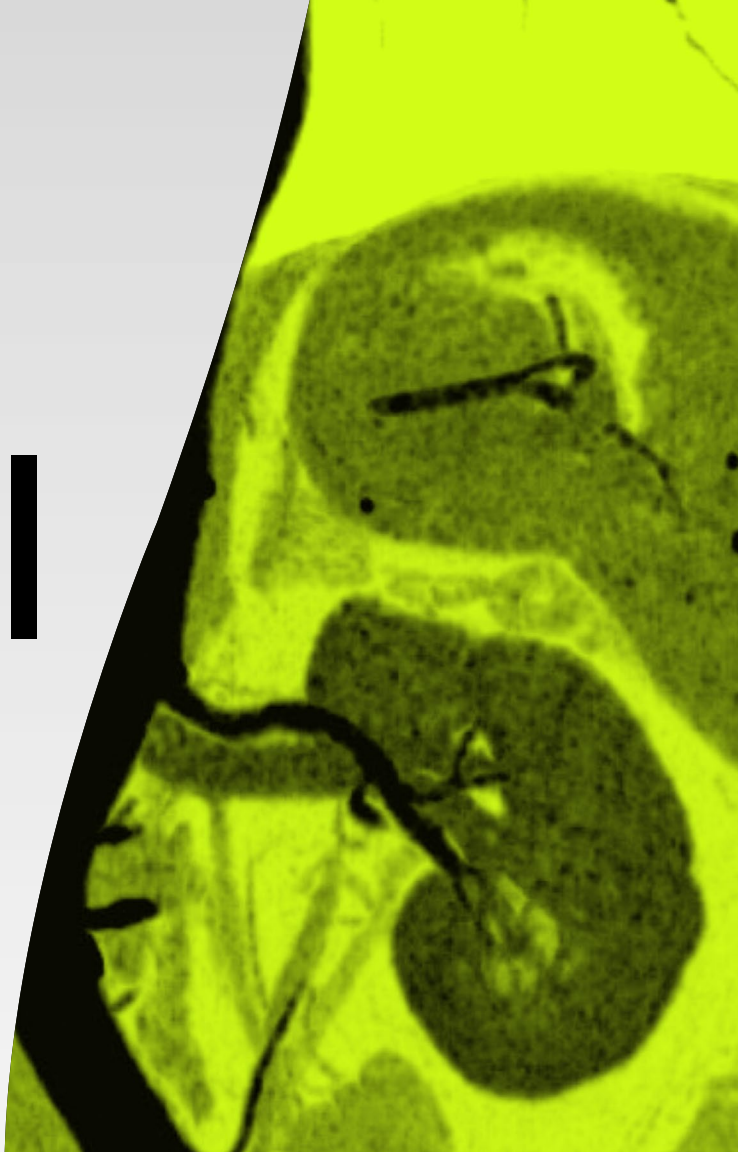
MODERN RADIOLOGY eBook

Urogenital Radiology



EUROPEAN SOCIETY OF RADIOLOGY

Preface

Modern Radiology is a free educational resource for radiology published online by the European Society of Radiology (ESR). The title of this second, rebranded version reflects the novel didactic concept of the ***ESR eBook*** with its unique blend of text, images, and schematics in the form of succinct pages, supplemented by clinical imaging cases, Q&A sections and hyperlinks allowing to switch quickly between the different sections of organ-based and more technical chapters, summaries and references.

Its chapters are based on the contributions of over 100 recognised European experts, referring to both general technical and organ-based clinical imaging topics. The new graphical look showing Asklepios with fashionable glasses, symbolises the combination of classical medical teaching with contemporary style education.

Although the initial version of the ***ESR eBook*** was created to provide basic knowledge for medical students and teachers of undergraduate courses, it has gradually expanded its scope to include more advanced knowledge for readers who wish to 'dig deeper'. As a result, *Modern Radiology* covers also topics of the postgraduate levels of the *European Training Curriculum for Radiology*, thus addressing postgraduate educational needs of residents. In addition, it reflects feedback from medical professionals worldwide who wish to update their knowledge in specific areas of medical imaging and who have already appreciated the depth and clarity of the ***ESR eBook*** across the basic and more advanced educational levels.

I would like to express my heartfelt thanks to all authors who contributed their time and expertise to this voluntary, non-profit endeavour as well as Carlo Catalano, Andrea Laghi and András Palkó, who had the initial idea to create an ***ESR eBook***, and - finally - to the ESR Office for their technical and administrative support.

Modern Radiology embodies a collaborative spirit and unwavering commitment to this fascinating medical discipline which is indispensable for modern patient care. I hope that this ***educational*** tool may encourage curiosity and critical thinking, contributing to the appreciation of the art and science of radiology across Europe and beyond.

Minerva Becker, Editor

Urogenital Radiology

CHAPTER OUTLINE:

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Urogenital Radiology

CHAPTER OUTLINE:

MODERN RADIOLOGY eBook

Based on the ESR Curriculum for Radiological Education

Urogenital Radiology

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Chapter Outline

- Anatomy and Anatomical Variants
- Diagnostic Imaging Techniques
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- Urogenital Diseases
  - Renal Diseases
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Anatomy and Anatomical Variants

CHAPTER OUTLINE:

/ Anatomy

The urogenital system can be functionally divided into two different units: the urinary system that filters the blood, removes, and excretes the wastes in the urine, and the genital system, which has a reproductive function.

The urinary system consists of the kidneys, ureters, urinary bladder, and urethra.

Kidneys

The kidneys are paired, and symmetrical organs located behind the parietal peritoneum. The kidney is encased in a fibrous connective tissue layer known as the renal capsule, which closely adheres to its surface. Surrounding the kidney is a layer of perirenal fat, providing cushioning and protection. The entire structure is secured in place by an additional connective tissue layer called the renal fascia.

Each kidney can be divided into three portions: **upper pole**, **middle third** and **lower pole**.

A newly developed kidney segmentation system divides the kidney into 12 distinct segments. Specifically, each section of the upper pole, middle third, and lower pole, is further subdivided into four parts: anterior, posterior, lateral, and medial (1), as illustrated in Fig. 1.

This system improves the diagnostic segmentation of the kidneys, playing a crucial role in treatment planning of renal tumours, especially in view of nephron- sparing surgery.

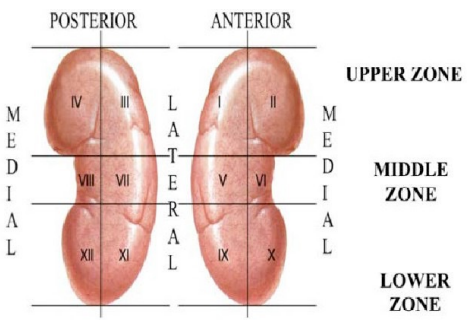

FIGURE 1

Renal segments.

From an anatomical and functional perspective, the kidney consists of two main regions: the outer cortex and the inner medulla. Describing the corticomedullary ratio in imaging is crucial, as it serves as an important index of renal function.

The renal medulla consists of a series of renal pyramids. Their pointed ends, known as renal papillae, project into the minor calyces, which merge to form the major calyces and ultimately converge to create the renal pelvis.

<!> ATTENTION

For differences between the adult and the paediatric kidneys > see chapter on Paediatric Radiology.

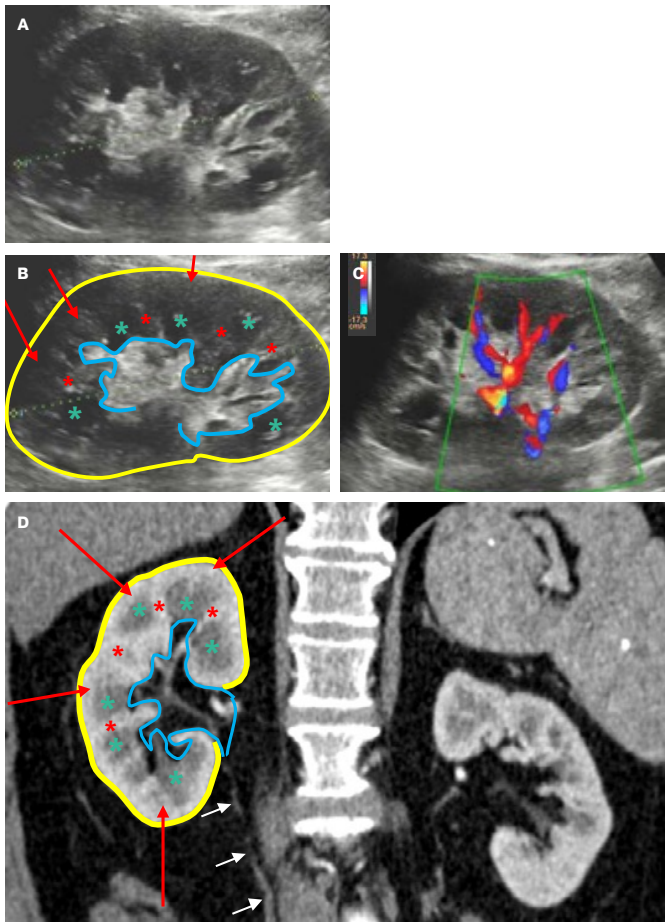

FIGURE 2

Normal renal anatomy. Sagittal ultrasonography (US) image of the left kidney (**A**) and corresponding annotated image (**B**), colour Doppler US (**C**) and coronal contrast enhanced arterial phase CT (**D**).

The renal cortex (indicated by **red arrows**) is located at the periphery, just beneath the renal capsule (highlighted by the **yellow line**). The medulla is composed of renal pyramids (marked with **green asterisks**), which are separated by renal columns (denoted by **red asterisks**). The renal sinus (**blue line**) is the connection between the calices and the ureter **(white arrows** in d). The renal sinus contains calices, renal vessels and nerves, fat and the renal pelvis. In c, arteries are shown in red (blood flow towards the transducer) and veins in blue (blood flow away from the transducer). Figure courtesy: Minerva Becker, MD, Geneva University Hospitals, Switzerland.

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The renal pelvis is a funnel-shaped reservoir that collects the urine produced by the kidneys, directing its flow into the ureter for excretion (Fig. 3).

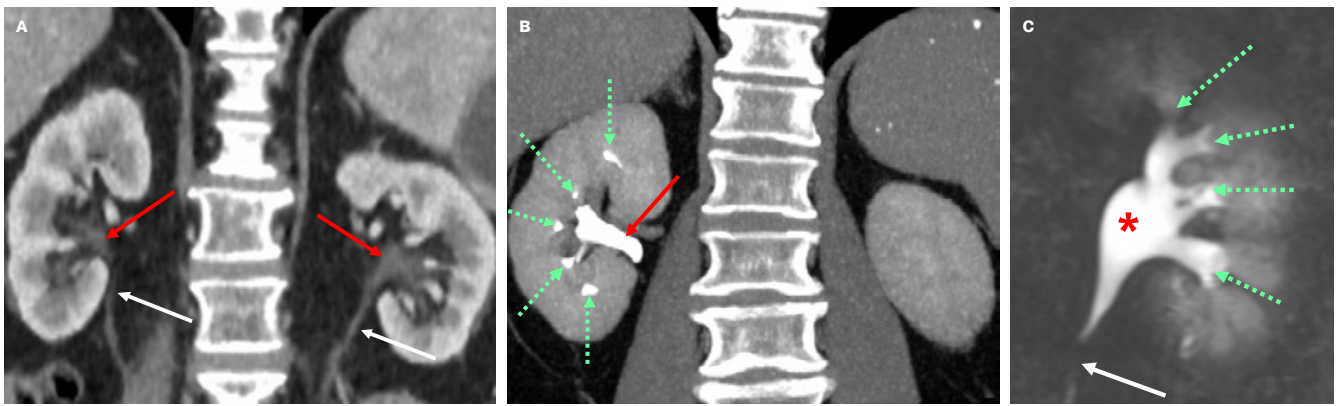

FIGURE 3

The normal renal pelvis (indicated by **red arrows**) is visualised on coronal reconstructions during the early arterial phase (**A**) and the late excretory phase (**B**) of contrast-enhanced CT. For a description of contrast-enhanced CT phases, see Figs. 6 and 15. MR urography image (**C**) of a normal left renal pelvis (**asterisk**). Normal proximal ureters (**white arrows** in a and c) and normal calices (**dashed arrows**). MR urography applies the same physical principle as MR cholangiography (heavily T2 weighted sequences to depict stationary fluids, no contrast material required), see also eBook chapter on biliary tracts. Figure courtesy: Minerva Becker, MD, University Hospitals Geneva, Switzerland

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The hilum is another essential renal region to be assed in imaging. It represents the anatomical site where the renal artery enters and the renal vein and ureter exit (Fig. 4).

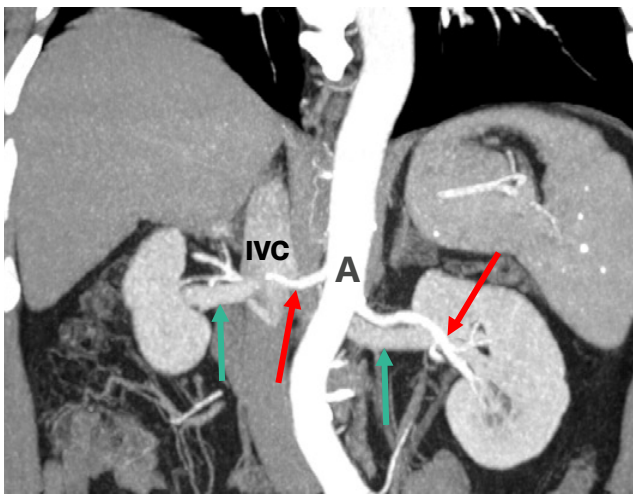

FIGURE 4

Normal renal vascular anatomy as seen on a thick slab coronal multiplanar reconstruction of an angio-CT. Renal arteries (**red arrows**), renal veins (**green arrows**), aorta (**A**), inferior vena cava (IVC). Note that the renal veins are located anteriorly to the renal arteries.

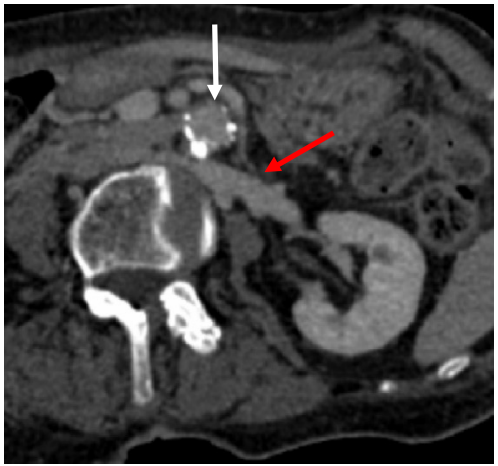

FIGURE 5

Retro-aortic left renal vein course (**red arrow**). Aorta (**white arrow**). Note that the aorta has calcified atheromatous plaques.

<!> ATTENTION

The radiological report should detail the precise number of renal arteries and veins, along with any variations in their course (e.g., a retro-aortic left renal vein) or morphology, as well as the presence of atheromatous changes (Fig. 5).

Urogenital Radiology

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After intravenous administration of contrast media, CT imaging enables visualisation of the arterial, nephrographic, and excretory phases (Fig. 6). Notably, the corticomedullary renal ratio is most distinctly defined during the arterial phase.

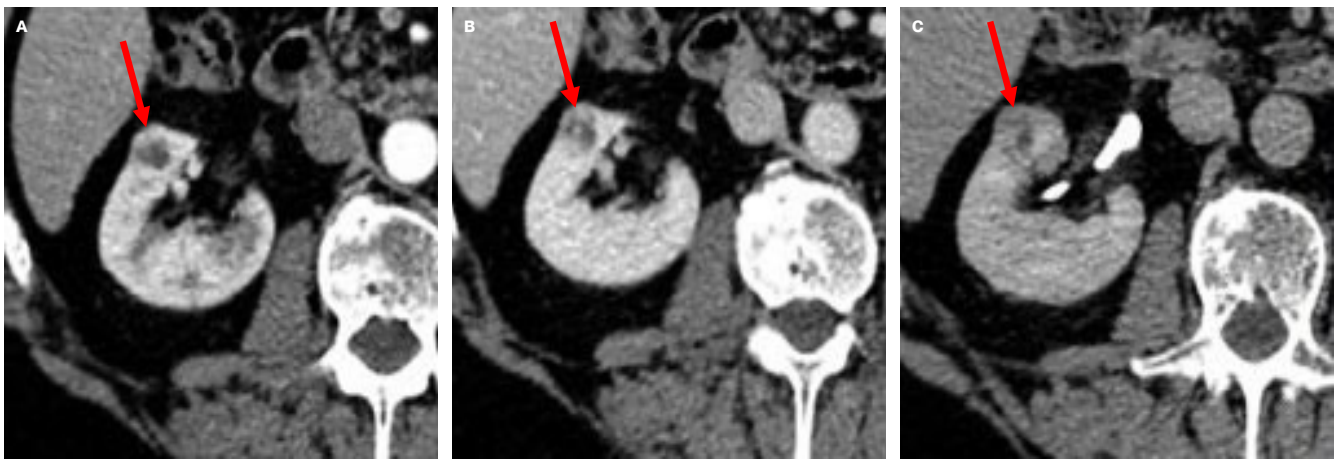

FIGURE 6

Arterial (**A**), nephrographic (**B**) and secretory phase (**C**) as seen after iv. Injection of contrast material on axial CT images. Arrows point at a renal mass.

Ureters

The ureters (Fig. 7) are bilateral tubular structures that transport urine from the renal pelvis into the bladder. Each ureter consists of three parts:

1. **abdominal ureter**: from the renal pelvis to the beginning of the anatomical pelvis, approximately at the level of the iliac crest
2. **pelvic ureter:** up to the bladder
3. **intravesical or intramural ureter**: within the bladder wall

In a normal ureter, three physiological constrictions are typically observed: the first located approximately 7-8 cm from the renal hilum, the iliac constriction, and the intramural constriction.

The **ureteral wall** and the bladder wall show comparable anatomical layers, with the muscular layer transitioning seamlessly into the bladder wall at the level of the ureteral orifice.

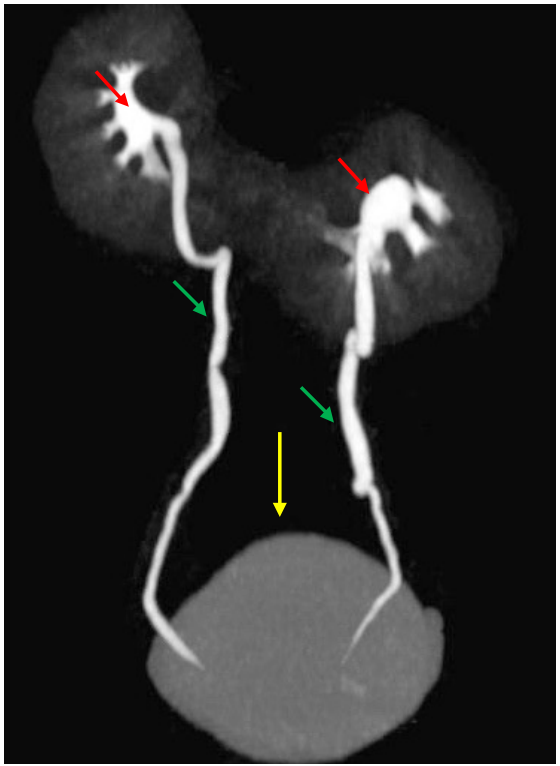

FIGURE 7

CT-Urography showing the excretory system: renal pelvis (**red arrows**), ureters (**green arrows** – please note the different anatomical parts) and the bladder (**yellow arrow**).

Anatomical variants of the kidneys and ureters are common and can occur in different forms (2):

Location anomalies:

- Pelvic kidney or renal ptosis, that can be a confounding factor during clinical evaluation: "renal colic" pain may be confused with appendicitis, pelvic inflammatory disease (PID), or ovarian torsion.
- Between the 5th and 9th week of gestation, the kidneys undergo a 90° rotation during their ascent. Incomplete rotation can result in the renal pelvis being directed anteriorly at an angle of less than 45°, while hyper-rotation may cause the pelvis to be directed posteriorly, or in reverse rotation, the renal pelvis may be directed laterally.

Shape anomalies:

- Persistent fetal lobulation (Fig. 8)
- Dromedary humps: prominent focal bulges on the lateral border of the left kidney, resulting from the splenic impression on the superolateral border of the kidney.
- Hypertrophied column of Bertin: the column of Bertin represents an extension of renal cortical tissue that separates the renal pyramids. When enlarged, it may be mistaken for a renal mass.

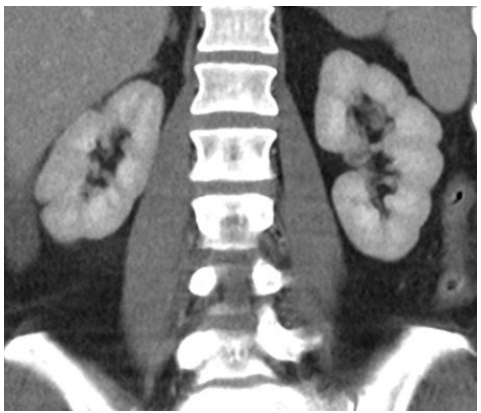

FIGURE 8

Persistent fetal lobulation. Case courtesy of Dr. Chris O'Donnell, Radiopaedia.org, rID: 41364

Number Anomalies:

- Renal agenesis
- Supernumerary kidney

Fusion Anomalies:

- Horseshoe kidney (Fig. 9): the most common form of renal fusion, occurring between the lower poles.
- Pancake kidney: both the upper and lower poles are fused.

Urinary Collecting System Anomalies:

- The duplicated collecting system is characterised by a complete or incomplete duplication of the collecting system. In incomplete ureteral duplication, two ureters originate from the same renal pelvis and share a common ostium. In complete ureteral duplication, each ureter opens separately into the bladder. Usually, the ureter draining the upper pole of the kidney opens lower and medially compared to the one draining the lower pole, which has a longer intramural portion, with a lower risk of reflux.

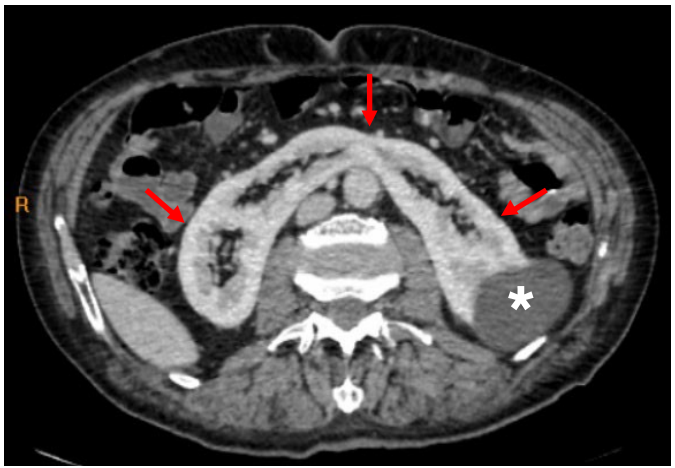

FIGURE 9

Horseshoe kidney (**arrows**) as seen on a CT image. Renal cyst (**asterisk**).

<!> ATTENTION

For anatomical variants > see chapter on Paediatric Radiology.

CHAPTER OUTLINE:

Bladder

The bladder is an expandable organ located in the pelvis. It is covered by peritoneum on its superior surface and partially on its posterior surface. The shape and position of the bladder change depending on the volume of urine it contains, expanding into the abdominal cavity as it fills.

Anatomically, the bladder is divided into four parts:

1. base (also known as a fundus) located posteroinferiorly
2. the anterior-superior portion, also referred to as the dome
3. body
4. the neck, which is continuous with the urethra (3).

The trigone is a triangular region within the bladder, defined by three key structures: the bilateral ureteric orifices located at the superolateral corners and the internal urethral orifice at the apex, where the urethra begins its role in transporting urine outside the bladder.

The bladder wall is composed of three layers: mucosa and submucosa, muscularis propria (which represents the detrusor muscle), and serosa. The mucosa consists of the urothelium, a specialised stratified epithelium with characteristic cells called umbrella cells, which form an impermeable barrier and can change shape according to the bladder's filling.

<!> ATTENTION

The muscular layer is crucial in the evaluation of bladder cancer, as staging and treatment depend on detrusor muscle invasion.

Anatomical Variants of the Bladder

- **Septation:** a septum may divide the bladder internally into two or more compartments (Fig. 10).
- **Persistent urachus:** The urachus is a remnant of a foetal channel that originally connected the bladder to the umbilicus, through which urine drained during fetal development. Normally, the urachus regresses after birth, transforming into a fibrous cord known as the middle umbilical ligament.
- **Congenital bladder diverticulum** (it occurs in the absence of obstructive factors such as posterior urethral valves and neurogenic bladder; it is related to a deficient detrusor layer).

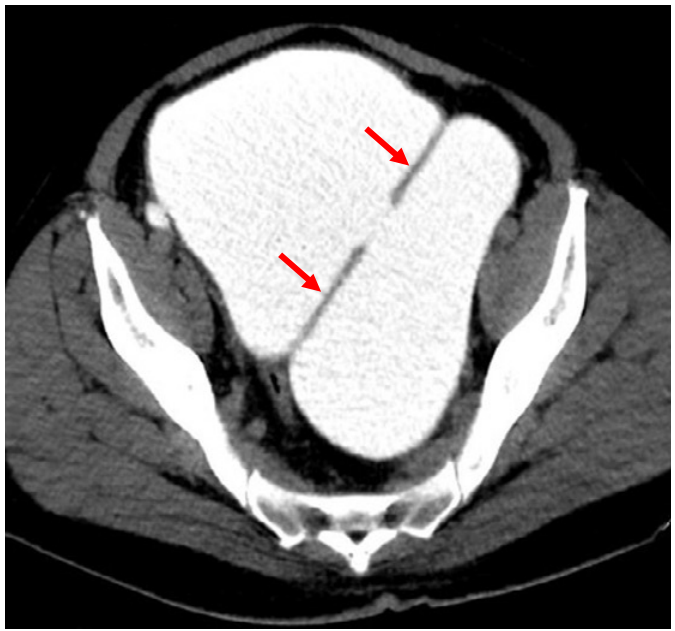

FIGURE 10

Bladder septation (**arrows**) as seen on an axial CT image during the excretory phase.

Genital System

The male genital system consists of the gonads (testicles), the spermatic ducts (epididymis, vas deferens and ejaculatory ducts), the accessory glands (seminal vesicles, prostate and bulbo-urethral glands) and the external genital organs (scrotal bursa and penis).

>=< FURTHER KNOWLEDGE

The most important anatomical anomaly involving the testicles is crytptorchism, a condition characterised by undescended testicles, which are located in the abdomen rather than the scrotum, due to an abnormality during their migration toward the inguinal canal, through which the testicles normally descend into the scrotum.

Testicles

The testicles are the male gonads responsible for producing spermatozoa and testosterone, which is essential for male growth. Each testicle is surrounded by a fibrous capsule known as the tunica albuginea, which extends inward to form septa that divide the testis into several lobes. Within these lobes lie the seminiferous tubules, where spermatogenesis—the process of sperm production—occurs. The testicles contain also supporting cells called Sertoli cells, and testosterone-producing cells called Leydig interstitial cells.

The testicles are located within the scrotum, external to the body, to maintain a lower temperature, which is essential for the protection and proper development spermatozoa. Ultrasonography represents the first-line imaging modality for the evaluation of testis and scrotum (Fig. 11).

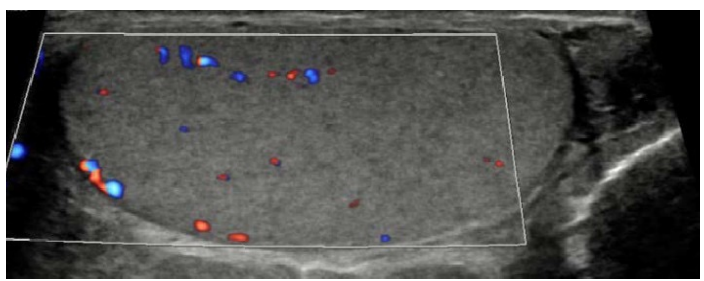

FIGURE 11

Sagittal testicle US image with colour Doppler. Note homogeneous mildly coarse texture.

Prostate

The prostate gland (Fig. 12) is located inferior to the bladder and surrounds the prostatic portion of the urethra. It is the largest male accessory gland, and its primary function is to produce the seminal fluid that nourishes and transports spermatozoa within the sperm. The prostate has an inverted pyramidal shape and is anatomically structured from superior to inferior as follows:

- The base (located inferior to the urinary bladder)
- the mid-gland
- the apex

It is divided into four histologic zones (fig. 12):

1. The **anterior fibromuscular stroma**, which does not contain glandular tissue
2. the **transition zone (tz)**, surrounding the urethra proximal to the verumontanum, contains 5% of the glandular tissue
3. the **central zone (cz)**, surrounding the ejaculatory ducts, contains about 20% of the glandular tissue
4. the outer **peripheral zone (pz)**, which contains 70%-80% of the glandular tissue (4)

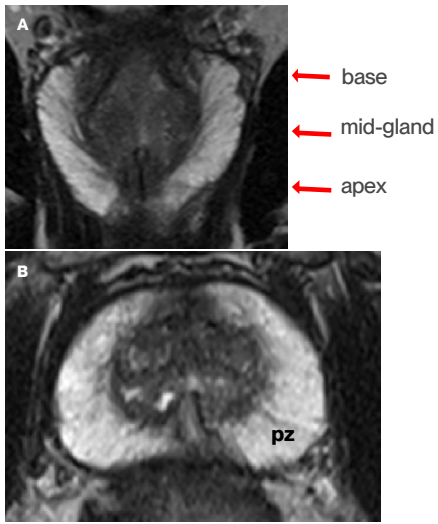

FIGURE 12

Prostate MRI. T2- weighted coronal (**A**) and axial (**B**) planes.

Penis

The penis is the external organ of male genital system. Its two main functions are sexual intercourse and urination, as the urethra connects to the bladder and passes through the entire length of the penis.

It is divided into:

- **Root:** the most proximal part, which is not externally visible
- **Body:** the external and mobile portion of the penis
- **Glands:** the terminal part of the penis which contains the urinary meatus, the external opening of the urethra, serving as the passage for the expulsion of urine and sperm.

The **tunica albuginea** is a connective, elastic tissue that envelopes the penis and is surrounded by Buck's fascia, which is covered by the fascia of Colles.

The **erectile tissues** (Fig. 13) are structures that become filled with blood during the erection.

In the root, the erectile tissue starts with the left and right crura and the bulb of the penis.

The left and right crura extend into the body of the penis, forming the two **corpora cavernosa**.

The bulb extends into the body of the penis, giving rise to the **corpus spongiosum**, which then enlarges to form the glans.

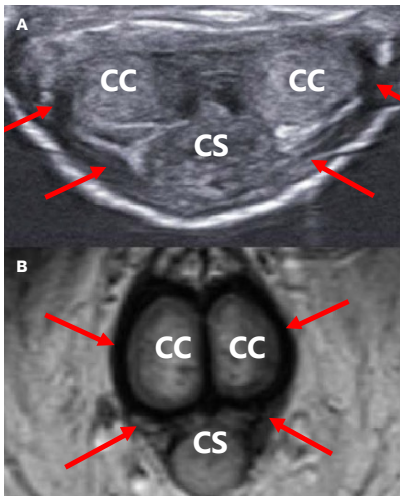

FIGURE 13

Penile ultrasound (**A**) and MRI (**B**) images. CC = corpus cavernosusm. CS = corpus spongiosum. Deep fascia (**red arrows**).

Diagnostic Imaging Techniques

CHAPTER OUTLINE:

/ Ultrasound

<!> ATTENTION

Ultrasonography (US) is the first-line imaging modality for patients with suspected urogenital pathology (Fig. 14); Second-level imaging techniques are required for a more detailed characterisation of lesions and for loco-regional staging of disease.

ADVANTAGES:

+ Low cost and easily available
+ Does not utilise ionising radiation
+ High accuracy in detecting hydronephrosis, intraluminal bladder masses and renal masses

DISADVANTAGES:

– Limited visualisation of upper urinary tract, particularly the ureter
– Operator-dependent imaging modality
– Inaccurate when patient preparation is not optimal (i.e., gas)

<!> ATTENTION

Additional imaging may be required!

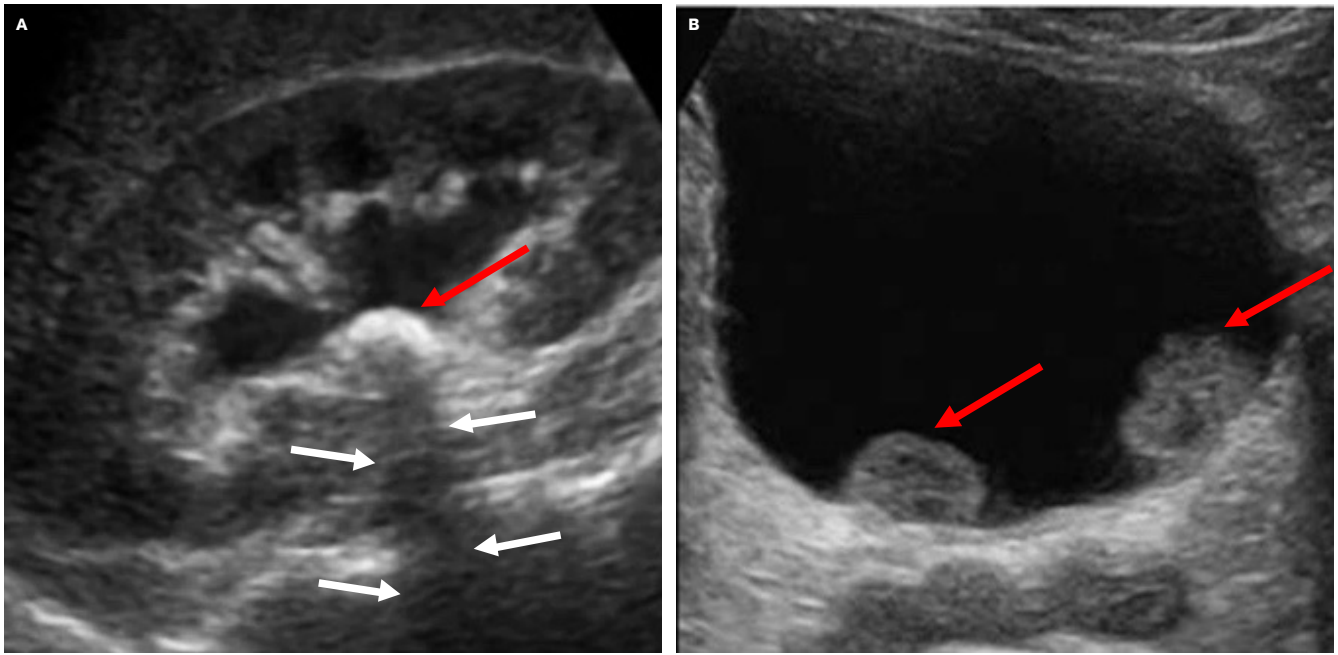

FIGURE 14

Kidney and bladder US. Characteristic features of lithiasis in the renal pelvis (**A**): red arrow points at the hyperechoic stone and **white arrows** indicate the acoustic shadow caused by the stone. (**B**) Two exophytic lesions of the bladder (**red arrows**). The differential diagnosis encompasses blood clots and bladder cancer. If exophytic lesions demonstrate central vascularisation on colour Doppler imaging and remain stationary when the patient changes position, a diagnosis of bladder tumour should be considered.

/ Computed Tomography

<!> ATTENTION

To comprehensively evaluate the entire urinary tract, **CT urography** should be performed, including acquisitions in the **non-contrast**, **corticomedullary**, **nephrographic** and **excretory phases**.

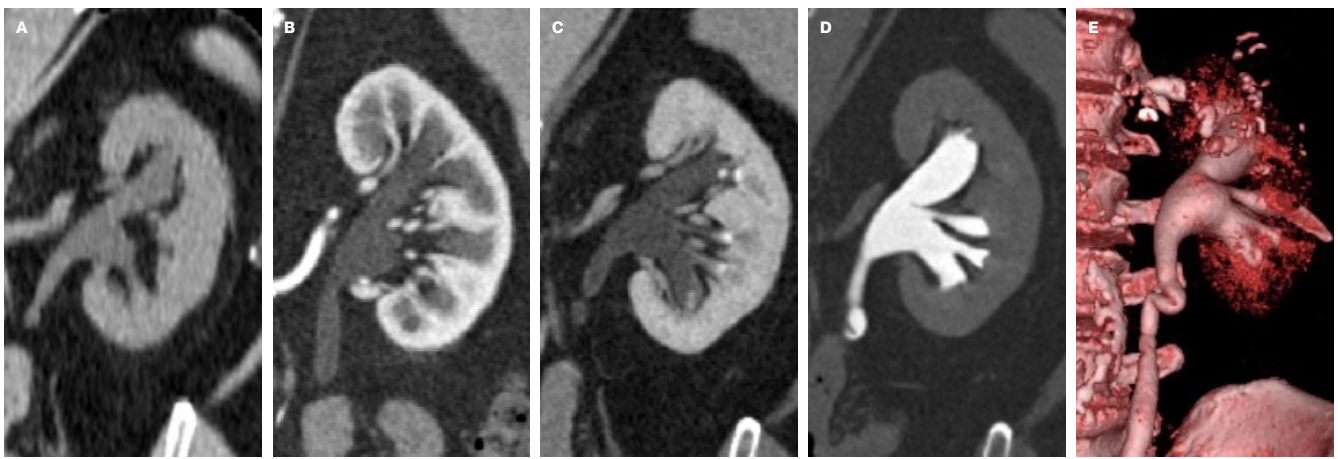

FIGURE 15

Normal CT urography (coronal reconstructions). Non-contrast (**A**), cortico-medullary (**B**), nephrographic (**C**), excretory (**D**) phase and 3D reconstruction of the excretory system (**E**).

Low dose and ultra low dose non contrast enhanced CT of the kidneys, ureters and bladder (**CT KUB**) represents a fast and noninvasive technique that enables the diagnosis of urinary tract stones in the emergency settings. Low dose CT equally allows the evaluation of stone size and location, as well as the presence of renal tract obstruction (Fig. 16).

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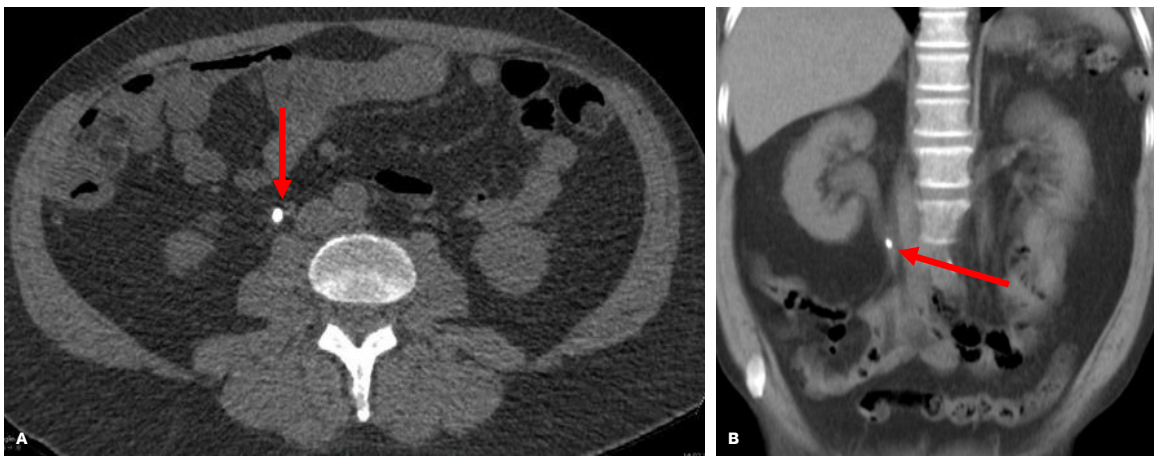


FIGURE 16

Axial (**A**) and coronal multiplanar reconstruction (**B**) of a low-dose CT acquisition depicting a calcified ureter stone (**arrows**). Figure courtesy: Alexandra Platon, MD, University Hospitals Geneva, Switzerland.

/ Magnetic Resonance Imaging (MRI)

<!> ATTENTION

Another highly advanced and powerful imaging technique is **multiparametric (mp) Magnetic Resonance Imaging (MRI)**, as illustrated in Fig. 17, which involves the administration of iv gadolinium-based contrast medium to acquire sequences that provide both morphological and functional information. This technique offers remarkable potential for the precise diagnosis and characterisation of urogenital lesions, particularly of bladder and prostate cancer.

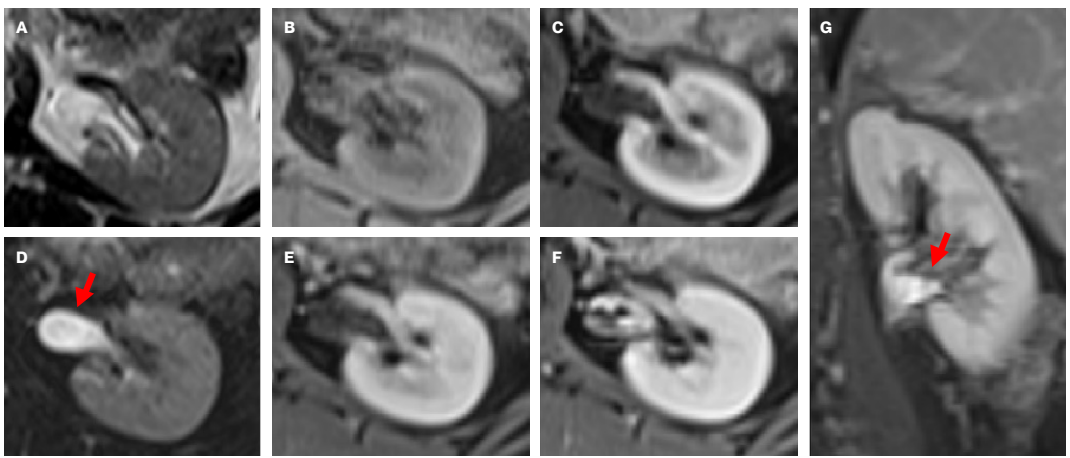


FIGURE 17

MR urography. T2 WI (**A**), fat-saturated non-enhanced T1WI (**B**), post-contrast sequences (**C-G**). Please note the urographic phase in the axial (**D**) and coronal plane (**G**) (**red arrows** point at the renal pelvis).

Urogenital Diseases

CHAPTER OUTLINE:

/ Urolithiasis

= calculi anywhere along the urinary tracts (i.e., caliceal, pelvic, pyeloureteral junction, ureteric, vesico-ureteric junction, bladder).

Approximately 12% of men and 5% of women are affected by urolithiasis. The most common renal stones are composed of calcium oxalate and they are often mixed with calcium phosphate. As stones pass from the kidneys into the ureters, they can lead to renal colic.

Calcium containing stones are radiopaque (Figs. 16 and 18). Non-contrast CT has the highest sensitivity for renal calculi detection (99%), whereas ultrasound (US) has a sensitivity of approximately 25%. The majority of calculi missed on US are less than 3 mm in size. Examples of renal stones are shown in Figs. 14, 16 and 18.

Complications of urolithiasis include:

- / renal pelvis rupture
- / urinary tract infection
- / hydronephrosis and hydroureter
- / parenchymal damage due to chronic obstruction

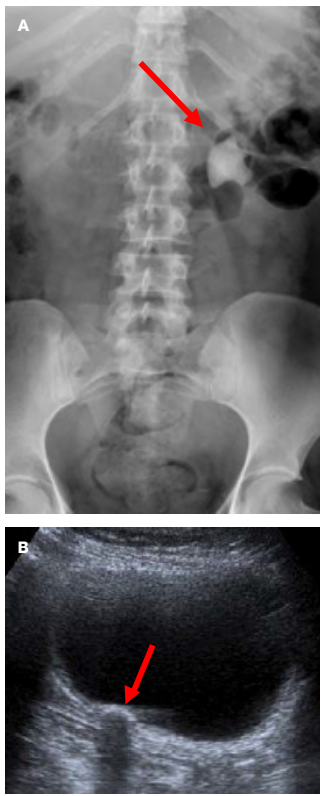


FIGURE 18

Two different patients with urolithiasis. Large left pelvic stone on plain radiograph (**arrow** in **A**).

Bladder stone on US (**arrow** in **B**). Figure courtesy: Alexandra Platon, MD, Geneva University Hospitals, Switzerland.

/ Hydronephrosis & Hydroureteronephrosis

Hydronephrosis = dilatation of the calices, infundibula and renal pelvis.

- Common causes include: urolithiasis, obstruction of the pelviureteric junction, cervical or prostate cancer.
- The role of imaging is to establish the underlying cause.
- On US, hydronephrosis is characterised by the dilation of the pelvicalyceal system. In cases of chronic hydronephrosis, the renal cortex may become thinned.
- CT not only facilitates the diagnosis of hydronephrosis but also helps identify its underlying cause.

Hydroureteronephrosis = hydronephrosis accompanied by ureter dilatation.

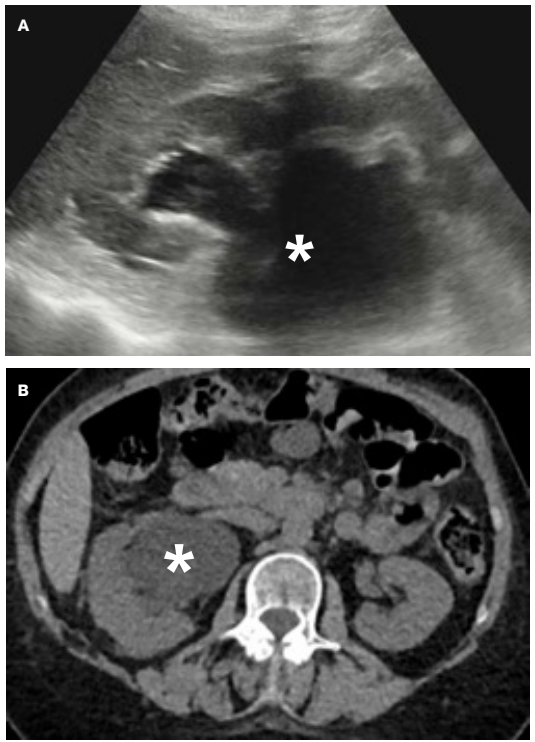


FIGURE 19

US image of the right kidney (**A**) showing characteristic features of hydronephrosis (**asterisk**). CT appearance of hydronephrosis (**asterisk** in **B**). Figure courtesy: Minerva Becker, MD, Geneva University Hospitals, Switzerland.

/ Acute Pyelonephritis

= infection of the upper urinary tract (i.e., renal pelvis, calyces and renal parenchyma).

Acute pyelonephritis is a bacterial infection typically caused by organisms from the gastrointestinal tract. It is most often seen in young women. Although the diagnosis is primarily based on clinical evaluation and laboratory findings, imaging is indicated to exclude the cause of renal obstruction, as well as in immunocompromised patients and those with underlying renal diseases (Fig. 20). Complications of acute pyelonephritis include abscess formation, urosepsis, renal vein thrombosis, renal infarction and chronic renal impairment.

Emphysematous pyelonephritis is a bacterial kidney infection with gas formation. It is seen more often in immunocompromised patients. It has a high mortality if it is not promptly treated.

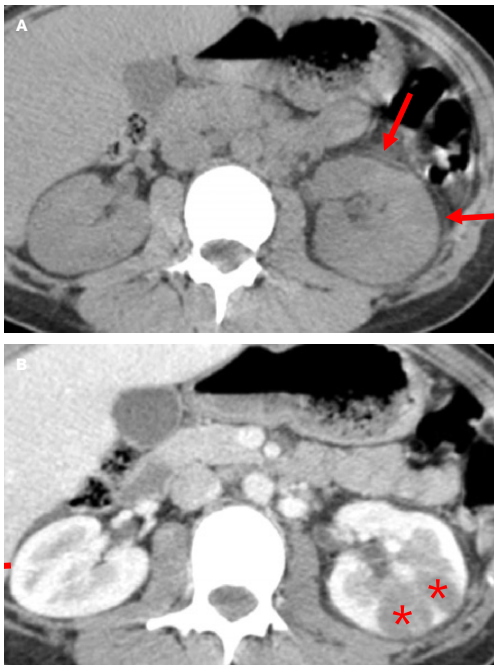


FIGURE 20

Acute pyelonephritis in a diabetic patient. Non- contrast enhanced CT shows swollen left kidney and perinephric fat stranding appearance (**arrows**). On post-contrast CT image, a swollen, wedge-shaped region involving the peripheral cortex is observed (**asterisks**).

Figure courtesy: Minerva Becker, MD, Geneva University Hospitals, Switzerland.

/ Renal Masses

<!> ATTENTION

Renal masses are common and are usually identified incidentally during ultrasound, CT, or MR exams performed for unrelated reasons.

Renal masses can be divided into two groups:

1. CYSTIC LESIONS: (FIGS. 21 AND 22)

/ Simple renal cysts are a very common collateral finding during imaging examination.

/ However, they may exhibit specific alarm features. In this scenario, the Bosniak classification (see next page, Fig. 21) plays a crucial role in assessing the risk of malignancy in cystic renal masses. It categorises them into five groups, helping to determine the appropriate follow-up (Bosniak IIF) or the need for surgical intervention (Bosniak III and IV).

2. SOLID MASSES (FIG. 23):

/ Approximately 80% of kidney masses are malignant, with renal cell carcinoma (RCC) comprising around 80% of all malignant kidney cancers. RCCs arise from the tubular epithelium and encompass several distinct histological subtypes.

- / Clear cell (70- 80%)
- / Papillary (10-15%)
- / Chromophobe (5%)
- / Other (< 1%, collecting duct carcinoma and medullary carcinoma).

/ 1. Cystic Lesions

CLASS	CURRENT BOSNIAK CLASSIFICATION
I	Hairline-thin wall; water attenuation; no septa, calcifications, or solid components; nonenhancing
II	Two types: 1. Few thin septa with or without perceived (not measurable) enhancement; fine calcification or a short segment of slightly thickened calcification in the wall or septa 2. Homogeneously high-attenuating masses ≤ 3 cm that are sharply marginated and do not enhance
IIF	Two types: 1. Minimally thickened or more than a few thin septa with or without perceived (not measurable) enhancement that may have thick or nodular calcification 2. Intrarenal nonenhancing hyperattenuating renal masses > 3 cm
III	Thickened or irregular walls or septa with measurable enhancement
IV	Soft-tissue components (ie, nodule[s]) with measurable enhancement

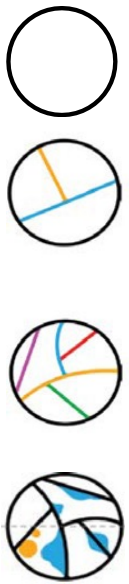


FIGURE 21

Determination of wall and septa thickness/irregularity by using the Bosniak classification of cystic renal masses, version 2019.

/ 1. Cystic Lesions

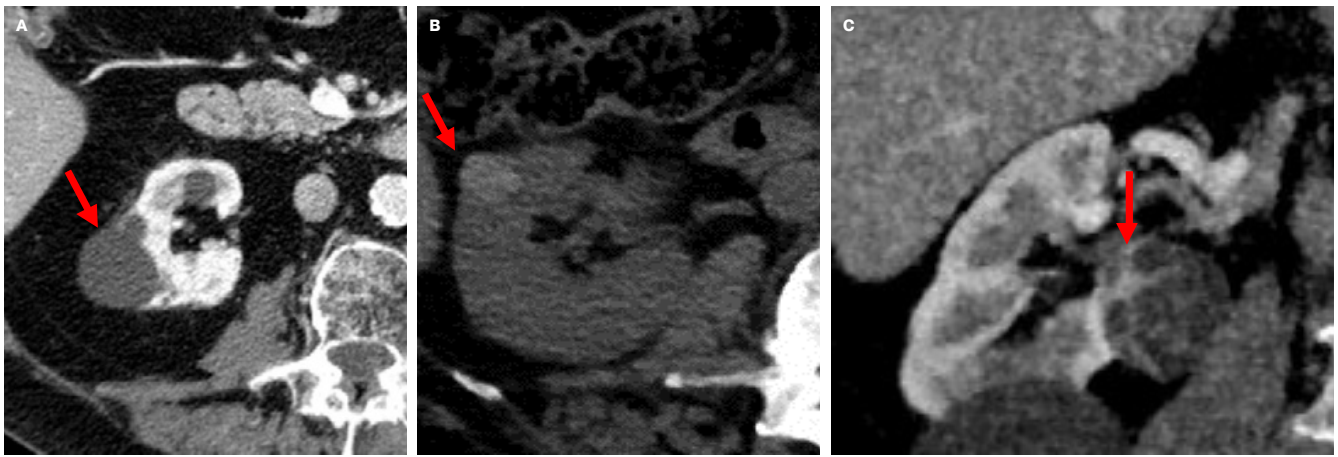


FIGURE 22

Spectrum of complex cystic lesions as categorised by the Bosniak classification. Cystic lesion with homogeneous simple fluid (**red arrow**), Bosniak type I (**A**); hyperdense cystic lesion (**red arrow**) in non-contrast phase, Bosniak type II (**B**); enhancing nodule (**red arrow**) and multiple septa, Bosnkia type IV (**C**).

/ 2. Solid Masses

Benign Lesions:

- / Angiomyolipoma
- / Oncocytoma
- / Pseudotumour

Malignant Lesions:

- / Renal Cell Carcinoma
- / Urothelial Carcinoma
- / Lymphoma

/ 2. Solid Masses

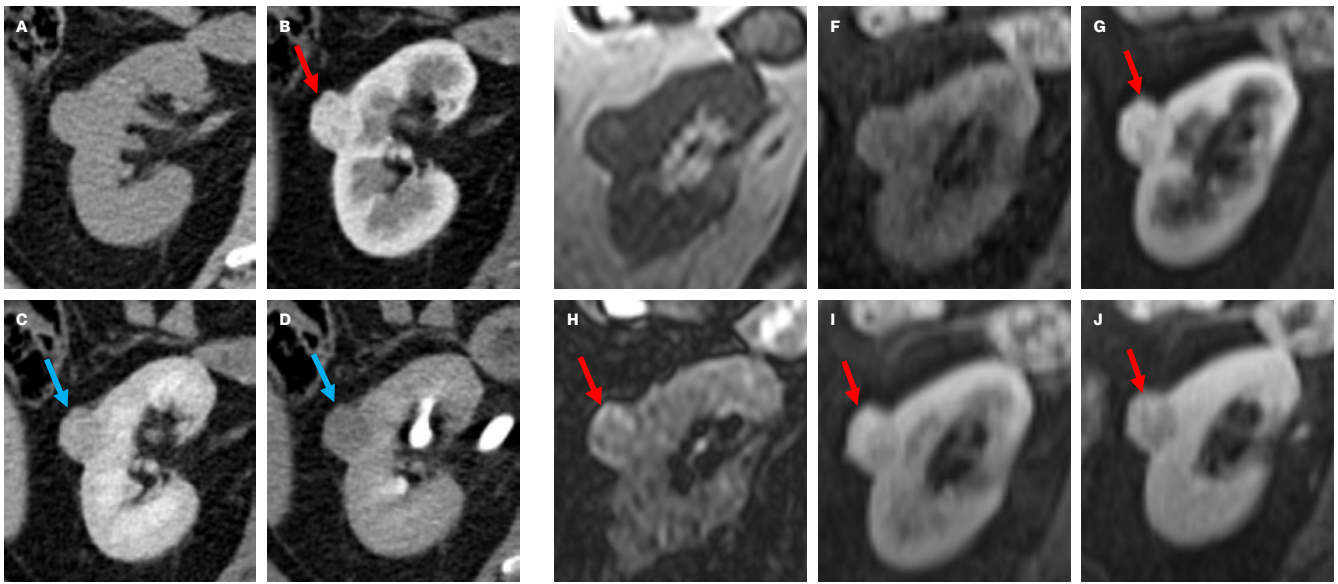


FIGURE 23

CT (**A-D**) and MRI (**E-J**) images showing imaging features corresponding to renal cell carcinoma. More specifically, the CT image on arterial phase (**B**) shows a hypervascular solid mass (**red arrows**), with «wash out» on nephrographic and delayed phases (**C** and **D**, respectively, **blue arrows**). T1WI (**E**), fat saturated T1 WI (**F**), arterial phase fat saturated T1WI (**G**), nephrogenic phase fat saturated T1WI **(I)**, excretory phase saturated T1WI (**J**).

<!> ATTENTION

Several anatomical characteristics of renal tumours are routinely evaluated in preoperative imaging to classify renal masses into low, intermediate, and high complexity, aiding in surgical planning.

These include:

/ Tumour size

/ Exophytic / endophytic tumour **growth pattern** and **exophytic rate**

/ **Proximity to the renal collecting system** or renal parenchyma.

/ Precise localisation (using **renal segmentation**)

/ Presence of **feeding artery**

/ Bladder Cancer

Bladder cancer (BCa) is one of the most frequently diagnosed cancers, with approximately 550,000 new cases reported annually. Urothelial cell carcinoma is the most common histologic type of BCa, representing more than 90% of all cases.

Staging and therapy depend on the **invasion of the muscularis propria**; in fact, **non muscle invasive BCa (NMIBC)** (stage T1) is managed with trans urethral resection of bladder tumour (TURBT), whereas **muscle invasive BCa (MIBC)** (stage T2 or higher) requires radical cystectomy or radiotherapy or, in selected cases neoadjuvant chemotherapy (6).

The detrusor invasion represents the most important predictive and prognostic factor: MIBC is associated with a significantly poorer prognosis compared to NMIBC. This highlights the crucial role of pathological and radiological assessment of muscle invasion, which has a significant impact on treatment strategies (3).

<!> ATTENTION

MRI is considered the best imaging modality for regional staging of bladder cancer (BCa) due to its superior contrast resolution of soft tissues and its ability to assess the muscularis propria, tumour infiltration grade and perivesical extension.

Multiparametric MRI (mpMRI) of the bladder is a crucial diagnostic tool for bladder cancer management since it combines anatomical and functional sequences, improving the local tumour staging compared to conventional imaging alone (Fig. 24).

On T2-weighted imaging (T2WI), the muscularis propria (detrusor muscle) appears as a low-signal intensity (SI) line, which is continuous in case of non-muscle-invasive bladder cancer (NMIBC). On the other hand, in case of muscle-invasive bladder cancer (MIBC), this low-signal intensity line is interrupted, indicating possible muscle infiltration.

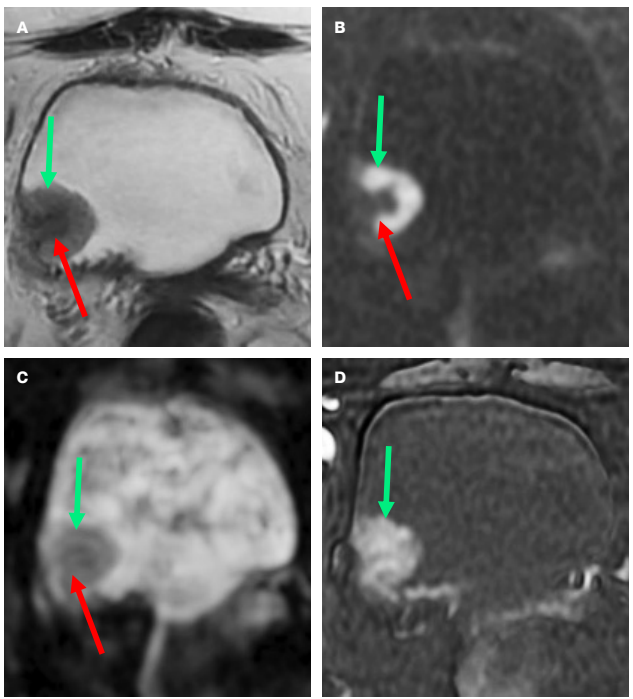


FIGURE 24

Bladder MRI (axial images) showing an exophytic and pedunculated lesion (**green arrows**), with a stalk (**red arrows**). T2 weighted image (**A**), DWI at b1000 image (**B**), ADC map (**C**), subtraction image T1 + Gd – T1 (**D**). Note restricted diffusion and strong contrast enhancement. Histology revealed non-muscle-invasive bladder cancer (NMIBC).

<!> ATTENTION

Bladder cancer has a high signal intensity on DWI and a low signal intensity on ADC map. After contrast injection tumours show early enhancement on dynamic contrast-enhanced (DCE) MRI. (7).

<!> ATTENTION

A new scoring system, the **VI-RADS (Vesical Imaging Reporting and Data System) score**, has been developed to define a standardised approach for image acquisition, interpretation and reporting of mpMRI of the bladder, defining the risk of BCa muscle invasion (7) as shown in **Fig. 25**.

The score is based on T2WI, DCE-MRI and DWI findings. Therefore, three categories can be identified: structural categories (SC) for T2WI, contrast-enhanced (CE) categories for DCE sequences, and diffusion weighted (DW) categories for DWI and ADC map. The final score is based on these categories on a 5-point scale, reflecting the likelihood of **muscle invasion**.

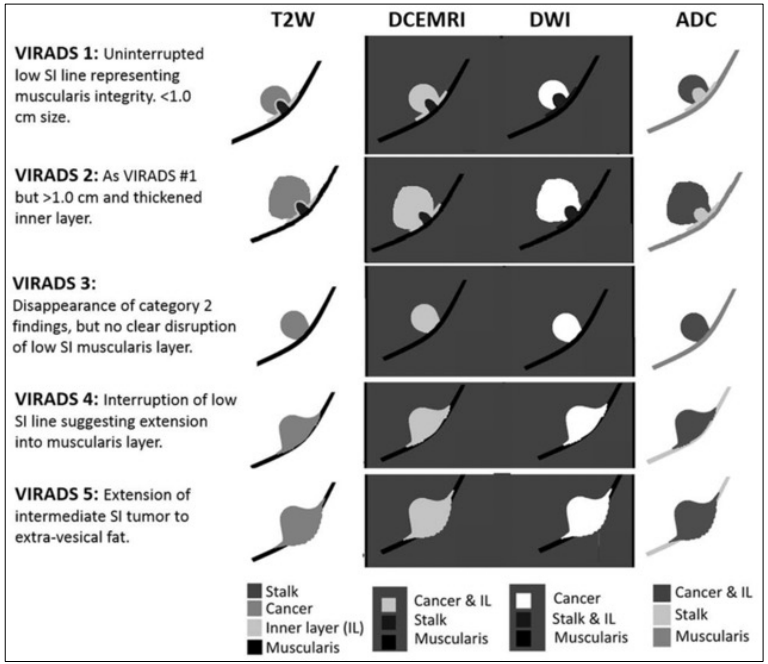


FIGURE 25

Schematic illustration of appearances of VI-RADS scores 1–5 on T2W, DCE, DWI and ADC sequences. ADC =apparent diffusion coefficient; DCE = dynamic contrast enhancement; DWI =diffusion-weighted imaging; SI =signal intensity. Image reproduced from : Panebianco V, Narumi Y, Altun E, et al. Multiparametric Magnetic Resonance Imaging for Bladder Cancer: Development of VI-RADS (Vesical Imaging-Reporting And Data System). Eur Urol. 2018 Sep;74(3):294-306. doi: 10.1016/j.eururo.2018.04.029. Free PMC article. Review.

CHAPTER OUTLINE:

/ Prostate Diseases

The two most common prostate diseases are:

- **Benign Prostate Hyperplasia (BPH)**, a non-cancerous enlargement of the prostate gland associated with urinary symptoms, including slow urinary stream, urinary frequency (especially nocturia), urgency and urinary retention with incomplete bladder emptying.
- **Prostate cancer**, the second most frequent cancer in men. Prostate cancer is usually suspected on the basis of PSA levels. Definitive diagnosis depends on histopathological verification of adenocarcinoma in prostate core biopsies.

<!> ATTENTION

As benign prostatic hyperplasia (BPH) progresses, the Transition Zone becomes a larger proportion of the prostate's total volume. On the other hand, prostate cancer typically originates in the Peripheral Zone (5).

US Role in the Prostate

- To measure prostate enlargement due to BPH in the pre-treatment setting
- To detect inflammatory conditions
- To guide procedures such as needle biopsies

<!> ATTENTION

Standard transrectal ultrasound (TRUS) is not considered reliable for detecting prostate cancer.

MRI Role for Prostate Cancer

Multiparametric MRI (mpMRI) combines anatomic T2W imaging with functional assessment, including DWI and ADC maps and dynamic contrast-enhanced (DCE) sequences.

MRI demonstrates high sensitivity and specificity for detecting and localising prostate cancer (Fig. 26). Additionally, the clinical applications of prostate MRI have expanded to include surveillance, assessment of suspected recurrence, and image guidance for biopsy, surgery, focal therapy and radiation therapy.

<!> ATTENTION

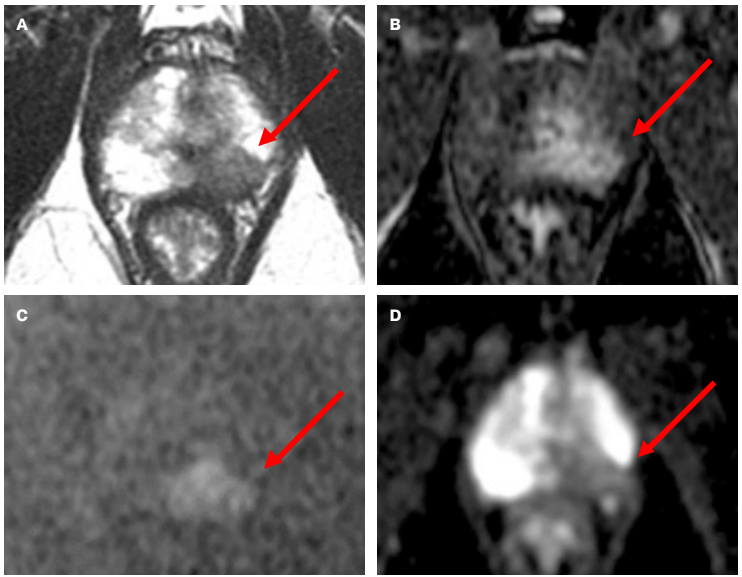


FIGURE 26

Prostate mpMRI (axial images) demonstrating the characteristic features of prostate cancer (**arrows**). T2 WI (**A**), DCE MRI image (**B**), DWI with a b value of 2000 (**C**) and ADC map (**D**). Figure part **A** shows a hypointense lesion in T2 WI localised in the peripheral zone (5 o'clock), with an early and focal enhancement (**B**) after administration of contrast medium (for the detection of neoangiogenesis). On (**C**), the lesion has a high signal intensity and on the ADC map (**D**), a very low signal because of restricted diffusivity. Restricted diffusivity reflects increased cellularity and high cell proliferation.

<!> ATTENTION

The Prostate Imaging-Reporting and Data System (PI-RADS, Fig. 27) was developed, to provide a systematic and standardised approach for the acquisition, interpretation, and reporting of prostate mpMRI (5).

Each lesion is assigned a PI-RADS Assessment Category on a 5-point scale, based on the likelihood that findings from T2WI, DWI, and DCE imaging are associated with clinically significant prostate cancer.

Lesions classified as PI-RADS score of 4 or higher are referred for a targeted biopsy. PI-RADS 3 lesions' management is stil highly debated.

>=< FURTHER KNOWLEDGE

PIRADS 1 – Very low (clinically significant cancer is highly unlikely to be present)

PIRADS 2 – Low (clinically significant cancer is unlikely to be present)

PIRADS 3 – Intermediate (the presence of clinically significant cancer is equivocal)

PIRADS 4 – High (clinically significant cancer is likely to be present)

PIRADS 5 – Very high (clinically significant cancer is highly likely to be present)

FIGURE 27

Risk assessment using PI-RADS score version 2.1

/ Testicular Diseases

The two most common types of testicular disease are:

1. Testicular torsion

Occurs when a testicle twists on the spermatic cord, cutting off its blood supply. The most common symptom is sudden and intense pain.

The diagnosis is initially suspected based on clinical findings but must be confirmed with colour Doppler ultrasound (10), as illustrated in Fig. 28. Early diagnosis is crucial, as testicular infarction can be avoided with a 100% salvage rate if treated within 6 hours.

<!> ATTENTION

US represents the imaging modality of choice for the assessment of suspected testicular torsion.

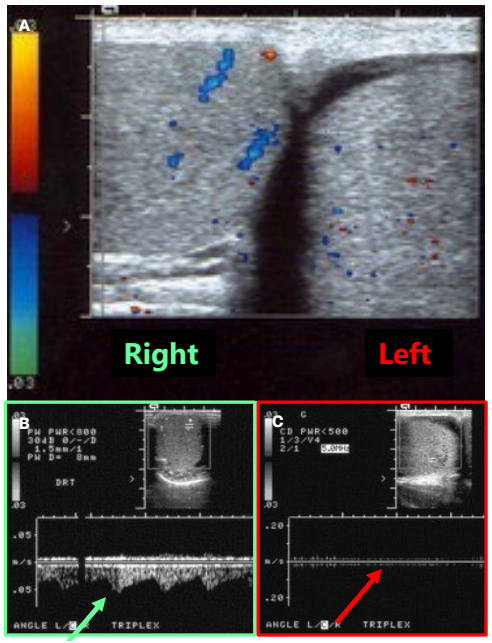


FIGURE 28

Testicular torsion as seen on colour Doppler US. The patient presented with severe pain in the left testis. Colour Doppler images (**A**, **B** and **C**) of the left and right testis showed massively altered blood flow on the left side with increased resistive index. Note normal arterial flow curve on the right (**B**) and absent arterial flow curve on the left (**C**). Figure courtesy: Alexandra Platon, MD, Geneva University Hospitals, Switzerland.

2. Testicular Cancer

Testicular cancer accounts for 1% of all male cancers and is the most common type in men during their 3rd and 4th decades of life. Over 90% of testicular cancers are primary germ cell tumours. In men over the age of 70, lymphoma is the most common type of testicular cancer.

EAU (European Association of Urology) recommends to perform:

- Bilateral testicular US in patients with suspicion of testicular cancer (Fig. 29)
- Contrast enhanced CT of the chest, abdomen and pelvis for staging

<!> ATTENTION

MRI of the scrotum provides higher sensitivity and specificity compared to ultrasound in the diagnosing testicular cancer, but its higher cost limits its routine use.

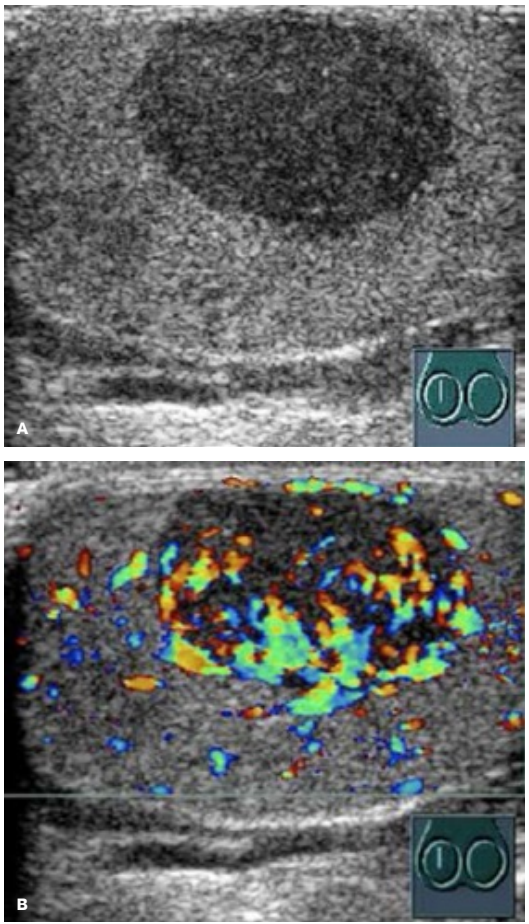


FIGURE 29

Example of a sagittal testicular US image showing a right, nodular, hypoechoic testicular tumour (**A**) with increased vascularity on the colour Doppler image (**B**). Image courtesy: Thomas de Perrot, MD, Geneva University Hospitals.

/ Penile Diseases

Penile cancer is a very rare tumour.

Although penile fractures (Fig. 30) are rare, they require immediate diagnosis and treatment as they constitute a medical emergency. These injuries involve rupture of the penile tunica albuginea of the corpora cavernosa or spongiosum, typically caused by trauma to an erect penis, most often during sexual intercourse.

- **Emergency ultrasound with Doppler** is usually the initial imaging modality, to verify the presence of fracture and haematoma (a common complication).
- **MRI** of the penis (Fig. 30) is the most valuable imaging technique for assessing the extent of the injury, determining its precise location and depth, and identifying potential complications. These are crucial points to be addressed, to guarantee the most appropriate therapeutic approach (surgery vs conservative approach).

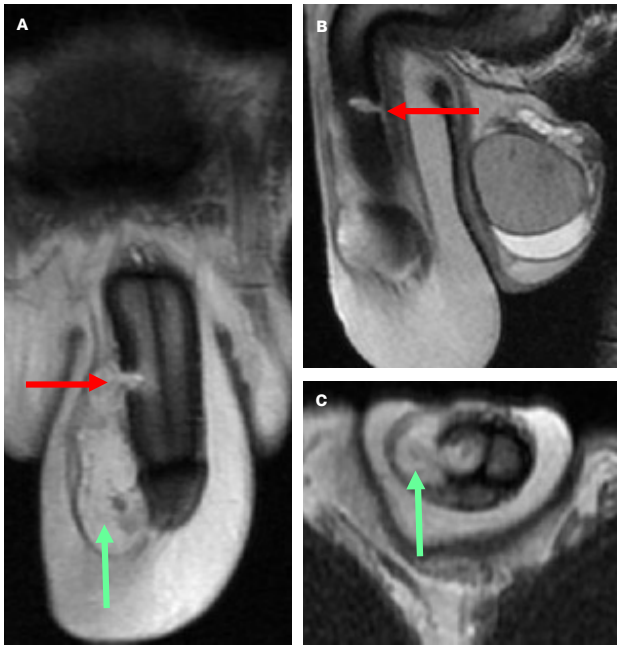


FIGURE 30

Penile fracture on MRI. Coronal (**A**), sagittal (**B**) and axial (**C**) T2 weighted images. Note the breach as red arrow in the band of fibrous tissue (tunica albuginea) and the haematoma alongside the breach (**green arrow**).

Interventional Procedures

CHAPTER OUTLINE:

/ Renal Procedures

Even if radical and partial nephrectomy remain the gold standard treatments for renal cancer, interventional procedures such as tumour ablation serve as viable alternatives for patients with small renal masses (< 3 cm).

Tumour ablation (TA) includes two main techniques:

CRYOABLATION (CA)

RADIOFREQUENCY ABLATION (RFA)

> See also eBook chapter on Interventional Radiology

<!> ATTENTION

A RENAL MASS BIOPSY prior to tumour ablation is mandatory, according to European Association of Urology guidelines!

These focal therapies have advantages for

- / Kidney function preservation
- / Minimising bleeding
- / Reducing operative time
- / Reduction in the duration of hospitalisation

/ MRI Targeted – Transrectal Ultrasound (TRUS) Biopsy "Fusion Biopsy"

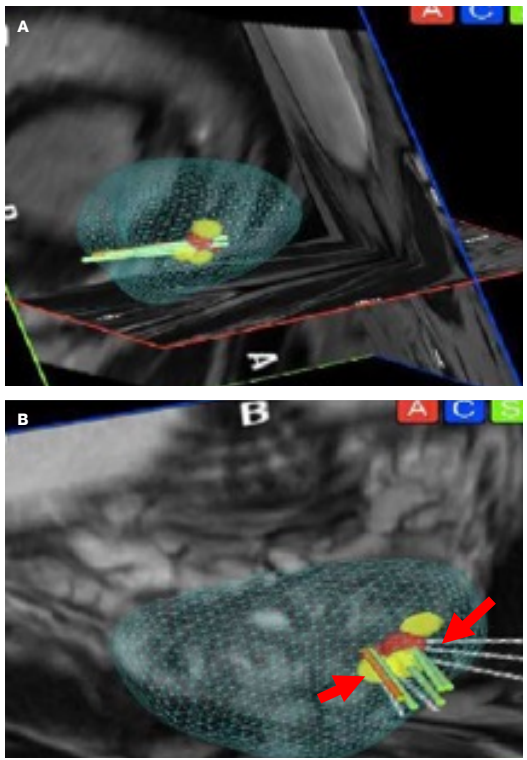
MRI targeted biopsy, which differs from traditional systematic biopsy, involves targeted procedures that focus on specific lesions identified on MRI images and includes:

1. "Fusion biopsy"

Pre-biopsy MRI images are "fused" with "real time" transrectal ultrasound (TRUS) images as shown in Fig. 31 to guide biopsy sampling (11) (12).

FIGURE 31

Virtual representation of a TRUS-biopsy. In particular, the figures show the co- registration of MRI and US images of the prostate, with the reconstruction of the biopsy targets and cores (**red arrows**).

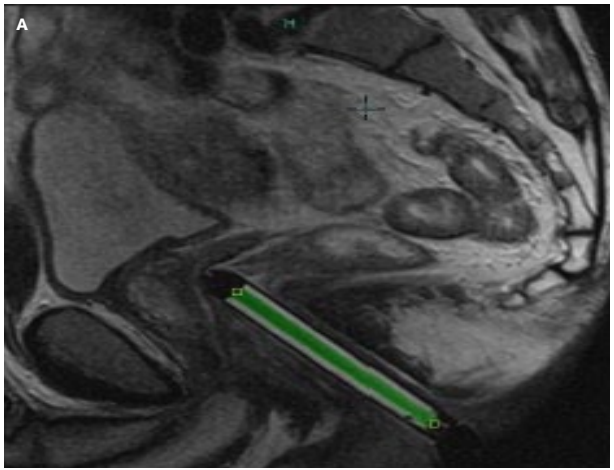


<!> ATTENTION

- / Enhanced accuracy and precision in tumour tissue detection
- / Reduced number of tissue samples required
- / Minimised pain and lower risk of complications
- / Faster post-procedure recovery

2. “In-bore” biopsy

This approach allows for prostate tissue sampling under direct MR guidance using a robotic system (Fig. 32), providing precise visualisation of the needle's position within the targeted lesion for improved accuracy and reliability.



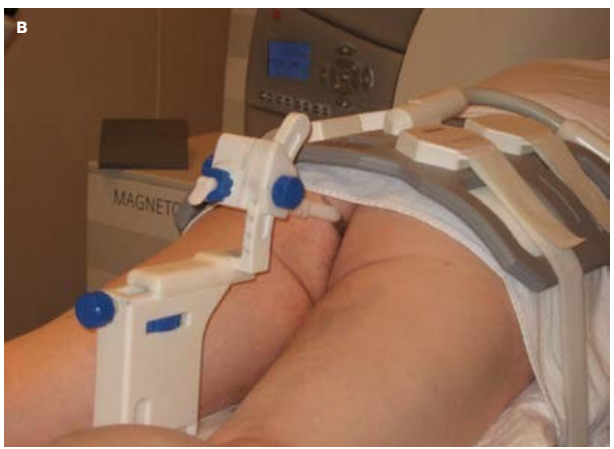


FIGURE 32

In-bore biopsy. Figure (**A**) shows a sagital T2-weighted image obtained before the biopsy to visualise the prostate and to identify the target lesion. Figure (**B**) shows the patient in the prone position and the optimal placement of the device.

The sequences are acquired along the axis of the amagnetic needle to assess the correct position with respect to the target lesion and establish its direction and depth.

/ Focal Therapy in Prostate Cancer

Focal therapy is an alternative to surgery or radiation therapy. It uses high doses of various types of energy to selectively target and eliminate malignant cells (13). Two examples:

>|< COMPARE

CRYOTHERAPY:

Rapidly cool the cancerous tissue, inducing extreme hypothermia which kills the cancer cells.

POTENTIAL ADVANTAGES:

Reduction of side effects

HIGH INTENSITY FOCUSED ULTRASOUND (HIFU):

Using sound waves to kill the cancer cells.

REMAINING QUESTIONS:

Cancer control

> See also eBook chapter on Interventional Radiology

/ Minimally Invasive Surgical Therapies (MISTs) in BPH

Recent advancements in the surgical management of benign prostatic hyperplasia (BPH) have led to significant improvements, thanks to the introduction of minimally invasive surgical techniques (MISTs).

Prostatic artery embolisation (PAE) is one of these endovascular procedures performed under local anaesthesia with access through the femoral or radial arteries. Digital subtraction angiography (DSA) is employed to visualise the arterial anatomy, enabling selective embolisation of the prostatic arteries responsible for the blood supply to the prostate (14).

<!> ATTENTION

Current evidence supporting the safety and efficacy of PAE endorses its use in men with moderate-to-severe lower urinary tract symptoms, although PAE is still under investigation.

/ Take-Home Messages

Kidney

Imaging is used for:

- / Detection and diagnosis of renal masses.
- / Therapeutic and surgical planning.
- / Establish time 0 for active surveillance.
- / Guide for Focal Therapies.

Bladder

- / If clinically suspected, perform an ultrasound of the bladder.
- / MRI of the bladder is useful for local staging of the disease and for differentiating NMIBC from MIBC, which significantly impacts patient management.

Prostate

- / MpMRI of the prostate is a first-line diagnostic tool for detecting prostate cancer, due to its combination of morphological and functional imaging sequences.
- / PI-RADS score defines the probability of clinically significant disease.
- / When MRI is suspicious, perform a targeted biopsy.

Testicles

- / Perform a bilateral testicular ultrasound in patients with clinical suspicion of testicular cancer and CT for staging.
- / Perform a Doppler ultrasound to confirm the diagnosis of testicular torsion.

Penis

- / In cases of penile cancer or penile fracture, MRI is indicated after US to confirm the diagnosis, assess complications, and guide correct treatment decisions.

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Test Your Knowledge

CHAPTER OUTLINE:

/ Test Your Knowledge

<?> QUESTION

1 Can cross-sectional imaging distinguish between renal cortex and medulla?

- ☐ Yes
- ☐ No

/ Test Your Knowledge

<?> ANSWER

1 Can cross-sectional imaging distinguish between renal cortex and medulla?

- ■ Yes
- ☐ No

/ Test Your Knowledge

<?> QUESTION

2 When can a duplicated collecting system be defined as complete?

(One or more than one answer can be correct.)

- ☐ There are two renal pelvises
- ☐ There are two ureters that open in the same ostium
- ☐ There are two ureters that separately open into the bladder
- ☐ There are two kidneys for side

/ Test Your Knowledge

<?> ANSWER

2 When can a duplicated collecting system be defined as complete?

(One or more than one answer can be correct.)

- ■ There are two renal pelvises
- ☐ There are two ureters that open in the same ostium
- ■ There are two ureters that separately open into the bladder
- ☐ There are two kidneys for side

/ Test Your Knowledge

<?> QUESTION

3 Ureters can be anatomically divided into:

- ☐ Two parts: proximal and distal ureter
- ☐ Two parts: abdominal and pelvic ureter
- ☐ Three parts: abdominal, pelvic and intramural ureter
- ☐ Four parts: abdominal, pelvic, extramural and intramural ureter

/ Test Your Knowledge

<?> QUESTION

3 **Ureters can be anatomically divided into:**

- ☐ Two parts: proximal and distal ureter
- ☐ Two parts: abdominal and pelvic ureter
- ■ Three parts: abdominal, pelvic and intramural ureter
- ☐ Four parts: abdominal, pelvic, extramural and intramural ureter

/ Test Your Knowledge

<?> QUESTION

4 When is a cystic renal lesion classified as Bosniak IV?

- ☐ Irregular septa with measurable contrast enhancement
- ☐ Wall/septa calcifications
- ☐ Hyperattenuating lesion at non-contrast CT
- ☐ Nodular components with measurable contrast enhancement

/ Test Your Knowledge

<?> ANSWER

4 When is a cystic renal lesion classified as Bosniak IV?

- ☐ Irregular septa with measurable contrast enhancement
- ☐ Wall/septa calcifications
- ☐ Hyperattenuating lesion at non-contrast CT
- ■ Nodular components with measurable contrast enhancement

/ Test Your Knowledge

<?> QUESTION

5 When is surgical therapy indicated for a renal cystic lesion?

(One or more than one answer can be correct.)

- ☐ Bosniak I
- ☐ Bosniak II
- ☐ Bosniak III
- ☐ Bosniak IV

/ Test Your Knowledge

<?> ANSWER

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/ Test Your Knowledge

<?> QUESTION

6 **The VI-RADS score suggests the probability of?**

(One or more than one answer can be correct.)

- ☐ Presence of bladder cancer
- ☐ Muscle invasiveness of bladder cancer
- ☐ Fat tissue involvement of bladder cancer
- ☐ All the answers

/ Test Your Knowledge

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/ Test Your Knowledge

<?> QUESTION

7

69 years old man undergoing mpMRI of the prostate, which shows on the left peripheral zone a hypointense 10 mm lesion on T2WI, associated with restricted diffusion on DWI/ADC map and post contrast early enhancement. Which PI-RADS score would you assign?

- ☐ PI-RADS 2
- ☐ PI-RADS 3
- ☐ PI-RADS 4
- ☐ PI-RADS 5

/ Test Your Knowledge

<?> ANSWER

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- ☐ PI-RADS 5

/ Test Your Knowledge

<?> QUESTION

8

How can you perform a prostate biopsy?

(One or more than one answer can be correct.)

- ☐ US-guided
- ☐ Fluoroscopy-guided
- ☐ MRI-guided
- ☐ CT-guided

/ Test Your Knowledge

<?> ANSWER

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/ Test Your Knowledge

<?> QUESTION

9 A 44-year-old male presents with right testicular pain and enlargement of the testis, without a history of trauma. What would be your initial management approach?

- ☐ X-ray
- ☐ US
- ☐ MRI
- ☐ CT with CE

/ Test Your Knowledge

<?> ANSWER

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- ■ US
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- ☐ CT with CE

/ Test Your Knowledge

<?> QUESTION

10 US in the patient from question 9 reveals testis enlargement with low signal on colour-Doppler; what do you suspect?

- ☐ Seminoma
- ☐ Testicular torsion
- ☐ Varicocele
- ☐ Acute orchitis

/ Test Your Knowledge

<?> ANSWER

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