy is the method of choice to relieve obstruction.

### Rejection

This can be acute or chronic. Acute rejection may be responsible for delayed graft function whereas chronic rejection is a gradual deterioration in renal function that may begin any time after 3 months of transplantation. Ongoing episodes of acute rejection should raise the possibility of non-compliance with therapy. Acute rejection cannot be differentiated on ultrasound from other causes of delayed function, particularly acute tubular necrosis, and therefore biopsy is invariably necessary.
Pathologically, rejection can be either cellular (98%) or vascular (now accounting for only 2% of cases). Improved immunosuppressive therapy has greatly reduced the problems of rejection.

Ultrasound appearances of rejection

These are varied and non-specific. In the majority of cases the kidney appears normal; however, greyscale findings include enlargement due to oedema (this change is subtle in the early stages and not a reliable ultrasonic indicator), increased corticomedullary differentiation with prominent pyramids, infundibular thickening (thickening of the PCS walls) and decreased fat in the renal sinus (Fig. 7.26). These findings are subjective, non-specific and limited in the diagnosis of rejection.

In chronic rejection there may be an overall increase in the echogenicity of the kidney with reduced corticomedullary differentiation. Eventually the kidney will shrink. The Doppler resistance indices are increased in rejection but, again, this finding is non-specific (see Table 7.4) (Fig. 7.26B). In general, the higher the RI or PI, the more likely is the diagnosis of acute rejection.

The cause of renal dysfunction is established by biopsy.

Fluid collections associated with transplantation

Up to 50% of renal transplants will demonstrate perirenal fluid. The size of the collection should be monitored with ultrasound, as significant growth may require intervention.

While it is not possible to classify the collection on the ultrasound appearances alone, the clinical picture, including the time interval following transplantation, can often be helpful.

- **Lymphocele** The commonest perirenal fluid collection, lymphoceles usually occur several weeks or months after the transplant. They may resolve spontaneously but occasionally require percutaneous drainage if large. They may compress the kidney, causing an increase in vascular resistance on spectral Doppler (Fig. 7.27). The collection is anechoic but may contain loculations or septa. If treated, then
surgical laparoscopic marsupialization is the treatment of choice.

- **Haematoma** An immediate postoperative phenomenon which usually resolves spontaneously. If the haematoma is due to an anastomotic leak at the main artery or vein, it can compress the renal vein, causing thrombosis in rare cases. On ultrasound, the haematoma can appear hyperechoic and ill-defined in the early stages. As it resolves and liquefies, the margins become more defined and the centre becomes anechoic. Hyperechoic blood clots and strands of fibrin may be seen within the haematoma.

- **Urinoma** This occurs as a result of an anastomotic leak in the ureter. Urinomas are uncommon, but may progress to urinary ascites. They occur early following the surgical procedure, unlike lymphoceles.

- **Abscess** If any of the above fluid collections becomes infected, this leads to an abscess. Hyperechoic debris can be seen in the collection and this may be treated with percutaneous drainage.

**Vascular complications**

**Vascular occlusion**

Colour and spectral Doppler are essential for the diagnosis of postoperative vascular complications. Non-perfusion may be total or lobar (Fig. 7.28). Focal areas of hypoperfusion may be due to oedema in focal infection, arteriovenous fistula or severing of an accessory artery during harvesting of the transplant or at the time of implantation. Total vascular occlusion is rare, but occurs early. Patients may be asymptomatic and non-perfusion of the transplant may be inadvertently seen on either a routine scan or isotope study. Graft nephrectomy is the most likely outcome. Conversely, the appearance of good renal perfusion throughout the kidney on colour or power Doppler does not necessarily indicate normal vascularity and severe...
Figure 7.28  (A) Lack of perfusion in the upper pole due to rejection. (B) High-velocity jet at the site of a magnetic resonance angiography stenosis. This patient had had increasing, badly controlled hypertension since his transplant. (C) The same kidney, demonstrating turbulence distal to the site of stenosis.
vascular rejection or acute tubular necrosis can be present under such circumstances.\textsuperscript{34}

Vascular complications can include arterial stenosis or thrombosis, venous stenosis or thrombosis, pseudoaneurysms and arteriovenous fistulae.\textsuperscript{33}

\textbf{Renal artery stenosis}

This generally occurs at the site of the anastomosis close to the iliac artery but can also occur along the length of the artery or even affect the intrarenal branches. The patient may present with severe, difficult-to-control hypertension, graft dysfunction, or both. Alternatively the patient's renal function may deteriorate following angiotensin-converting enzyme inhibitor therapy and this is also an indication of a possible underlying RAS. Careful Doppler examination is now the accepted first-line investigation in the diagnosis of RAS.

In most cases it is possible to trace the artery back to its anastomosis with the iliac artery, using colour Doppler. If the site of the stenosis is identified, spectral Doppler will demonstrate an increase in peak systolic velocity at the lesion, followed by poststenotic turbulence (Fig. 7.28, B,C). This can be difficult to pinpoint with MRA, especially if bowel is overlying the vessel.

A delayed systolic rise (the \textit{parvus tardus} waveform) can be identified in the intrarenal spectral Doppler waveforms, as for the native kidney (see above). The diagnosis however is primarily made on the peak systolic velocity within the renal artery. A value of $< 2.5 \text{ m/s}$ is normal while $> 2.5 \text{ m/s}$ constitutes RAS. If the stenosis is severe, it may be difficult to identify colour flow in the kidney and the waveform may be reduced in velocity with a tiny, damped trace in the main vessel.

A stenosis affecting an interlobar artery may result in focal, segmental changes in the kidney.

In general, contrast angiography is only used to grade and treat stenoses after a positive ultrasound scan, or when a high index of clinical suspicion persists, despite a negative ultrasound.\textsuperscript{33}

\textbf{Renal vein thrombosis}

The occlusion may be partial or complete and the venous Doppler spectrum may therefore be absent (Fig. 7.29).

If venous thrombosis is partial, the arterial spectral waveform becomes very pulsatile, with reverse end diastolic flow; in the clinical setting of an oliguric patient with a tender graft in the early postoperative period, this is almost pathognomonic for RVT.

During the early stages, when thrombosis is incomplete, venous flow may be seen in the kidney, but the artery is of reduced velocity.\textsuperscript{35}

The ultrasound findings of renal vein thrombosis may be indistinguishable from severe rejection; however venous flow is generally unaffected in the latter.

Thrombosis is rare, occurring typically in the immediate postoperative period.\textsuperscript{33} It may be associated with a faulty venous anastomosis, secondary to compression of the vein, for example by a large, perivenous collection, or the patient may have an increased thrombotic tendency for a number of reasons.

\textbf{Pseudoaneurysms and arteriovenous fistulae}

These may sometimes form as a result of vascular damage during biopsy procedures. They are usually not significant and tend to resolve spontaneously (Fig. 7.30A).

An arteriovenous fistula shows an irregular knot of vessels on colour or power Doppler with a pulsatile venous waveform and high peak and end diastolic velocity in the feeding artery. A large draining vein may also be seen.

A pseudoaneurysm may appear cystic on the grey-scale image, but will demonstrate filling on colour Doppler with a pulsatile venous waveform (Fig. 7.30B, C). Careful biopsy technique helps to avoid such lesions (see Chapter 11).

\textbf{Infection}

This is characterized by swelling of the uroepithelium, especially with fungal infections. Fungal balls may be visible as relatively hyperechoic structures within the PCS (Fig. 7.31).

\textbf{Acute tubular necrosis}

This may demonstrate prominent medullary pyramids on ultrasound, with low end diastolic flow. Reverse end diastolic flow is uncommon but recognized. A biopsy is required for confirmation.
Figure 7.29  Renal vein thrombosis. (A) Poor transplant perfusion, with scanty demonstration of arterial flow. (B) The same vessels demonstrate reversal of flow at the end of the cardiac cycle. (C) The bidirectional flow is demonstrated on the spectral trace.
Ciclosporin nephrotoxicity

The toxic nature of the immunosuppressive regime requires the dose to be very carefully adjusted. There may be increased Doppler resistance, as for acute tubular necrosis, but normally indices remain unaffected. Histology is required to confirm the diagnosis, or a clinical improvement following reduction or withdrawal of the immunosuppressive agent.

Renal transplant dysfunction and Doppler correlation

Doppler correlation with the different types of renal graft dysfunction is not possible. However, by taking the clinical picture into account it is possible to differentiate these situations. (Table 7.4).
References


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Chapter 8

The retroperitoneum and gastrointestinal tract

NORMAL ANATOMY

The peritoneum is the large sheet of serous membrane which lines the abdominal cavity and surrounds the organs. The peritoneum has several ‘extensions’ which bind the organs together: the mesentery, which loosely anchors the small bowel ensuring it does not twist, the transverse mesocolon, which attaches the transverse colon to the posterior abdominal wall, and the greater and lesser omentum. These projections coat the viscera and form pouches, or sacs, within the peritoneal cavity in which dependent fluid can collect.

The retroperitoneal space contains the kidneys and ureters, adrenal glands, pancreas and duodenal loop, great vessels and the ascending and descending portions of the large bowel, including the caecum (Fig. 8.1).

THE ABDOMINAL AORTA

The abdominal aorta can be visualized proximally in the midline, posterior to the left lobe of the liver. The coeliac axis and superior mesenteric artery (SMA) are easily demonstrated in longitudinal section (LS), arising from its anterior aspect (Fig. 8.2).

In transverse section (TS) the coeliac axis branches, the main hepatic and splenic arteries, may be better appreciated. Just below this level, the origin of the renal arteries is seen.

The distal abdominal aorta, which runs more anteriorly, and bifurcation are frequently obscured by bowel gas in sagittal section. A coronal
approach from the patient’s left side often over-
comes this problem (Fig. 8.2D) and is also useful
in displaying the origin of the renal arteries.

The aorta often becomes ectatic and tortuous
with age, and it is not unusual to detect consid-
erable calcification of the walls (Fig. 8.2G).

Aortic aneurysm

The most frequent referral for aortic scanning is to
establish or monitor the presence of an aneurysm.
The incidence of aortic aneurysm increases with
age and patients may present with a pulsatile, mid
abdominal mass. Patients most at risk are men aged
60 or over, with an incidence of up to 9% after age
75. The risk of aneurysm rupture increases with
diameter, increasing dramatically when it reaches
6 cm, with a 1-year mortality of 50%.1

Figure 8.1  (A) Axial and (B) sagittal sections through
the abdomen, showing the relationship of the abdominal
viscera to the peritoneum (red).

Figure 8.2  (A) Longitudinal section (LS) through the
abdominal aorta, demonstrating the coeliac axis
(arrowhead) and the superior mesenteric artery (SMA)
(arrow). The splenic vein (SV) and body of pancreas are
seen anterior to the SMA. (B) Transverse section (TS)
through the proximal abdominal aorta. The coeliac axis,
(C), divides into the hepatic and splenic arteries.

(Continued)
Figure 8.2 cont’d (C) TS slightly distal to (B). The right renal artery (RRA) is seen arising from the lateral aspect of the aorta; the left renal vein (LRV) passes anteriorly to drain into the inferior vena cava (IVC). (D) A coronal plane, from the patient’s left side, demonstrates the aortic bifurcation. (E) Coronal section of the aorta at the level of the renal arteries (arrows). (F) The Doppler spectrum from the aorta demonstrates a highly pulsatile waveform with reversed flow in early diastole. (G) The aorta of an elderly patient contains calcification in the walls, which causes acoustic shadowing.
For this reason, aortic aneurysms are monitored, and a graft placed within the vessel in aneurysms over 5 cm which are increasing in size. Postoperative complications of grafts, such as infection or pseudoaneurysm, are usually monitored with CT or MRI.

Discussions of the benefits of screening programmes for selected populations are ongoing. However, there is some evidence that, despite the reduction of mortality due to aneurysm rupture, overall mortality in men over 65 remains unaffected by screening, and it has not been widely adopted into patient management.

Most aneurysms are associated with atherosclerosis, which weakens the media of the wall, causing the vessel to dilate and eventually rupture.

The aneurysm may be fusiform or saccular (Fig. 8.3). Blood flow within it is turbulent, and the slow-flowing blood at the edges of the vessel tends to thrombose.

Surgery is always complicated by the involvement of the renal arteries. Fortunately, the vast majority of aneurysms are infrarenal, but it can be difficult to determine the relationship of the aneurysm to the renal artery origins on ultrasound, and CT is helpful in such cases. The use of angiography can be beneficial in this respect; however its disadvantage is that, unlike ultrasound, it displays only the lumen of the vessel and can underestimate the pathology present.

Occasionally the aneurysm affects the bifurcation and common iliac arteries, which should be examined during the scan as far as possible.

The true maximum diameter of the aneurysm should be ascertained in TS and LS. A true anteroposterior diameter is most accurately measured in LS, by ensuring the calipers lie in a plane perpendicular to the vessel axis at its widest part. To measure the lateral diameter in TS, care must be taken to keep the angle of the transducer perpendicular to the vessel axis to ensure an accurate and reproducible measurement. The ability of ultrasound to locate the

Figure 8.3  (A) LS demonstrating an aneurysm of the lower abdominal aorta. (B) TS through the aneurysm containing thrombus with an eccentric lumen demonstrating turbulent flow. (C) LS demonstrating flow around the thrombus in the aneurysm.
correct plane, regardless of vessel tortuosity, is a distinct advantage over CT, which may over- or underestimate the size of the aneurysm in an axial plane.

Complications of aortic aneurysm

Dissection of the aneurysm, in which the intima becomes detached, is uncommon in the abdomen. Ultrasound may visualize the intimal flap and the false lumen created between the media and intima often contains slower, more turbulent or even reversed flow. Layers of thrombus may mimic a dissection, and colour flow Doppler is particularly useful in such cases.

Leakage of an aneurysm may cause retroperitoneal haematoma, but CT is usually more reliable in detecting leaks than ultrasound.

Rupture of an aortic aneurysm is not unknown in the ultrasound department or emergency department, and is accompanied by abdominal pain and severe hypotension. It is associated with a high mortality rate and is a surgical emergency.

Involvement of the renal arteries may cause renal artery thrombosis and subsequently small kidney(s). Always check the kidneys at the time of scanning to ensure they are of normal size and appearance.

THE INFERIOR VENA CAVA (IVC)

Ultrasound is highly successful in demonstrating the proximal IVC, by using the liver as an acoustic window, especially if the patient is turned right anterior oblique. The distal IVC may be obscured by overlying bowel gas and, unlike the aorta, is also susceptible to compression, making visualization difficult in some cases.

The normal IVC has thinner walls and a more flattened profile than the aorta, and its lumen alters with changing abdominal pressure; for example, during respiration the lumen decreases on inspiration, or with the Valsalva manoeuvre (Fig. 8.4). Its course becomes slightly anterior as it passes through the diaphragm, unlike the aorta which travels posteriorly at this point.

The main renal veins may be seen in TS, entering the IVC just below the level of the pancreas (Fig. 8.2).

Haemodynamically, the blood flow spectrum from the IVC alters according to the distance of the sample volume from the right atrium (Fig. 8.4 F, G). The blood flow through the IVC and proximal hepatic veins is pulsatile, with reverse flow during right atrial systole. Pulsatility reduces in the distal IVC.
The most common anomaly of the IVC is that of duplication. However this is infrequently picked up on ultrasound and is best demonstrated with CT or MRI. Transposition of the IVC may be seen in situs inversus.

Pathology of the IVC

Thrombus in the IVC may be due to benign causes, or the result of tumour. It is not usually possible to tell the difference on grey-scale appearances alone, but vascularity may be demonstrated on power or colour Doppler within tumour thrombus, and the clinical history is helpful. Tumour thrombus invades the renal vein and

Figure 8.4  (A) LS through the IVC. The RRA is seen passing underneath the IVC. (B) TS through the IVC, demonstrating the difference in profile during the Valsalva manoeuvre (left) compared with normal expiration (right). (C) IVC at the level of the confluence of the hepatic veins, just beneath the diaphragm. (D) Power Doppler of the IVC overcomes problems associated with its perpendicular angle to the transducer. Portal vein (PV) anterior to IVC. (E) The right renal vein (RRV) (in red) is seen draining into the IVC on colour Doppler.
enters the IVC in around 10% of renal carcinoma cases. Tumour thrombus from hepatic or adrenal masses can also invade the IVC.

Coagulation disorders, which cause Budd–Chiari syndrome (see Chapter 4) predominantly affect the hepatic veins, but may also involve the IVC (Fig. 8.5).

Patients may require the insertion of a caval filter, which is performed under X-ray guidance, but may be monitored for patency using ultrasound with Doppler.

Dilatation of the IVC is a finding commonly associated with congestive heart failure, and is frequently accompanied by hepatic vein dilatation.

Compression of the IVC by large masses is not uncommon. This may be due to retroperitoneal masses, such as a large lymph node, or liver masses such as tumour or caudate lobe hypertrophy. Colour or power Doppler is particularly useful in confirming patency of the vessel and differentiating extrinsic compression from invasion. Insertion of metallic stents may be performed under angiographic control to maintain the vessel patency, particularly if the compression is due to inoperable hepatic metastasis (Fig. 8.6).

Tumours of the IVC are rare. Leiomyosarcoma is a primary IVC tumour, appearing as a hyper-echoic mass in the lumen of the vein. This causes partial or complete obstruction of the IVC, resulting in Budd–Chiari syndrome. In partial occlusion, the hepatic veins and proximal IVC may be considerably dilated. Resection of the tumour, with repair of the IVC, is possible provided the adjacent liver is not invaded.

The normal adrenal glands can be seen on ultrasound in the vast majority of patients, if you know where and how to look. Each adrenal gland is constructed with a central fold or ridge, which points anteromedially, from which extend two thin ‘wings’ of tissue—a medial and a lateral wing (Fig. 8.7).

The ultrasound appearances are therefore of a shape in LS, or a thin, linear structure as the transducer is moved medially towards the central ridge.

The wings of the gland appear hypoechoic and are no more than 2 mm in thickness.

For the right adrenal, use the liver as an acoustic window. Scan the upper pole of the kidney intercostally through the liver, and angle slightly medially to the kidney, where the gland can be located between the liver and the diaphragmatic crus (Fig. 8.7A). Continue angling slightly medially towards the IVC and the central ridge of the gland is seen behind the IVC (Fig. 8.7B).

For the left gland the spleen must be used as a window. To avoid overlying bowel this is best achieved with the patient supine, using a coronal section. When the upper pole of the left kidney is located through the spleen, the left adrenal can be seen in the small triangular area between the spleen, kidney and diaphragmatic crus (Fig. 8.7D).
Figure 8.5  (A) Tumour thrombus from a left renal carcinoma completely occludes the IVC (arrows). Liver metastases are also present. (B) Advanced renal carcinoma. The IVC is full of tumour. (A hyperechoic liver metastasis is also seen on the left.) (C) TS through the IVC containing thrombus. This is the result of proximal compression of the IVC by a large liver abscess. (D) Tumour thrombus from a renal carcinoma has spread up the IVC and invaded the right hepatic vein (RHV), causing a partial Budd–Chiari effect.
Adenoma

Small (less than 3 cm) solid adrenal nodules are a common, incidental finding in non-symptomatic patients (Fig. 8.8A).

Benign, non-hyperfunctioning adenomas account for the majority of adrenal nodules, and are of no clinical significance. Their incidence increases with age and they are present in around 2% of adult autopsies.

Small nodules in asymptomatic patients generally require no further action, but endocrine function may be evaluated to rule out a functioning mass.

A hyperfunctioning adenoma (a determination made by evaluation of the endocrine function), although an essentially benign mass, usually requires surgical resection.

As a solitary abdominal finding in a patient with no relevant clinical history, it is generally safe to assume a small adrenal nodule requires no further action. However, because it is not possible to distinguish benign, incidental nodules from other forms of more serious pathology, incidental nodules of greater than 4 cm should be investigated further to confirm their benign nature. Non-functioning adenomas will remain stable in size on ultrasound follow-up.

Metastasis

The adrenal glands are a common site for metastases, particularly from lung, breast and bowel cancer. Although frequently accompanied by liver metastases, they may be present in the absence of any other obvious abdominal deposits, and therefore the adrenal glands should routinely be examined when staging malignant disease.

The adrenal glands are also commonly involved in non-Hodgkin’s lymphoma.

Like adenomas, they are often small, well-defined and hypoechoic on ultrasound (Fig. 8.8B). It is not possible to differentiate between benign adenoma and metastasis on the ultrasound appearances alone, but a small adrenal mass in the absence of a known primary carcinoma is likely to be benign, and will remain stable on follow-up. A solitary adrenal mass in the presence of known carcinoma requires biopsy for diagnosis.

Adrenal cysts

Simple cysts are uncommon in the adrenal gland, but are easily differentiated from solid lesions with ultrasound. Some cysts may be the sequelae of previous haemorrhage, but most are simple, epithelial cysts.
Myelolipoma

The adrenal myelolipoma is found, uncommonly, as an incidental mass. It is highly echogenic and well-defined, due to its fatty content (Fig. 8.8C). These are relatively rare, require no further management, and are endocrinologically non-functioning.

Phaeochromocytoma

The phaeochromocytoma is uncommon, but may be found in up to 1% of patients with hypertension. It is a tumour arising in the chromaffin cells of the adrenal medulla (most commonly) or in autonomic nervous tissue. It may be bilateral and appears solid on ultrasound, although larger masses may have
Figure 8.8  (A) Typical, incidental, non-functioning adrenal adenoma <2 cm in size. (B) TS through the right adrenal showing a small, 2.4 cm metastasis from a primary lung carcinoma. No liver metastases were present at the time. The lesion showed a reduction in size following chemotherapy. (C) Left adrenal myelolipoma—an incidental finding which was confirmed on CT and remained stable over a period of 3 years. Its high fatty content makes it hyperechoic. (D) Adrenal phaeochromocytoma between the upper pole of the RK and the IVC. (E) LS through the midline, between the IVC and aorta, demonstrating an extra-adrenal phaeochromocytoma. (The differential diagnosis was of lymphadenopathy.)
areas of necrosis within them. Most are benign, but 5–10% are malignant. It presents on a background of episodic, severe hypertension and the urine contains catecholamines. (Although this is also a feature of adrenal neuroblastoma, the latter is predominantly a childhood tumour.) These lesions should be treated with great care—vigorous palpation may precipitate a severe hypertensive episode and biopsy should therefore be avoided.

Although most phaeochromocytomas arise in the adrenal glands, and are therefore demonstrable on ultrasound, those arising in the sympathetic chain may be obscured by bowel gas and are not possible to exclude on ultrasound (Fig. 8.8D, E). If there remains biochemical evidence of phaeochromocytoma in the presence of normal adrenal glands, a Meta-Iodobenzylguanidine isotope scan will demonstrate increased activity in a phaeochromocytoma and CT scan can then be targeted to the appropriate area.

Phaeochromocytomas are also associated with von Hippel–Lindau syndrome.

Adrenal carcinoma

Primary adrenal carcinomas are rare in the adult. They are commonly endocrinologically inactive in adults, and therefore tend to present late when they are quite large. They may invade the IVC and metastasize to the liver. Surgical removal of tumours in the absence of liver metastases has a good prognosis9 and, in patients with metastases, radiofrequency ablation of the adrenal mass may have some benefit in prolonging survival.10

GASTROINTESTINAL (GI) TRACT

Contrast radiographic investigations, including CT, are generally accepted as the methods of choice for investigating diseases of the GI tract. Although ultrasound is not considered a primary tool in the investigation of bowel lesions, as the gas-filled lumen makes visualization difficult in many cases, ultrasound is remarkably successful in diagnosing GI tract pathology in the hands of an experienced operator. GI tract ultrasound can be time-consuming, but a wealth of information can be obtained with a high-frequency linear probe in a symptomatic patient. Considerable diagnostic benefit has been shown for careful, targeted, percutaneous ultrasound of the large and small GI tract using high-frequency transducers.11

It is important to be aware of the variable ultrasound appearances of normal bowel, as it may be responsible for mimicking other pathology. Normal bowel is frequently difficult to examine on ultrasound as the gas-filled lumen reflects the sound, requiring careful compression techniques. Abnormal bowel is particularly accessible to ultrasound, however. A fluid-filled lumen also make easy the demonstration of valvulae conniventes of the small bowel and haustra of the large colon.

Oesophagus and stomach

The oesophagus is not usually accessible to percutaneous ultrasound; however, the lower end can be demonstrated as it passes through the diaphragm in the midline, just anterior to the aorta (Fig. 8.9A). Its normal appearances should not be confused with a mass. Occasionally, ultrasound demonstrates the thickened wall associated with an oesophageal carcinoma involving the lower oesophagus (Fig. 8.9B).

Endoscopic ultrasound (EUS), with its high frequency and proximity to the relevant structures, is able to demonstrate the layers of the gut wall, and to demonstrate pathology and accurately stage malignant disease in both the oesophagus and stomach, and also to guide invasive procedures.12,13

Barium X-ray studies are still the first-line investigation of choice for many potential GI tract conditions; however, endoscopy is regarded as the gold standard for investigating the lining of the stomach and duodenum and can be combined with biopsy when necessary. Although percutaneous ultrasound has had modest success in revealing stomach masses if the stomach is filled with water,14 it can never replace endoscopy. However, if such lesions are discovered, this helps to direct subsequent radiological management (Fig. 8.10).

Appendix

Acute appendicitis is a common diagnosis on admission to the casualty department with right lower abdominal pain. However around 15–25% of
patients who undergo laparotomy turn out to have normal appendices.

The use of ultrasound in the investigation of acute abdominal pain is well established and can increase the reliability of the diagnosis of acute appendicitis when performed by an experienced operator.\textsuperscript{15}

The normal appendix is difficult to locate. A high-frequency (7 MHz or more) linear or curved array probe is useful. Gentle, graduated compression may move overlying bowel. Raising the patient’s left side may encourage bowel gas to move away from the area of interest. The normal appendix is compressible by gentle transducer pressure, which is usually well tolerated by the patient.

The ultrasound features of acute appendicitis include an enlarged, usually hypoechoic appendix greater than 6 mm in diameter. The inflamed appendix is non-compressible. Attempted compression of the acutely inflamed appendix obviously requires great care from the operator. Compression must be very slow and the release of compression must be equally as gentle. These features have a high sensitivity and specificity for acute appendicitis (74% and 94% respectively).\textsuperscript{15} Acute appendicitis often demonstrates hypervascularity on power Doppler.

Other causes for right iliac fossa masses in patients presenting with pain include inflamed diverticula in patients with diverticulitis.\textsuperscript{16}

Perforation of the appendix may result in a demonstrable periappendical fluid collection, or free fluid plus or minus dilated loops of non-peristaltic small bowel. The presence of an ill-defined fluid mass in the right iliac fossa of a symptomatic patient is highly suggestive of acute appendicitis with perforation (Fig. 8.11). This may become infected, leading to peritonitis.

Occasionally, a hyper-reflective appendicolith may be seen in the blind end of the inflamed appendix, casting an acoustic shadow.

**Mesenteric ischaemia**

Mesenteric ischaemia is a potentially lethal condition, associated with atherosclerosis of the mesenteric vessels, which can cause bowel necrosis and death if left untreated. It is a difficult diagnosis to make on clinical grounds because the symptoms are varied and non-specific, including acute abdominal pain following meals, diarrhoea and
subsequent weight loss. Patients frequently undergo a number of comparatively invasive investigations before a diagnosis is reached, and this delay increases the mortality and morbidity of the condition.\(^{17,18}\)

Treatment involves restoring the blood flow via angioplasty or surgery and, if necessary, resecting segments of necrosed bowel.

Atherosclerosis may be demonstrated in the SMA in a number of cases. Signs of occlusion or stenosis of the SMA may be identified with colour or power Doppler\(^{19}\) as a filling defect within the lumen of the vessel. However, significant stenoses have been diagnosed with Doppler in a relatively high percentage (18\%) of the asymptomatic, elderly population. The finding of a stenosis on ultrasound, therefore, is an indication for further imaging in symptomatic patients, rather than an absolute indicator of mesenteric ischaemia.\(^{20}\)

In a normal patient, the response of the SMA to food can be demonstrated as an increase in end diastolic flow velocities (Fig. 8.12).

Mesenteric compromise has also been associated with an abnormal postprandial response; Doppler waveforms of the SMA have decreased peak systolic and end diastolic velocities after food.\(^{21}\)

None of these ultrasound signs and appearances are specific for mesenteric ischaemia; the mesentery is supplied by three arteries which cannot all be evaluated with ultrasound and, in addition, numerous other conditions are associated with altered SMA Doppler resistance, including inflam-
Inflammatory bowel conditions, haemorrhage, elevation of venous pressure and cirrhosis.

**Inflammatory bowel conditions**

Both barium studies and ultrasound have a useful role to play in the management of patients with inflammatory bowel disease. Diagnosis is generally made with conventional barium X-ray studies, while ultrasound may be used to monitor disease and identify extraluminal complications of the disease.22

Crohn’s disease is a common cause of inflammation affecting the small bowel and particularly the terminal ileum. It usually presents with pain, diarrhoea and weight loss. The terminal ileum/ileocaecal junction is involved in the majority of cases, and thickened, hypoechoic bowel wall can often be demonstrated in this area.16 Ultrasound may be used to identify complications of Crohn’s disease, screen patients at risk, and monitor patients for recurrence of disease following surgery.23

Crohn’s disease affects the entire thickness of the bowel wall, and one of the common complications is that of intramural abscesses. These can sometimes be seen within the thickened wall as gas-containing, highly echogenic areas. When large, they may perforate, resulting in an ill-defined collection of pus, which may be drained percutaneously (Fig. 8.13). Fistulae are another complication of Crohn’s, and are easier to demonstrate with contrast radiography.

Ulcerative colitis affects the mucosa, rather than the whole wall. On ultrasound it produces a thickened, stratified hypoechoic wall, unlike Crohn’s, in which the entire thickness of the wall is affected.

A wall thickness greater than 3 mm is considered abnormal. Like Crohn’s, small ulcer craters within the wall of the colon in ulcerative colitis may appear as hyperechoic gas-filled foci.

Inflammatory bowel diseases increase the perfusion of the intestine, decreasing vascular resistance. Hypervascularized bowel wall has been identified.
in both Crohn’s and ulcerative colitis compared with normal subjects. Doppler of the SMA has revealed an increase in flow velocities (both peak systolic and end diastolic) and a decrease in resistance index in numerous types of pathological bowel, including Crohn’s. However the lack of specificity limits its use in clinical work.

Changes in resistance index have been found to be related to the activity of Crohn’s disease, which could prove valuable in monitoring patients with known disease.

Diverticulitis may also be recognized on ultrasound as outpouchings from the bowel wall, most commonly affecting the sigmoid colon (Fig. 8.13C). Perforation of a diverticulum may give rise to a diverticular abscess, although the presence of air makes ultrasound limited in its evaluation of this condition.

**Malignant tumours**

The most common site for a bowel tumour in the adult is around the caecum. It is useful to target this area in patients with altered bowel habit in whom bowel carcinoma is suspected, although detection with ultrasound is usually incidental.

The mass tends to be hypoechoic, or of mixed echogenicity, with a small, eccentric, gas-filled lumen. This cannot be differentiated, however, from an inflammatory mass on ultrasound. Vigorous Doppler flow can usually be visualized in both inflammatory and malignant masses (Fig. 8.14).

The finding of a colonic mass would normally prompt a barium enema, to delineate the nature, extent and position of the mass, with subsequent staging by CT if malignancy is confirmed. The advantage of ultrasound over barium enema is that of displaying the tumour itself, rather than just the narrowed lumen.

The role of ultrasound in patients with known bowel carcinoma is to identify and document the presence of distant metastases, particularly in the liver, as metastases from colorectal carcinoma are particularly amenable to curative resection.

Bowel tumours should be considered in the list of differential diagnoses when the origin of a mass discovered on ultrasound is unclear.

Endosonography may be used to detect and stage rectal cancers, although it is only able to demonstrate perirectal nodes and cannot evaluate distant disease. Endosonography is ideal however,
in the follow-up of rectal cancer, and can detect early recurrence of disease.

**Obstruction**

Ultrasound has been found to be helpful in the investigation of acute obstruction. It can confirm obstruction, by demonstrating dilated, fluid-filled bowel loops with ineffective peristalsis (Fig. 8.15). These fluid-filled loops of bowel are highly amenable to ultrasound scanning, which has the advantage of being able to visualize peristalsis directly, unlike a plain X-ray. It is possible to trace the dilated bowel to the site of obstruction, distal to which are normal loops of collapsed bowel.²⁷

The confirmation of obstruction with ultrasound has been proved to be as sensitive as and more specific than plain X-rays and can potentially reduce the need for surgery in such patients, save costs and reduce radiation dose.

However, identifying the actual site and cause of obstruction is time-consuming and frequently unsuccessful. Patients with suspected bowel obstruction, therefore, usually proceed straight to CT.
OTHER RETROPERITONEAL ABNORMALITIES

Ultrasound is successful in identifying retroperitoneal masses, but CT and MRI are more effective at establishing the extent and nature of many of these masses, particularly those partly obscured by gas-filled bowel.

The majority of malignant retroperitoneal tumours are renal or adrenal in origin. Other primary tumours, apart from lymphomas, are rare, and include liposarcoma and leiomyosarcoma. These tend to be large when they present, and of variable/complex ultrasound appearance. Encasement of major vessels by tumour is a further characteristic of the retroperitoneal origin of the mass, together with anterior displacement of structures such as the pancreas, kidneys, aorta and IVC.

Ultrasound is also able to identify peritoneal and omental deposits in patients with late-stage carcinoma. These are particularly amenable to diagnosis when surrounded by ascites (Fig. 8.16) and usually arise from gynaecological or urological tumours.

Benign retroperitoneal masses identifiable on ultrasound include haematomas, psoas abscesses, lymphadenopathy (Fig. 8.17) and pancreatic pseudocysts.

Figure 8.14  (A) Hypoechoic, caecal carcinoma. The eccentrically thickened bowel wall is demonstrated with a narrow, hyperechoic lumen (arrow). (B) Caecal carcinoma presenting as a mass in the right iliac fossa.

Figure 8.15  Dilated, fluid-filled loops of bowel as a result of an obstructing caecal carcinoma. Ascites is also present.
Figure 8.17  (A) Enlarged lymph node anterior to the aorta (arrow). (B) Lymphadenopathy may be the cause of obstructive jaundice.

Figure 8.16  (A) Late-stage breast carcinoma demonstrates abdominal ascites with a hyperechoic omental cake of metastatic deposit in the left upper quadrant (LUQ). (B) A large, irregular omental deposit from ovarian carcinoma was palpable during the scan. (C) Retroperitoneal metastases from a teratoma.
References


Ultrasound of the paediatric abdomen requires different techniques and skills from those used in the adult. Although there are a few situations in which knowledge of adult pathology can be applied to the paediatric patient, the child cannot simply be considered a mini-version of an adult. The presenting symptoms and pathological processes in the child are generally quite different from those in adults and the operator must be fully aware of the special considerations of the paediatric patient in terms of both diagnosis and technique. This chapter addresses only the most common paediatric situations likely to be encountered in a general department, and further specialist paediatric reading is recommended. (See the general reading list at the end of this chapter.)

**Techniques**

The operator can minimize any distress to the child, and make the examination considerably easier and quicker, in numerous ways.

- The ultrasound environment should be as friendly as possible, with appropriate decorations and toys, and should always be kept warm (nothing is more likely to make your patient uncooperative than cold gel). Minimize the time the child spends in the scanning room by having everything ready first. Small children may benefit from seeing a video of a scan beforehand and being reassured that it will not hurt.
- Most children find it reassuring to be accompanied by their carer during the examination.
● Separate facilities, such as a dedicated children’s waiting area, are preferable and more reassuring for the child.

● The equipment should incorporate a range of high-frequency (5–15 MHz) transducers with small as well as conventional footprints. A small curvilinear transducer is useful for most abdominal work and a high-frequency linear probe is essential for bowel sonography and assessment of the acute abdomen. Transducers with a dynamic frequency facility are an excellent choice, as it is easy to switch to the highest possible frequency without having to change the transducer. The use of more than one transducer, that is, both curvilinear and linear, may be necessary, particularly in the assessment of the acute abdomen.

● A cine facility on the ultrasound machine is invaluable, and cuts down scanning time. Colour Doppler is essential in the assessment of hepatobiliary problems and the examination of the acute abdomen.

● Generally speaking it is necessary to employ a fast frame rate. (The smaller field of view needed for children allows the line density to remain high, maintaining adequate resolution.)

HEPATOBIILIARY PATHOLOGY

Cystic fibrosis

Cystic fibrosis (CF) is a common, autosomal recessive multisystem disease. The main organs affected are the lungs, liver and pancreas. Accumulation of mucus in the bronchi rapidly leads to respiratory problems including infections, with a predisposition to abscess formation with destruction of the terminal bronchioles developing into bronchiectasis.

Pancreatic insufficiency, requiring enzyme supplements, is a feature of CF, with gradual fatty replacement and subsequent fibrosis of pancreatic tissue, resulting in increased echogenicity of the pancreatic parenchyma. The pancreas is generally reduced in size. Cysts, calcification and ductal dilatation may also be found. Advances in the management of pulmonary problems associated with CF have led to longer survival and a subsequent increase in the prevalence of chronic liver disease. Annual ultrasound examination is recommended as sonographic changes may be identified in the absence of abnormality on biochemical assessment. The liver may be hyperechoic and the texture becomes coarse and nodular as fibrosis develops (Fig. 9.1). Increased periportal echogenicity may be demonstrated. Eventually cirrhosis develops, causing portal hypertension. Assessment of the portal venous system with colour and spectral Doppler is useful, providing a baseline with which to compare progression of the disease.

The gallbladder is small in up to one-third of patients (Fig. 9.1E). This microgallbladder measures less than 3 x 1 x 1 cm after fasting and is filled with mucus. Up to 10% of patients with CF may have gallstones; cholecystitis and biliary strictures may occur.

Neonatal cholestasis and biliary atresia

Neonatal hepatitis and biliary atresia are the most common causes of neonatal cholestasis, presenting around the age of 4 weeks with neonatal jaundice, dark urine and pale stools. Early diagnosis of biliary atresia and differentiation from hepatitis and other causes of neonatal cholestasis is crucial to successful treatment. The aetiology of biliary atresia remains unclear but progressive inflammation, destruction and fibrosis of the biliary tree occurs, resulting in obliteration of all or part of the bile ducts and gallbladder, with the subsequent development of biliary cirrhosis.

The ultrasonic features of neonatal hepatitis and biliary atresia overlap. The gallbladder is generally small and thick-walled or absent in biliary atresia, but may occasionally appear normal, whereas in hepatitis the gallbladder, although often normal in size, may be difficult to visualize. The presence or absence of a gallbladder is not a reliable sign of biliary atresia. In cases of biliary atresia where only the hepatic duct is atretic (that is, with a normal gallbladder and common duct), the gallbladder can appear normal in size and contract postprandially. The liver may appear normal but in more severe cases the liver parenchyma shows increased echogenicity due to developing cirrhosis. The intra- and extrahepatic biliary tree is not dilated, although occasionally small choledochal cysts or...
intrahepatic bile lakes may be seen close to the porta hepatis in infants with biliary atresia. Approximately 10–20% of infants with biliary atresia have associated congenital abnormalities, including choledochal cyst, situs inversus, polysplenia, preduodenal portal vein and interruption of the inferior vena cava (IVC) with azygous continuation, all of which may be detected on sonography.

The main role of sonography is to exclude other less frequent causes of neonatal cholestasis such as a congenital choledochal cyst and obstruction to the common bile duct due to bile inspissation where
biliary tract dilatation will be noted. The diameter of the normal common bile duct should not be greater than 2 mm in the infant up to 1 year old (or 4 mm in children up to 10 years of age).\

Liver biopsy and radioisotope studies are used to differentiate biliary atresia from neonatal hepatitis. Excretion of radionuclide from the liver into the duodenum excludes biliary atresia although a lack of excretion into the duodenum may be seen in both atresia and severe neonatal hepatitis. In these cases laparotomy with intraoperative cholangiogram will be necessary to reach a final diagnosis, although in a few centres MR cholangiography and/or endoscopic retrograde cholangiopancreatography (ERCP) have been used to identify a patent biliary tree and thus exclude the diagnosis of biliary atresia.

Biliary atresia is usually treatable by early surgery, provided the diagnosis is made before the age of 8 weeks, at which time irreversible biliary cirrhosis may have developed. Liver transplant may eventually be required, particularly in those presenting late with established biliary cirrhosis.

**Choledochal cyst**

Choledochal cysts are congenital dilations of the biliary tree that may present at any age, and can be diagnosed in the fetus during routine obstetric scanning. In the neonate the main presenting feature will be cholestatic jaundice but the classic triad of pain, jaundice and a palpable mass is more likely to be seen in the young adult. A number of types of choledochal cysts have been recognized and in many cases there is an anomalous insertion of the bile duct into the pancreatic duct of Wirsung. On sonography a well-defined cyst will be identified close to the porta hepatis and in about 50% of patients there will be dilatation of the proximal bile ducts which may be seen to communicate directly with cyst (Fig. 9.2A). Sludge or calculi may be seen within the cyst. Small choledochal cysts may be seen in association with biliary atresia but in these cases there will be no associated biliary tract dilatation (Fig. 9.2B). Definitive diagnosis is made by MR cholangiography, although scintigraphy and ERCP may be useful in difficult cases.

Other causes of cholestasis in children and neonates include bile duct stones (more common in girls), sclerosing cholangitis, CF, infections and Alagille’s syndrome (a congenital paucity of the bile ducts). Acute cholestasis may also be caused by viral hepatitis, drugs, toxins, metabolic diseases or hypoxaemia.

**Hepatoblastoma and hepatocellular carcinoma (HCC)**

Primary malignant tumours of the liver are comparatively rare in children and frequently present as a large abdominal mass. Large hepatic tumours may present acutely as a result of haemorrhage. Hepatoblastoma is the commonest primary liver malignancy in childhood, generally occurring in children under 3 years of age, and may be associated with predisposing conditions such as Beckwith–Wiedemann syndrome and children infected with HIV (Fig. 9.3A). HCC is more usually associated with chronic liver disease and tends to develop during the later stage of disease with peak incidences of 4–5 years and 12–14 years. Both tumours are associated with increased levels of serum alpha-fetoprotein.

On ultrasound, these tumours appear solid, heterogeneous and are often large and poorly demarcated from the adjacent liver parenchyma. Areas of necrosis or haemorrhage may be identified in the mass. Occasionally they may be multifocal. Although
the two types of tumour are not distinguishable on ultrasound, the clinical history may give a clue and ultrasound-guided biopsy can be used to obtain a histological diagnosis.

Ultrasound is useful in identifying the extent of the tumour and, when combined with colour flow Doppler imaging, adjacent vascular invasion can be evaluated. CT or MRI complements the ultrasound findings and is essential for staging and assessment of suitability for resection or transplantation. Chemotherapy may be used to shrink the tumour prior to surgery.

Rhabdomyosarcoma is a rare tumour which may originate in the biliary ducts, causing biliary dilatation. It is indistinguishable from other liver tumours on ultrasound. Rhabdomyosarcoma originates from muscle cells and is the commonest type of soft-tissue sarcoma seen in childhood, with a