

- Retroperitoneal structures, including ureters, may not be seen easily
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(d) COMPUTED TOMOGRAPHY (CT)

Introduction

The advances in computed tomography (CT) scanning have revolutionized urological imaging, such that in many practices it often is the first—and only—investigation performed for a variety of urological complaints. Collimation allows a rotating thin beam of X-rays to pass through the patient's body, which is attenuated by absorption and scattered as it is passed through the patient. A computer produces a composite image using the transmitted beams.

The present third- and fourth-generation CT scanners are faster and offer outstanding picture definition. The current spiral (helical) CT scanners permit continuous X-ray exposure through a fast rotating X-ray tube (often one rotation in <1 s), thereby allowing superior images for 3D reconstruction. CT scanning technology continues to develop, and it is beyond the realm of this book to deal with the entire array of radiological techniques and findings. Therefore only important principles pertaining to urological practice are highlighted.

Indications

1. Kidneys

- Detection, definition, and staging of renal masses (Fig. 3.4a–c)
- Delineation of complex renal stones
- Evaluation of renal vasculature (e.g., renal artery stenosis, aneurysms, a-v malformations, aberrant crossing lower pole vessels)
- Characterization of perirenal and bladder inflammatory masses (Fig. 3.4d)
- Investigation of level and cause of hydronephrosis
- Investigation of filling defects in the collecting system (Fig. 3.4e)
- Extent and staging of renal tract trauma
- Evaluation of renal transplants
- Investigation of congenital renal malformations
- Adjunct to interventional procedures (e.g., renal biopsy, puncture)

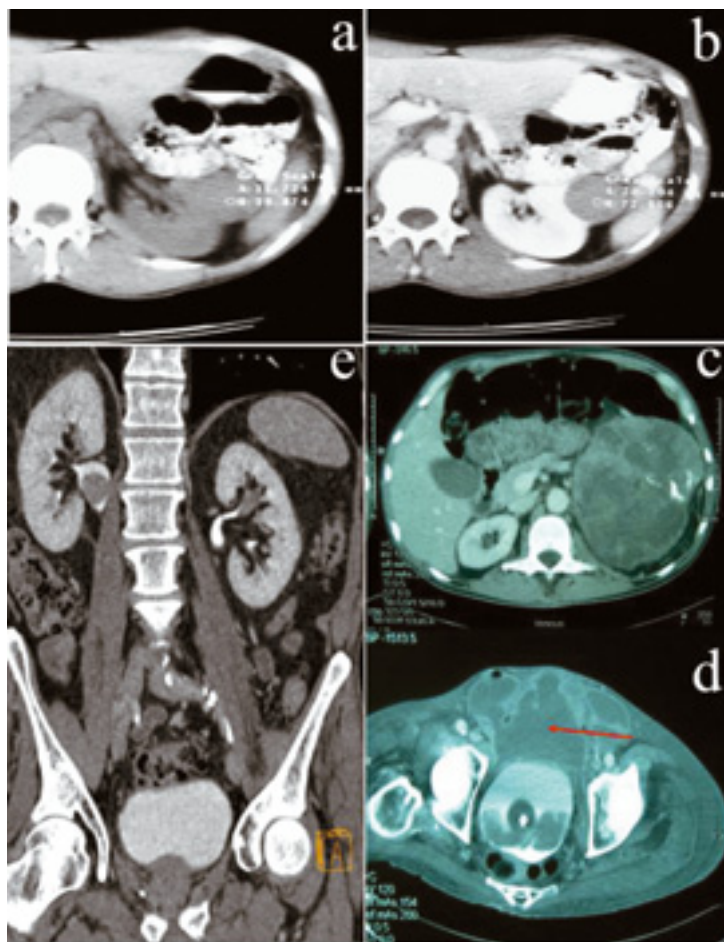


FIGURE 3.4. (a) Pre- and (b) post-contrast CT papillary RCC left kidney—mass enhances from 40 to 72 HU, (c) large left RCC, (d) CT pelvis showing abscess cavity anterior to the bladder secondary to a bladder perforation, (e) bilateral upper tract TCC (Courtesy of Dr A Bradley, Wythenshawe, Manchester)

2. Retroperitoneum

- CT scanning is the investigation of choice for the assessment of retroperitoneal lymph nodes, masses, abscess or fibrosis

3. Ureter
 - Suspected ureteric stones (accuracy >97% with non-contrast CT scan) (Fig. 3.5)
4. Adrenal
 - Investigation of suspected adrenal mass
5. Bladder
 - Staging of invasive bladder tumors
6. Prostate and seminal vesicals
 - Staging of prostate tumors
 - Investigation of abscess, congenital deformities, and cysts
7. Testes
 - Detection of metastases from testis cancer

Technique and radiation

Contrast

Oral contrast will opacify bowel and avoid confusion of fluid-filled bowel and abdominal masses and lymph nodes. Water-soluble contrast medium (20 mL of Urografin 150 diluted with 1 L of orange squash) or low-density barium suspensions (2% w/v) can be used. Further details are given in Table 3.3. Oral contrast is not required when performing CT angiography or unenhanced CT for detection of renal calculi.

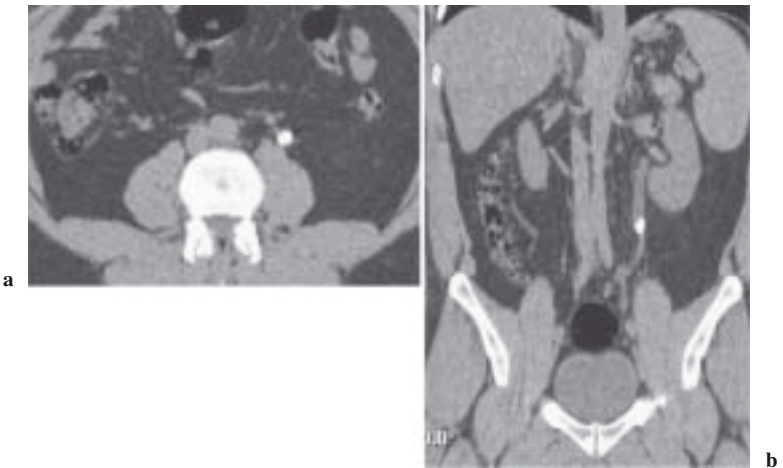


FIGURE 3.5. Non-contrast CT showing left ureteric stone in (a) axial and (b) coronal views (Courtesy of Dr A Bradley, Wythenshawe, Manchester)

TABLE 3.3. Oral contrast for CT

	Contrast Volume (mL)	Time Before Scan
Adult		
Abdomen and pelvis	1,000	Gradually over 1 h before scan
Renal only	500	Gradually over 30 min before scan
Child		
Newborn	60–90	Full dose 1 h before scan and a further half-dose immediately prior to scan
1 mo–1 yr	120–240	
1 yr–10 yr	240–480	
>10 yr	Adult dose	
<i>If colon needs to be opacified, then give contrast night before scan</i>		

Intravenous (IV) contrast should be given in virtually all urological patients, except when looking for a renal tract calculi. Intravenous contrast permits—

- Improved delineation of renal masses
- Evaluation of surrounding vasculature
- Characterization of masses by their pattern of contrast enhancement. The contraindications and side effects of intravenous contrast agents have been discussed earlier (see Chapter 3b: IVU)

The standard renal mass protocol is based on renal enhancement post IV contrast injection.

1. Non-contrast scan: best for identification of renal tract calculi, fat, and baseline enhancement
2. Arterial (cortical) phase scan: 15–25 seconds after contrast injection allows evaluation of renal arteries
3. Corticomedullary (nephrographic) phase scan: 70–120 seconds after contrast injection allows visualization of renal parenchymal anatomy. Also provides good hepatic and portal vein enhancement

4. Excretory phase scan: 3–5 min after contrast injection allows evaluation of the collecting system and renal pelvis

Delaying the scan beyond this period will demonstrate opacification of the ureters and bladder.

Enhancement (Hounsfield units)

Tissue enhancement (density/attenuation value) is standardized on the Hounsfield scale. The scale extends from $-1,000$ to $+1,000$ Hounsfield units (HU) (see Table 3.4). Enhancement of >10 HU post-contrast compared to the non-contrast phase is indicative of a solid, enhancing, malignant mass.

Data processing and images

3D reconstruction—With the increased use of multislice CT scanners, it is now possible to obtain a large number of very thin (<2.5 mm) cross-sectional axial images of the entire urinary tract in a matter of minutes. In addition, these images can be displayed in a variety of multiplanar and 3D reformatted images. Currently, one of three different 3D reconstructions algorithms may be used:

- Average-intensity projection (most closely resembles IVU images)
- Maximum-intensity projection
- Volume rendering

Evidence of the superiority of one over the other is not available yet, but volume rendering seems to be the most preferred owing to the fact that image creation is quick, is least dependent on

TABLE 3.4. Hounsfield scale

Tissue	Hounsfield Units (HU)
Bone	$+1,000$
Renal tract calculus	$>+400$
Non-specific calcification	$>+150$
Acute hemorrhage	$+50$ to 90
Clotted blood	$+70$
Soft tissue	$+10$ to $+50$
Water	0
Fat	-50 to -100
Air	$-1,000$

technical factors, and provides excellent data-rich images of the urinary tract in its entirety without any loss of information. The improved resolution and accuracy of reconstructed images, combined with CT angiography, is increasing its use in a range of conditions where demonstration of renal and perirenal vasculature is essential, including—

- Assessment and staging of renal tumors
- Planning for nephron-sparing surgery
- Prior to surgery for uretero-pelvic junction obstruction surgery (e.g., endopyelotomy)
- Prior to complex stone surgery
- Assessment of renal transplant donors
- Arterio-venous malformation
- Assessment of complex urinary fistulas

It is important to study the actual axial 2D images as certain small lesions may not be easily identified on reconstructed images. In one recent study, standard 2D CT images correctly demonstrated 89% of small upper tract TCC, compared to a 25% pick-up rate with 3D reconstruction images.

Virtual endoscopy

By using a surface-rendering technique, CT images can be utilized to enable imaging of hollow organs such as the bladder and ureter. Virtual endoscopy—

- Has the main advantage of being non-invasive
- Permits good visualization of the tumor morphology as well as reasonable demonstration of the bladder/ureter wall
- Is unable to detect flat mucosal lesions, such as carcinoma in situ
- Imparts no data with regard to tumor grade and stage

The overall sensitivity and specificity of virtual ureteroscopy are 81% and 100%, respectively, for the detection of polypoidal ureteric lesions, and 80% and 75% for the detection of upper tract TCC. While virtual cystoscopy is unlikely ever to gain popularity in the assessment of bladder cancers, virtual ureteroscopy may, with further refinements, be incorporated into the management of selected patient groups (e.g., patients unfit for repeated general anesthetic procedures, single kidneys, surveillance in patients with previous upper tract TCC).

The effective radiation dose for a non-contrast abdominal CT scan is 8mSv (equivalent to 4 years of background radiation or 20,000 miles traveled by car). However, performing a four-phase contrast CT urography can expose the patient to an effective radiation dose of 25–35mSv (at least five times that of the IVU).

Interpretation

1. Kidneys and surrounding structures

The kidneys are easily seen in the retroperitoneum within Gerota's fascia, with surrounding perinephric fat. A careful and systematic examination is made of the kidneys, renal vessels, collecting system, peri-renal tissue, adrenals and the rest of the retroperitoneum. Basis principles are discussed below.

- Renal cysts
 - Most common of all renal masses
 - USS usually able to distinguish between solid and cystic masses
 - Doubt may exist with 20–40% of renal lesions
 - CT scan alone has an accuracy approaching 100%
 - For a simple renal cyst to be considered thus, all of the following stringent criteria must be met:
 - a. Homogenous water density contents with attenuation no greater than 20 HU
 - b. Smooth-contoured, rounded, or oval shape without a perceptible wall
 - c. No contrast enhancement

Any other cysts must be considered complex and further enquiry is mandatory. Bosniak has proposed the following categorization of cystic renal masses based on CT findings:

- Category I: (benign) simple benign cyst meeting all the CT criteria described above
- Category II: (usually benign, but 13–27% malignant) simple cystic lesions which are minimally complicated including septation; minimal calcification; obviously infected and non-enhancing high-density cysts (category IIF—these cysts are more complex and cannot be neatly categorized into type II or III. These may contain a slightly increased number of hairline septa; minimal but smooth thickening of septa wall; contain

calcification. The “F” indicates the need for follow-up imaging)

- Category III: (between 45% and 60% malignant) more complicated cysts which demonstrate findings associated with malignancy including multi-loculation; hemorrhage; coarse calcification; non-enhancing solid components
- Category IV: (about 90% malignant) clearly malignant lesions with cystic components; irregular and enhancing solid areas

Thin areas of linear calcification within cyst walls, or thin septations within a cyst are of no significance when noted in isolation. High-density areas, calcification, and hemorrhage noted in patients with polycystic kidney disease can often mimic malignant changes.

- Renal cell carcinoma (RCC)
 - Typically appears as solid masses
 - Frequently associated with hemorrhage, necrosis, and calcification
 - Pre-contrast attenuation is similar to that of the surrounding renal parenchyma (+30 to +60 HU), with obvious enhancement following contrast injection (but to a lesser degree than the parenchyma)
 - Allows accurate staging of RCC and provides information on—
 - ◊ Tumor size
 - ◊ Local invasion
 - ◊ Venous involvement
 - ◊ Tumor vascularity (using angiography techniques)
 - ◊ Presence of obvious lymph node metastases

- Renal lymphoma

One in 20 of all patients with lymphoma will have renal involvement, and separating these lesions from metastatic renal deposits (from an extra-renal source) can prove challenging. Retroperitoneal lymphadenopathy is almost always observed with renal lymphoma. CT scanning may reveal single or multiple, unilateral or bilateral, enhancing parenchymal lesion, or may demonstrate diffuse renal infiltrative enlargement.

- Upper tract TCC
 - CT has a poorly defined role in the management of upper tract urothelial malignancies

- Reported sensitivities have been as high as 89–98% (compared to between 60% and 79% for retrograde pyelograms) but false-negative rates are disappointing
- Unlikely to replace direct access endoscopic visualization of the renal tract
- Ureteric or renal pelvic TCC may appear as either filling defects, mass lesions, or urothelial thickening
- Main role is in the detection of lymph node or extra-urinary metastases
- Angiomyolipoma
 - Benign lesions
 - May be confused with RCC
 - Characterized by their gross fat content
 - Diagnosis must be suspected in the pre-contrast films (by the presence of fat) as post-contrast enhancement usually occurs due to the vascular nature of these lesions
 - Angiomyolipomas contain both muscle and vascular elements and appear as large, low-density, irregular, fatty tumors, and may be associated with surrounding hemorrhage
 - Bilateral lesions are usually associated with tuberous sclerosis
- Oncocytoma
 - Renal oncocytomas often difficult to diagnose pre-operatively
 - CT angiography may demonstrate a large, homogenous, well-circumscribed central mass with a scar, surrounded by a “spoke-wheel” configuration of tumor vessels
 - Confusion with an RCC is common
- Hydronephrosis
 - CT scanning has a false-negative rate of 10–20% for the detection of hydronephrosis
 - May provide useful information of the degree and level of obstruction as well as preservation of renal cortex
 - Contrast extravasation is a feature of acute obstruction
 - Mild hydronephrosis—minor splaying of renal fat and sinus structures secondary to pelvi-calyceal dilatation
 - Moderate hydronephrosis—more prominent dilatation of the collecting system
 - Severe hydronephrosis—marked dilatation with minimal or no contrast, in association with loss of cortex

- Renal calculi
 - Non-contrast CT has a detection rate approaching 100% for all types of renal calculi
 - Calcium and oxalate containing stones have an attenuation value of between +400 and +1,200 HU
 - Less dense cystine and uric acid stones measure in at between +100 to +200 HU
- Inflammatory lesions
 - USS may be sufficient in the majority of patients with inflammatory conditions affecting the kidneys
 - CT gives superior imaging compared to USS and IVU
 - CT indicated in patients unresponsive to antimicrobial therapy
 - Acute pyelonephritis may reveal a diffusely enlarged kidney with general or focal wedge-shaped areas of diminished contrast enhancement
 - Renal and perirenal abscesses containing pus, stones, blood, and gas are easily visible
 - Xanthogranulomatous pyelonephritis, seen in patients with a history of chronic infection, is usually secondary to stone disease and is frequently characterized by the presence of renal calculi within a fibrotic kidney containing multiple abscess cavities
- Renal trauma

CT is the investigation of choice in the initial assessment of the extent of renal trauma. The advantages of CT include (i) reasonably quick examination, (ii) non-invasive, (iii) contrast use allows for good demonstration of even subtle arterial or venous injuries, (iv) can identify non-renal organ injuries.

Indications for CT imaging following renal trauma include—

- i. Penetrating trauma
- ii. Clinical suspicion of other abdominal or retroperitoneal organ injury
- iii. Blunt trauma, if associated with macroscopic hematuria
- iv. Blunt trauma with microscopic hematuria, plus either (1) shock (systolic BP <90 mmHg at any time) or (2) clinical suspicion of additional abdominal organ injury, or (3) significant deceleration injury (e.g., fall from height)

Using helical CT, a two-phase technique is recommended. Immediate films following contrast injection will permit diagnosis of

reno-vascular injury, while a delayed (5–20 min) scan will aid recognition of injury to the collecting system or ureters.

Renal pedical injuries are accurately diagnosed with CT. Complete renal artery or segmental arterial occlusions are seen as absence of contrast enhancement in whole or part of the kidney. Complete renal artery occlusion usually results in an absent nephrogram, but may also demonstrate the “rim sign” (peripheral cortical enhancement due to collateral arterial supply).

The severity of renal trauma can be accurately assessed and graded using the American Association for the Surgery of Trauma system (Table 3.5).

- Adrenals
 - Primary radiological investigation for suspected adrenal masses
 - Virtually all masses >1 cm diameter are easily identified
 - Lipomas and adenomas have a higher lipid content and low enhancement (<10 HU)
 - CT will readily distinguish between cysts and malignant masses

TABLE 3.5. American Association for the Surgery of Trauma Classification for renal trauma

Grade	Type	Description
1	Contusion	Subcapsular injury with no parenchymal lacerations
2	Hematoma	Renal laceration (limited to cortex or <1 cm parenchymal depth); non-expanding peri-renal hematoma confined to retroperitoneum; no urine extravasation (75–85% of renal traumas are ≤grade 2)
3	Deep laceration	Deep laceration involving medulla (depth >1 cm) not involving collecting system; no urine extravasation; segmental arterial thrombosis
4	Deep laceration	Laceration extending through cortex, medulla, and collecting system; urinary extravasation; main renal artery or vein injury with contained hemorrhage
5	Laceration/ vascular	Shattered kidney; renal pedicle avulsion (causing devascularisation of kidney); renal artery thrombosis

(add one grade for bilateral injuries up to grade 3)

- Distinguishing between an adrenal adenoma and adrenal metastases can prove more difficult
- Bilateral adrenal masses are more suggestive of secondaries or lymphoma
- Masses >2 cm are likely to be malignant

2. CT of the pelvis

Traditionally, CT scanning has been the primary imaging modality in the staging of bladder and prostate cancer, but recent evidence suggests that magnetic resonance imaging (MRI) provides superior resolution and therefore may be more accurate. In addition, metastatic disease within the pelvis is easily demonstrated on CT.

On CT, normal lymph nodes are up to 10 mm in maximum transverse diameter in the para-aortic and iliac chains, and 6 mm in the retrocrural region. While this size criteria is reasonably accurate, CT cannot differentiate between lymphadenopathy secondary to tumor or inflammation. It is also well recognized that tumor infiltration may be present in smaller nodes considered insignificant on the basis of size criteria.

- Bladder cancer
 - Bladder tumors may be seen as mass lesions, filling defects, or bladder wall thickenings on CT
 - CT is reasonably accurate (70–88%) at detecting locally advanced tumor (stage T3b and above)
 - CT is unable to distinguish between tumors of a lower stage and over-staging is a distinct possibility
 - Accuracy of CT for lymph node detection lies between 70% and 92%
 - CT is primarily utilized for patients with advanced disease or those at risk of metastatic spread
- Prostate cancer
 - MRI scanning is now the principal imaging technique for CAP
 - CT cannot distinguish between the various grades of organ-confined disease
 - CT able to detect local invasion into bladder or seminal vesicals and the presence of gross lymphadenopathy
 - overall accuracy of CT in the staging of prostate cancer varies between 50% and 80%
 - CT unable to differentiate confidently between malignant and benign conditions involving the prostate
- Bladder trauma

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