EUROPEAN SOCIETY OF RADIOLOGY

eBook for Undergraduate Education in Radiology

CHAPTER: Urogenital Radiology

Preface

Undergraduate teaching of radiology in Europe is provided according to national schemes and may vary considerably from one academic institution to another. Sometimes, the field of radiology is considered as a "cross-cutting discipline" or taught within the context of other clinical disciplines, e.g., internal medicine or surgery.

This e-book has been created in order to serve medical students and academic teachers throughout Europe to understand and teach radiology as a whole coherent discipline, respectively. Its contents are based on the *Undergraduate Level of the ESR European Training Curriculum for Radiology* and summarize the so-called ***core elements*** that may be considered as the basics that every medical student should be familiar with. Although specific radiologic diagnostic skills for image interpretation cannot be acquired by all students and rather belong to the learning objectives of the *Postgraduate Levels of the ESR Training Curricula*, the present e-book also contains some ***further insights*** related to modern imaging in the form of examples of key pathologies, as seen by the different imaging modalities. These are intended to give the interested undergraduate student an understanding of modern radiology, reflecting its multidisciplinary character as an organ-based specialty.

We would like to extend our special thanks to the authors and members of the ESR Education committee who have contributed to this eBook, to Carlo Catalano, Andrea Laghi and András Palkó, who initiated this project, and to the ESR Office, in particular, Bettina Leimberger and Danijel Lepir, for all their support in realizing this project.

We hope that this eBook may fulfil its purpose as a useful tool for undergraduate academic radiology teaching.

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eBook for Undergraduate Education in Radiology

Based on the ESR Curriculum for Undergraduate Radiological Education

Chapter: Urogenital Radiology

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Test Your Knowledge

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 are located behind the parietal peritoneum. A fibrous connective tissue, the renal capsule, tightly envelopes each kidney that is surrounded by perirenal fat, which helps protect it, and held in place by connective tissue, called renal fascia.

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

A *new kidney segmentation system* has recently been developed. It divides the kidney into *12 segments*, in particular, the upper pole, the middle third and the lower pole are further divided into 4 parts, anterior/posterior and lateral/medial (1) as shown in Fig. 1.

This system improves the diagnostic segmentation of the kidneys which plays an important role in the treatment planning of renal tumours, especially in view of nephron-sparing surgery.

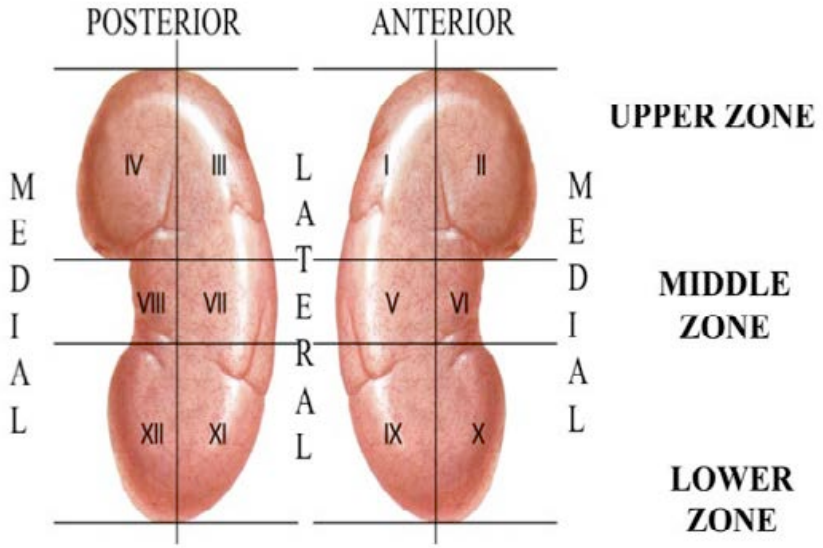

Figure 1 Renal segments.

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The kidney is composed of the *medulla* and *cortex.*

It is very important to describe corticomedullar ratio in imaging, as an index of renal function. The renal medulla consists of a series of renal pyramids; their pointed ends are called renal papillae which open into the minor and major calyces, that converge to form the renal pelvis (Fig. 2).

For differences between the adult and the paediatric kidneys => see chapter on paediatric radiology.

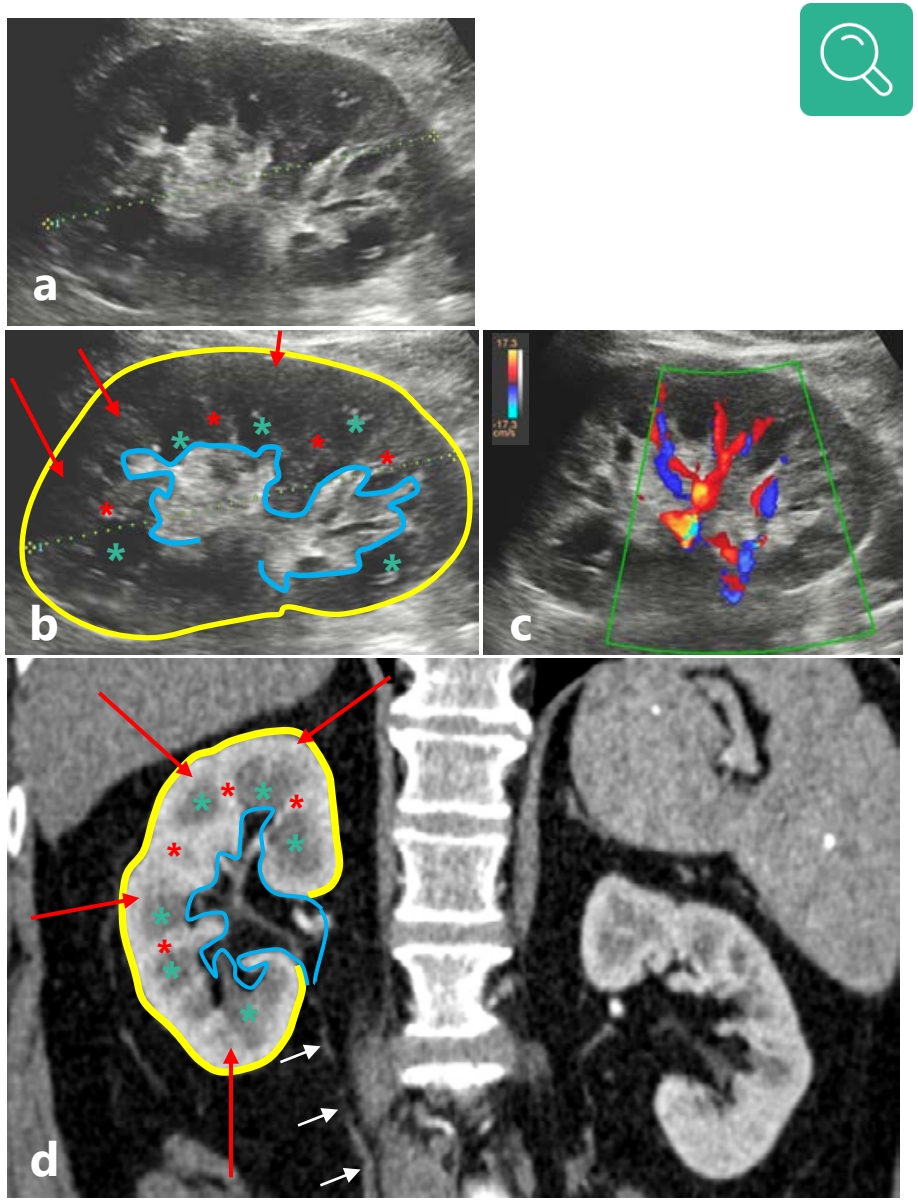

Figure 2. Normal renal anatomy. Sagittal ultrasonography (US) image of the left kidney (a) and corresponding annotated image (b), colour Doppler US (c) and coronal reconstruction of arterial phase CT (d). The renal cortex (red arrows) lies at the periphery under the renal capsule (yellow line). The medulla consists of renal pyramids (green asterisks), which are separated from each other by renal columns (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 large cavity that collects the urine as it is produced; from there, it flows into the ureter (Fig. 3)

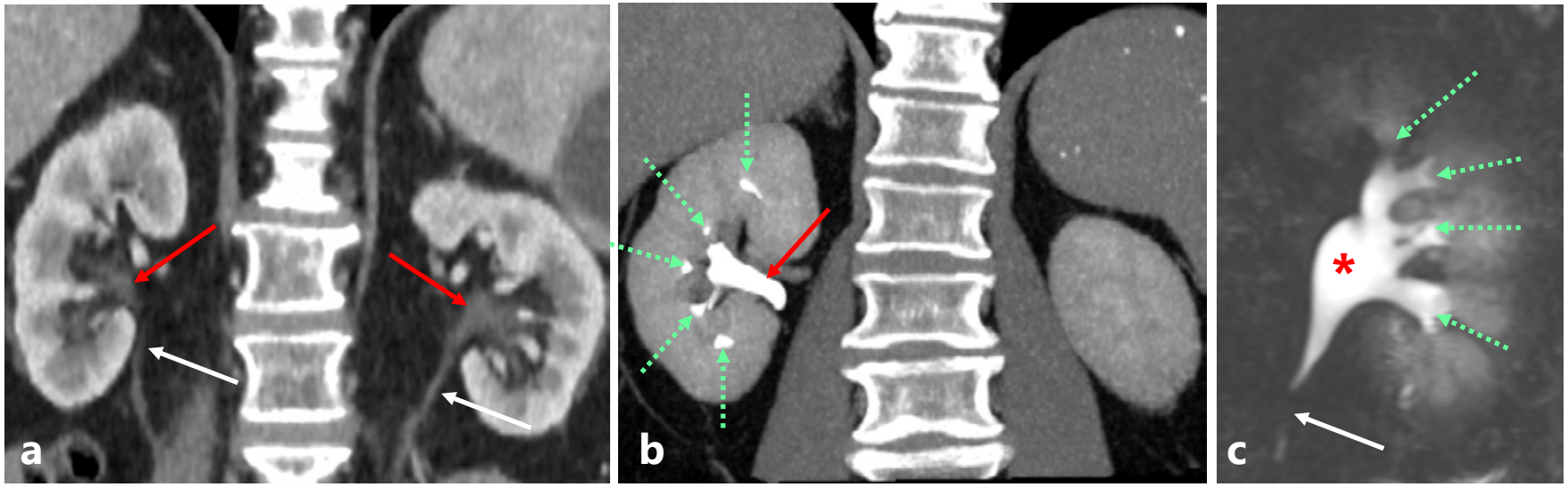

Figure 3. Normal renal pelvis (red arrows) as seen on coronal reconstructions of early arterial (a) and late excretory phase contrast-enhanced CT (b). For a description of contrast-enhanced CT phases, see Figs. 6 and 15. MR urography image (c) of a normal left renal pelvis (asterisk). Normal proximal 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 e book chapter on biliary tracts. Figure courtesy: Minerva Becker, MD, University Hospitals Geneva, Switzerland.

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Another key renal region to evaluate in imaging is the hilum, where the ureter and renal vein leave the kidney and the renal artery enters the kidney from the hilum (Fig. 4).

The radiological report should include the number of renal arteries and veins, any pathological features regarding their course (e.g., retro-aortic left renal vein course) or morphology, and atheromatous pathology (Fig. 5).

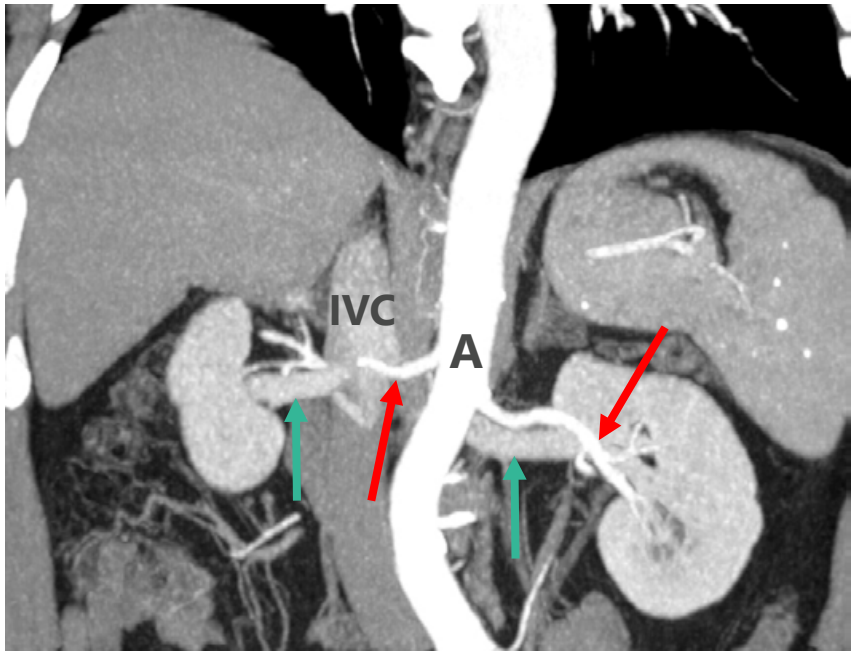

Figure 4. Normal renal vascular anatomy as seen on a thick slab coronal multiplanar reconstruction of an angio-CT. Renal arteries (red arrows), renal veins (blue arrows), aorta (A), inferior vena cava (IVC). Note that the renal veins are located anteriorly to the renal arteries.

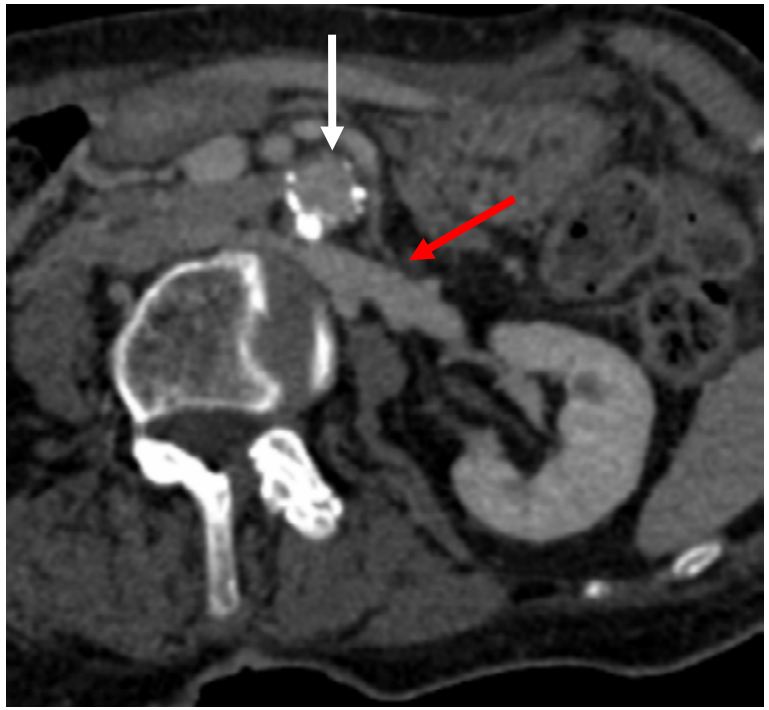

Figure 5. Retro-aortic left renal vein course (red arrow). Aorta (white arrow).

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On CT images after iv. contrast media injection, the arterial, nephrographic and excretory phase can be seen (Fig. 6). Note that the corticomedullary renal ratio is well identified in the arterial phase.

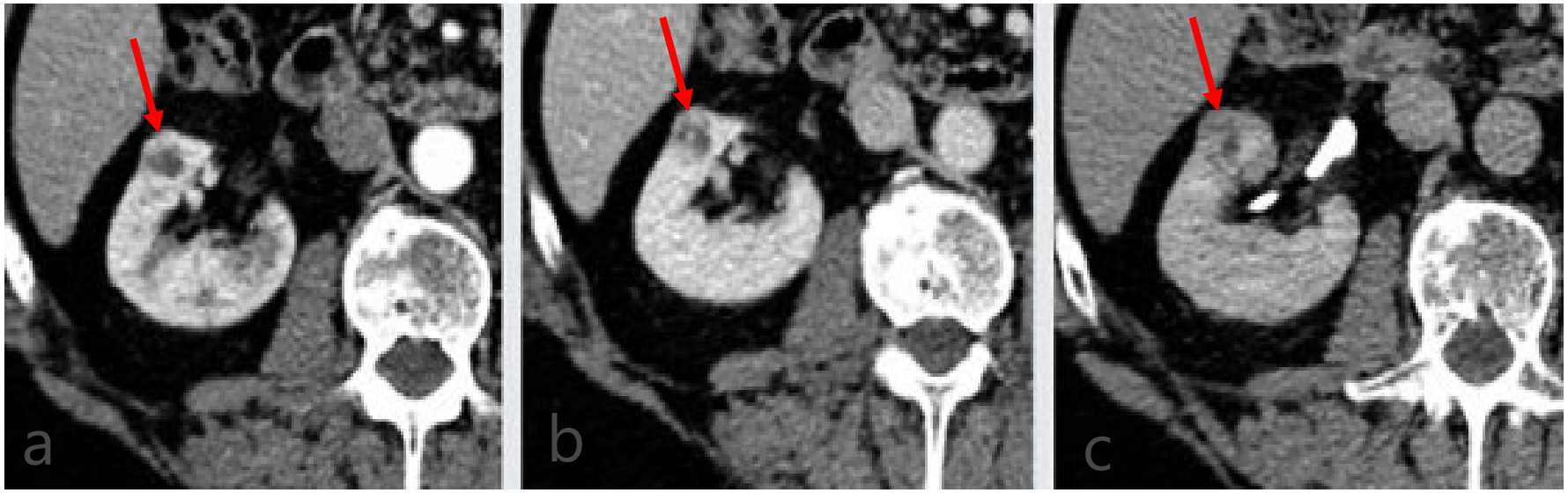

Figure 6. *Arterial (a), nephrographic (b) and secretory phase (c) as seen after iv. Injection of contrast material on axial CT images. Arrows point at a renal mass.*

Chapter Outline

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 iliac crest);
2. pelvic ureter: up to the bladder;
3. intravesical or intramural ureter: inside the bladder wall.

In a normal ureter, *three physiological constrictions* are usually found, the first at about 7-8 cm from the renal hilum, the iliac constriction and the intramural constriction.

The anatomy of the ureter wall is very similar to the bladder wall and the muscular layer is continuous with that of the bladder at the level of the ureteral orifice.

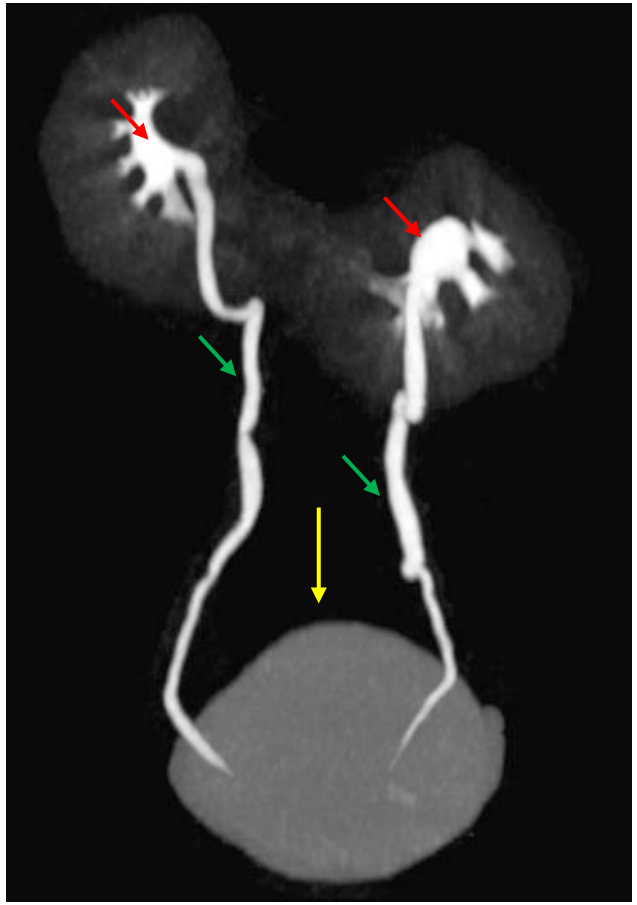

Figure 7. *CT-Urography showing the excretory system: renal pelvis (red arrows), ureters (green arrows – please note the different anatomical parts) and the bladder (yellow arrow).*

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Anatomical variants of the kidneys and ureters are numerous and of different kinds (2):

- *Location* anomalies:

- pelvic kidney or renal ptosis, that could be a confounding factor during clinical evaluation: "*renal colic*" pain may be confused with appendicitis, pelvic inflammatory disease (PID), or ovarian torsion.

- renal malrotation: between the 5th and 9th week of gestation, the kidneys rotate about 90° during their ascent from the pelvis to the abdomen and thus the renal hilum is normally antero-medially oriented. Renal malrotation can result in an incomplete rotation with the pelvis directed anteriorly at an angle <45°, in the hyper-rotation with the pelvis directed posteriorly or in a reverse rotation, with the pelvis directed laterally.

- *Shape anomalies*:

- persistent fetal lobulation (Fig. 8)

- dromedary humps: prominent focal bulges on the lateral border of the left kidney caused by the splenic impression onto the superolateral border of the kidney.

- hypertrophied column of Bertin: column of Bertin represent the extension of renal cortical tissue which separates the pyramid. When enlarged it could be mistaken for a renal mass.

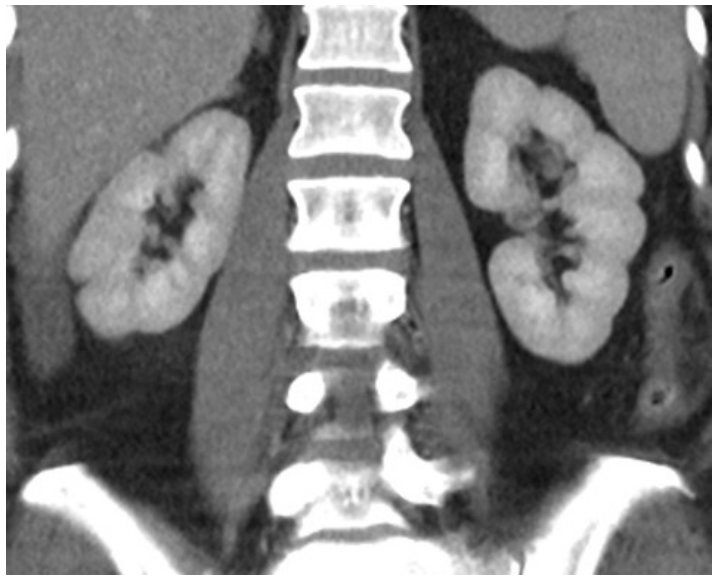

Figure 8. Persistent fetal lobulation. Case courtesy of Dr. Chris O'Donnell, Radiopaedia.org, rID: 41364

Chapter Outline

- *Number Anomalies*:

- renal agenesis

- supernumerary kidney

- *Fusion Anomalies*:

- horseshoe kidney (Fig. 9): most common, the fusion is between the lower poles.

- pancake kidney: both the upper and lower poles are fused.

- *Urinary Collecting System* Anomalies:

- *duplicated collecting system*, characterized by a complete or incomplete duplication of the collecting system. In the incomplete ureteral duplication, there are two ureters and a common ostium. In the complete ureteral duplication, there are two ureters that separately open into the bladder: the ureter of the upper pole opens more caudally and medially than the lower pole ureter, has a longer intramural route and is therefore at lower risk of reflux.

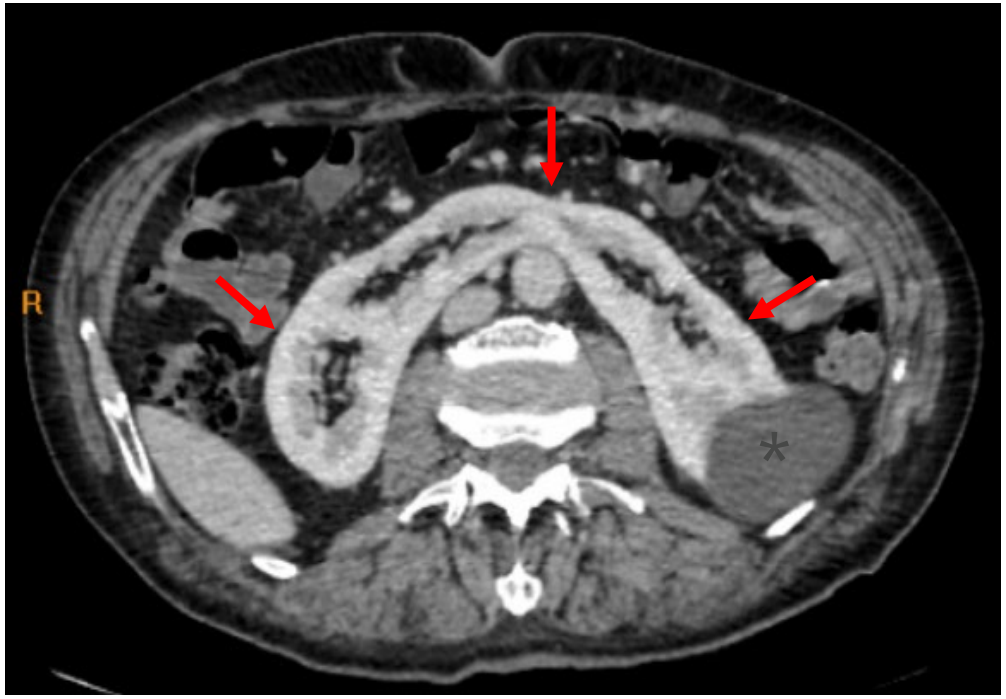

Figure 9. Horseshoe kidney (arrows) as seen at CT. Renal cyst (asterisk).

For anatomical variants => see chapter on paediatric radiology.

Chapter Outline

Bladder

The bladder is an expandable organ located in pelvis, which is covered by peritoneum on its superior and part of the posterior surface. Bladder shape and location vary depending on the amount of the urine stored, extending into the abdominal cavity when it is full.

Anatomically, the bladder is divided into four parts:
1. *base* (also known as a fundus) located posteroinferiorly,
2. anterior-superior apex (also known as *dome*),
3. *body*,
4. *neck* that is continuous with the urethra (3).

The *trigone* is a specific area of the bladder. The trigone is *a triangular area of mucosa formed* by three structures: the bilateral *ureteric orifices*, at the superolateral angles, and the *internal urethral orifice* at the apex, where the urethra begins transporting the urine outside.

The bladder wall is composed by three layers: *mucosa and submucosa*, *muscularis propria* that represents the detrusor muscle and *serosa*. The mucosa is composed by the *urothelium*, a specialized stratified epithelium with typical cells, called umbrella cells that form an impermeable barrier and that can change shape according to the filling of the bladder.

The muscular layer is crucial for the assessment of the bladder cancer because staging and therapy depend on detrusor invasion.

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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 channel between the bladder and the umbilicus where urine initially drains in the fetus. The urachus normally is destined to regress, transforming into a fibrous cord (middle umbilical ligament).

- *Congenital bladder diverticulum*.

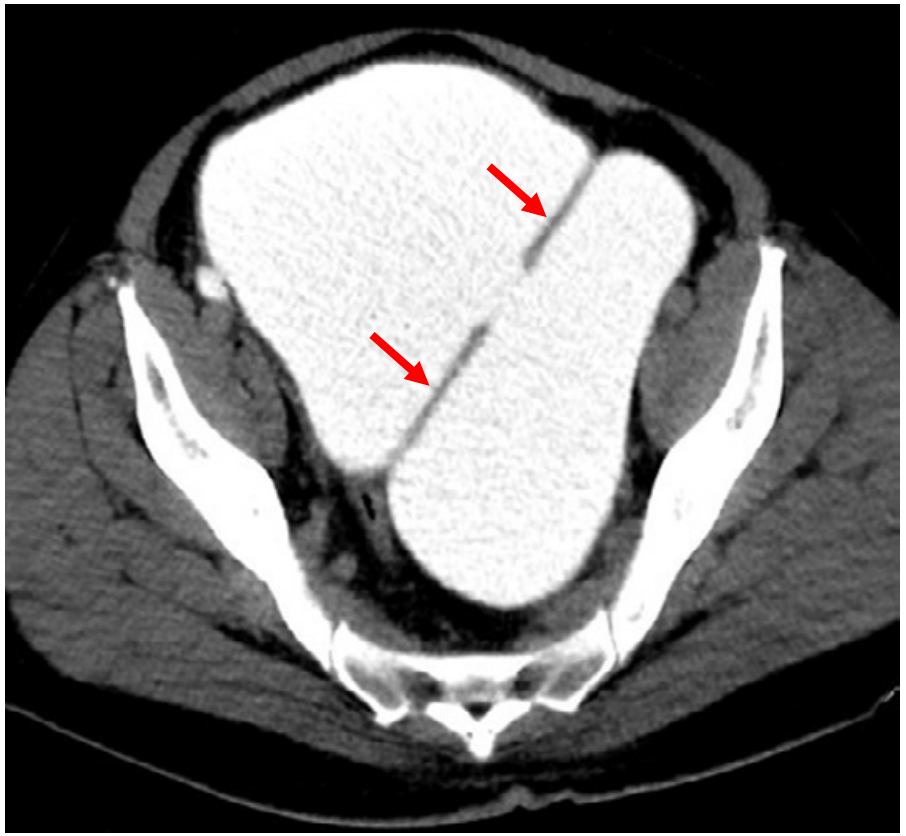

Figure 10. Bladder septation (arrows) as seen on an excretory phase axial CT image.

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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).

Testicles

The testicles are the male gonads and are responsible for the production of sperm and testosterone, which plays a major role during male maturation. Each testicle is covered by a fibrous capsule called the tunica albuginea and is divided by partitions of fibrous tissue from the tunica albuginea into several lobes. Within each lobe are the *seminiferous tubules*, which produce the *sperm cells*. The testicles contain also supporting cells called Sertoli cells, and testosterone-producing cells called Leydig interstitial cells.

The testicles are contained within the *scrotum*, outside of the body, to keep the testicles at a lower temperature and thus protect the spermatozoa. Ultrasonography is the primary imaging modality to image the testis and scrotum (Fig. 11)

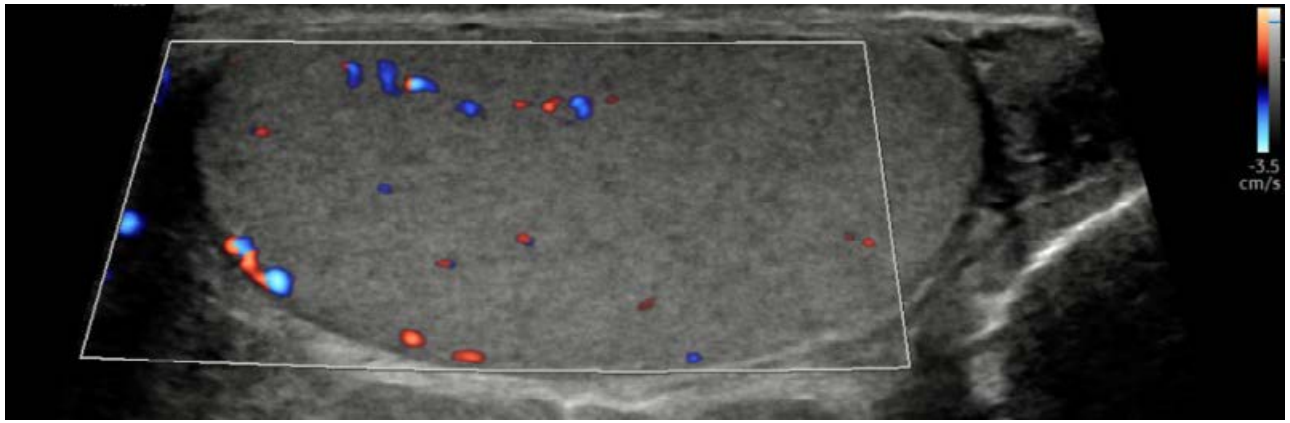

Figure 11. Sagittal testicle US image with colour Doppler. Note homogeneous mildly coarse texture.

The most important **anatomical anomaly involving the testicles** is *Cryptorchidism*, a condition characterized by undescended testicles, that are not located in the scrotum but in the abdomen due to an alteration during migration toward the inguinal canal through which the testicles descend into the scrotum.

Chapter Outline

Prostate

The prostate gland (Fig. 12) is located just below the bladder and surrounds the prostatic urethra. It is the largest male accessory gland, and its primary function is to *produce the seminal fluid that nourishes and transports sperm*. The prostate has a shape of an inverted pyramid and anatomically, from superior to inferior, it consists of:

- The *base* (just below the urinary bladder),
- The *mid-gland*,
- The *apex*.

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

1. The **anterior fibromuscular stroma**, contains no 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),** contains 70%–80% of the glandular tissue (4).

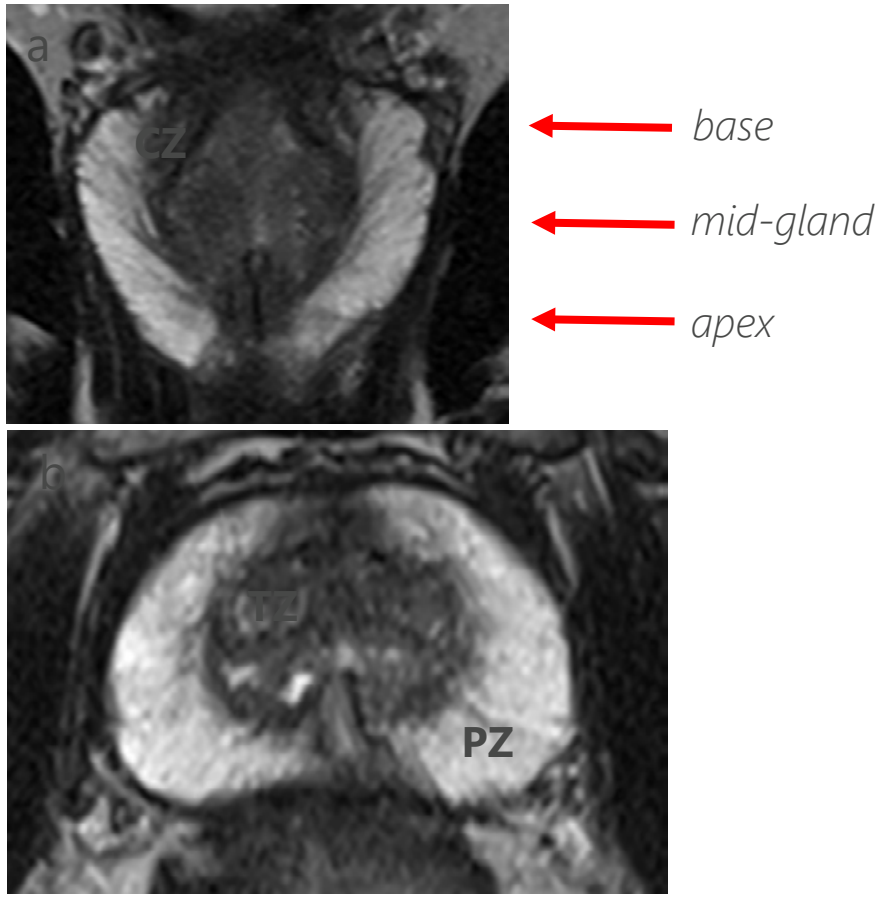

Figure 12. Prostate MRI. T2- weighted coronal (a) and axial (b) images

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Penis

The penis is the external organ of male genital system. The two main functions of the penis include *sexual intercourse* and *urination* since urethra connects to the bladder and passes through all parts of the penis.

It is divided into:

-*Root*: the most proximal and not externally visible part;

-*Body*: the external and mobile portion of the penis;

-*Glands*: the terminal part of the penis that holds the urinary meatus, the external opening of the urethra, which serves for the expulsion of urine and of semen.

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 the tissues that are filled with blood during arousal, allowing an 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 continue into the body of the penis and form the two corpora cavernosa.

The bulb continues into the body and forms the corpus spongiosum that then expands to form the glans of the penis.

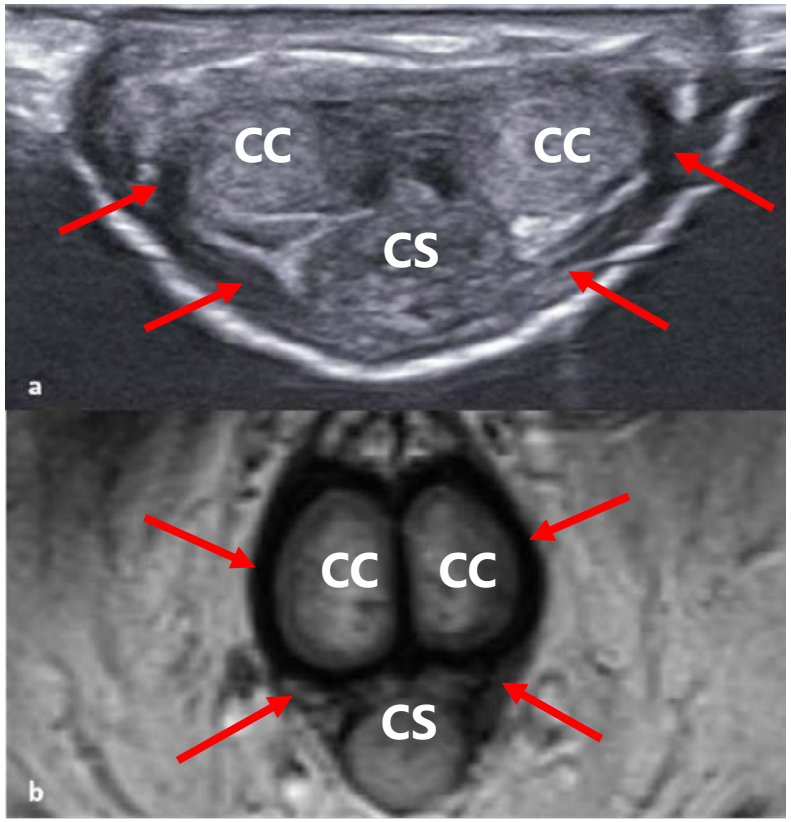

Figure 13. Penile ultrasound (a) and MRI (b). CC = corpus cavernosusm. CS = corpus spongiosum. Deep fascia (red arrows) .

Chapter Outline

Strengths, Weaknesses & Role of Imaging Modalities – Ultrasound

- Ultrasonography (US) is the primary and initial imaging modality of choice for patients presenting with suspected pathology of the urogenital system (Fig. 14). However, it remains only as a first-level technique; second-level imaging techniques are necessary to better characterise lesions and for locoregional staging of the disease.

Advantages:
- Low cost and availability,
- Does not use ionizing radiation,
- High accuracy in detecting hydronephrosis, intraluminal bladder masses and renal masses.

Disadvantages:
- Inadequate visualization of upper urinary tract, mainly the ureter
- Operator-dependent imaging modality
- Inaccurate when patient preparation is not optimal (i.e., gas)

Additional imaging may be required!

Strengths, Weaknesses & Role of Imaging Modalities – Ultrasound

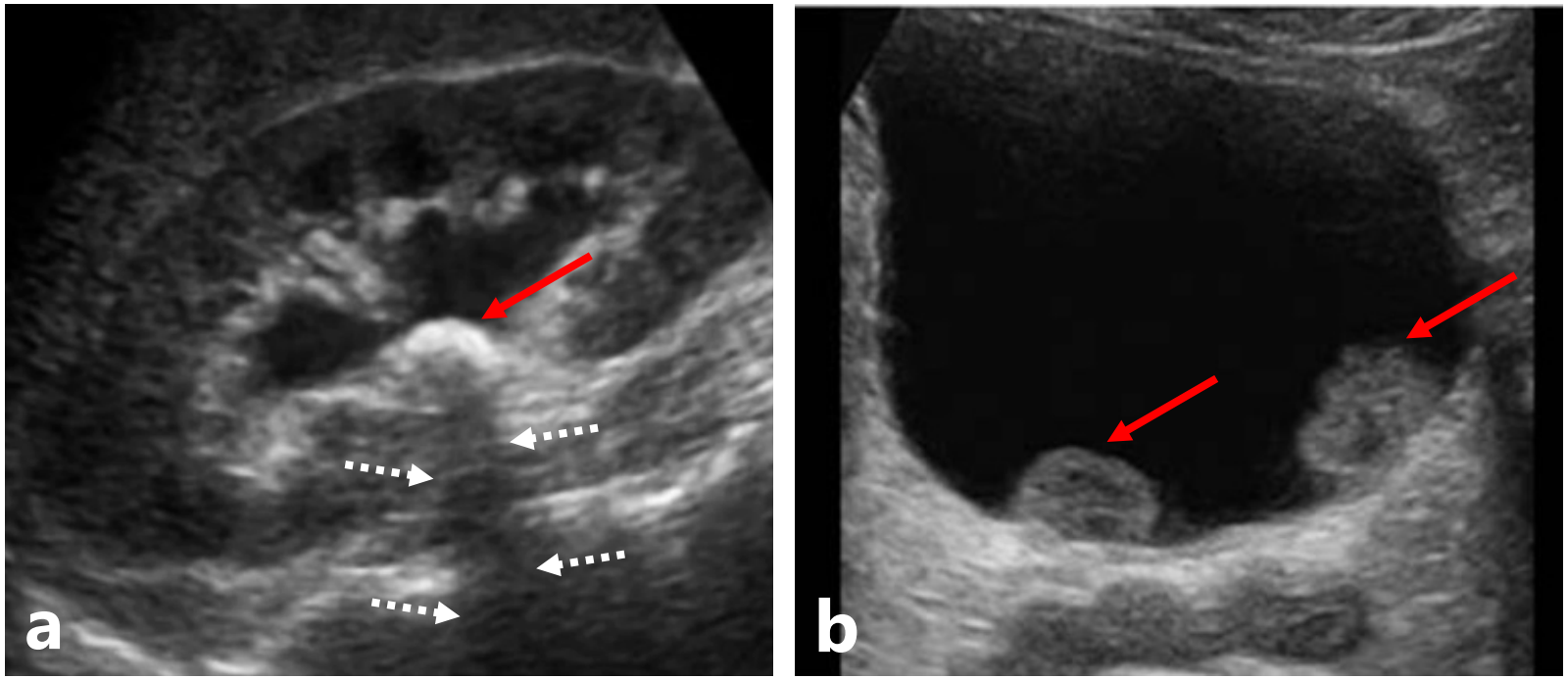

Figure 14. *Kidney and bladder US. Characteristic features of lithiasis in the renal pelvis (a): red arrow points at the hyperechoic stone and short dashed arrows point at the acoustic shadow caused by the stone. These US features are characteristic of lithiasis. Two exophytic lesions of the bladder (red arrows) are seen in b. The differential diagnosis includes blood clots and bladder cancer. If the exophytic lesions have a central vascularisation on colour Doppler images and if they do not move while the patient changes position, the diagnosis of a bladder tumour should be made.*

Chapter Outline

Strengths, Weaknesses & Role of Imaging Modalities – Computed Tomography

To investigate the urinary tract in all its length a CT urography should be performed with acquisition of non-contrast, cortico-medullary, nephrographic and excretory phases (Fig. 15).

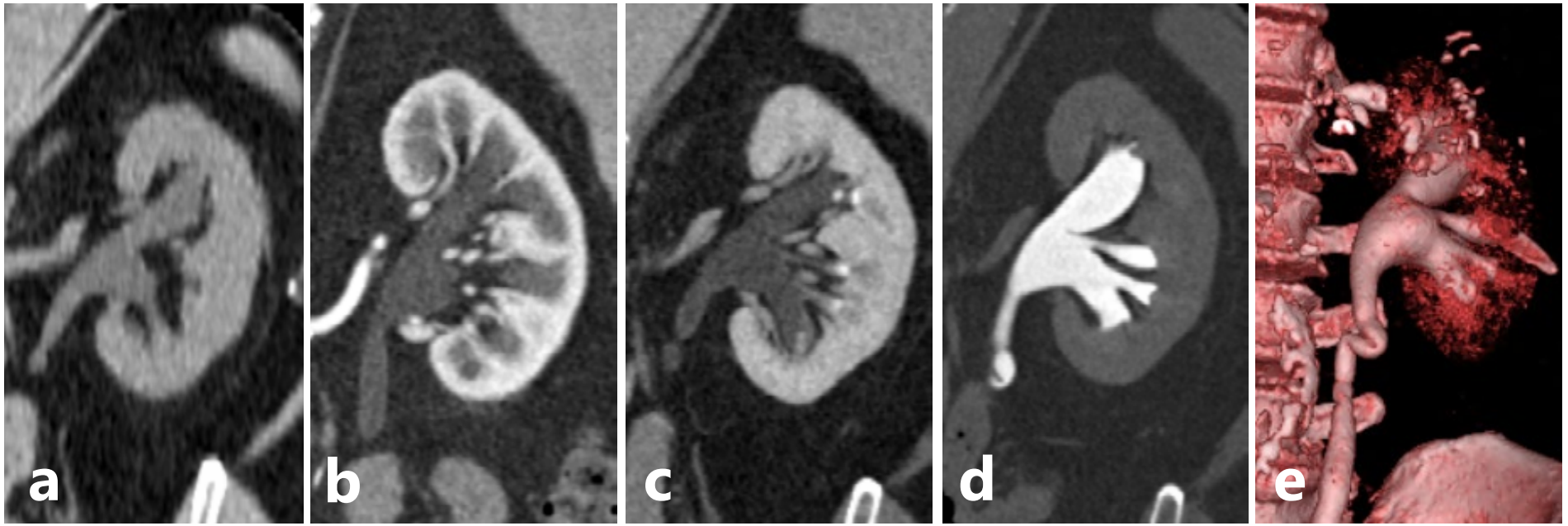

Figure 15. Normal CT urography (coronal reconstructions). Non-contrast (a), cortico-medullary (b), nephrographic (c), excretory (d) phase and 3D reconstruction of the excretory system (e).

Strengths, Weaknesses & Role of Imaging Modalities – Computed Tomography

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

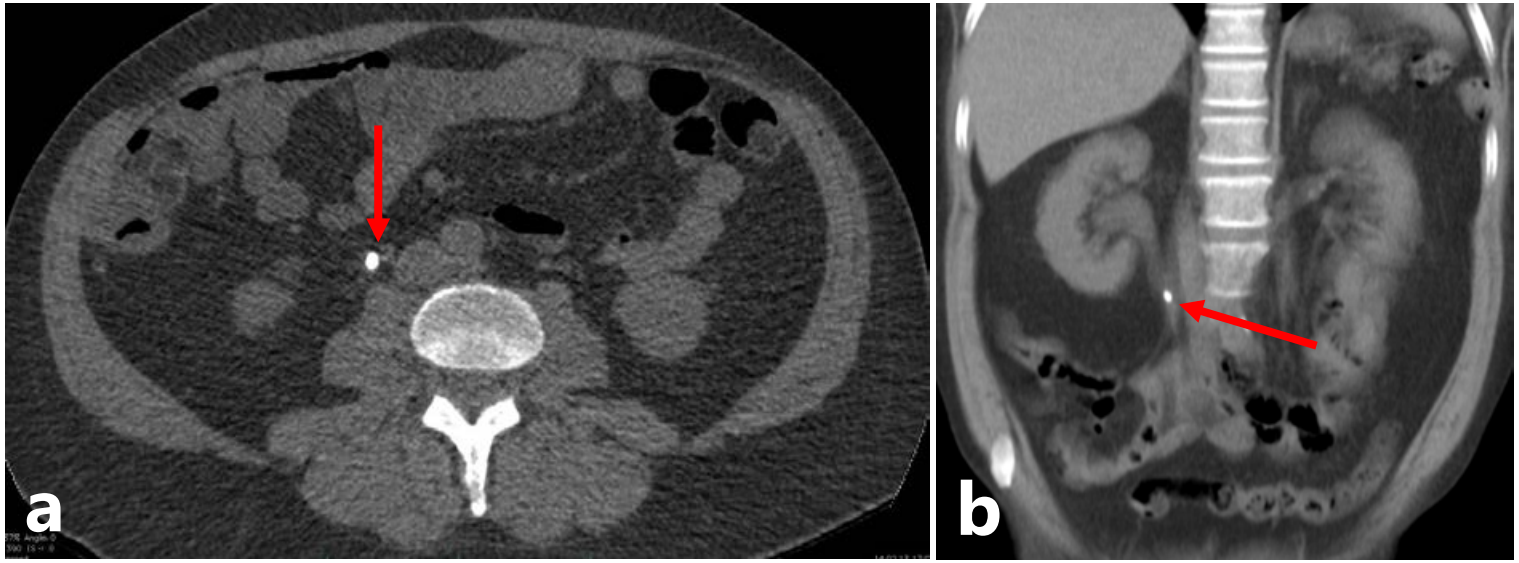

Figure 16. Axial (a) and coronal multiplanar reconstruction (b) of a low-dose CT acquisition depicting a calcified ureter stone (arrows). Figure courtesy: Alexandra Platon, University Hospitals Geneva, Switzerland.

Chapter Outline

Strengths & Weaknesses of Magnetic Resonance Imaging (MRI)

Another most powerful imaging technique is multiparametric (mp) Magnetic Resonance Imaging MRI) as shown in Fig. 17, which implies the administration of iv. gadolinium-based contrast medium, obtaining sequences with morphological and functional information and with an extraordinary potential for the diagnosis and characterisation of urogenital lesions, especially of bladder and prostate cancer.

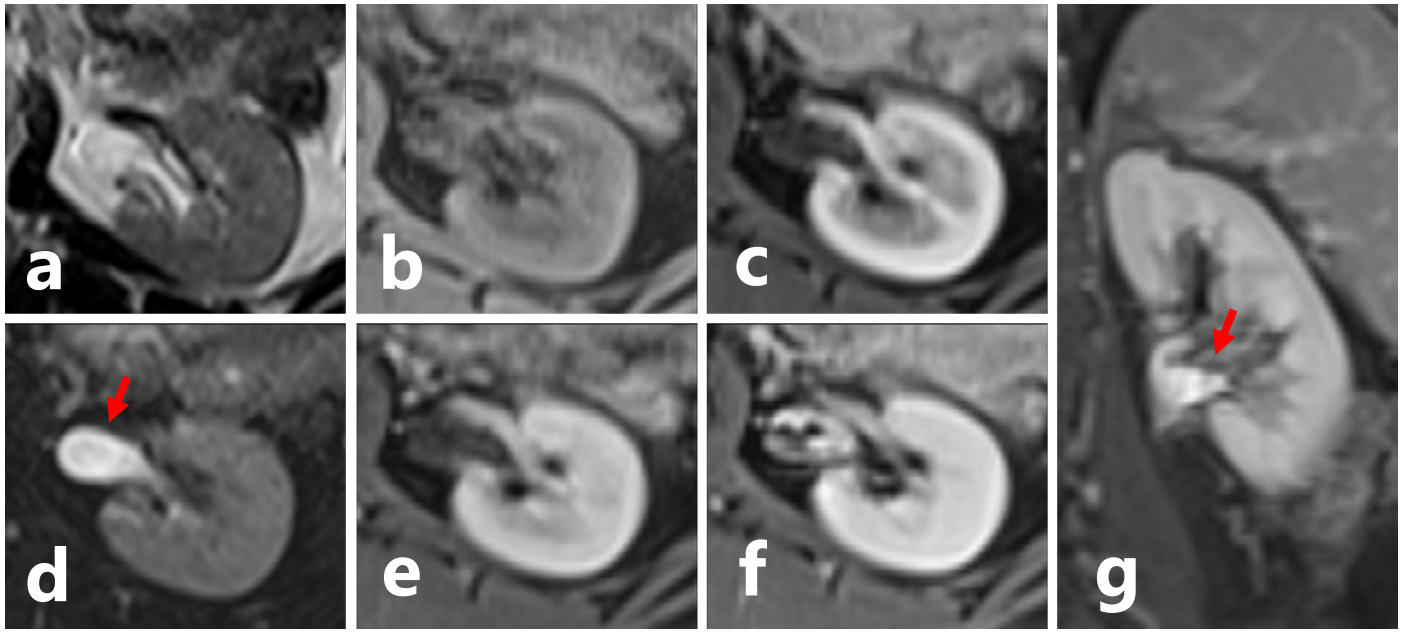

Figure 17. MR urography. T2 WI (a), fat-saturated non-enhanced T1WI (b), post-contrast sequences (b-g). Please note the urographic phase in axial (d) and coronal plane (g) (red arrows).

Chapter Outline

Urogenital Diseases

Urolithiasis

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

As many as 12% of men and 5% of women have renal stones. The most common renal stones are composed of calcium oxalate and they are often mixed with calcium phosphate. As the stones pass from the kidney into the ureters, they can cause a renal colic.

Calcium containing stones are radiopaque (Figs. 16 and 18). Non-contrast CT has the highest sensitivity to detect renal calculi (99%), whereas ultrasound (US) has a sensitivity of only about 25%. The majority of calculi missed at US are <3mm 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.

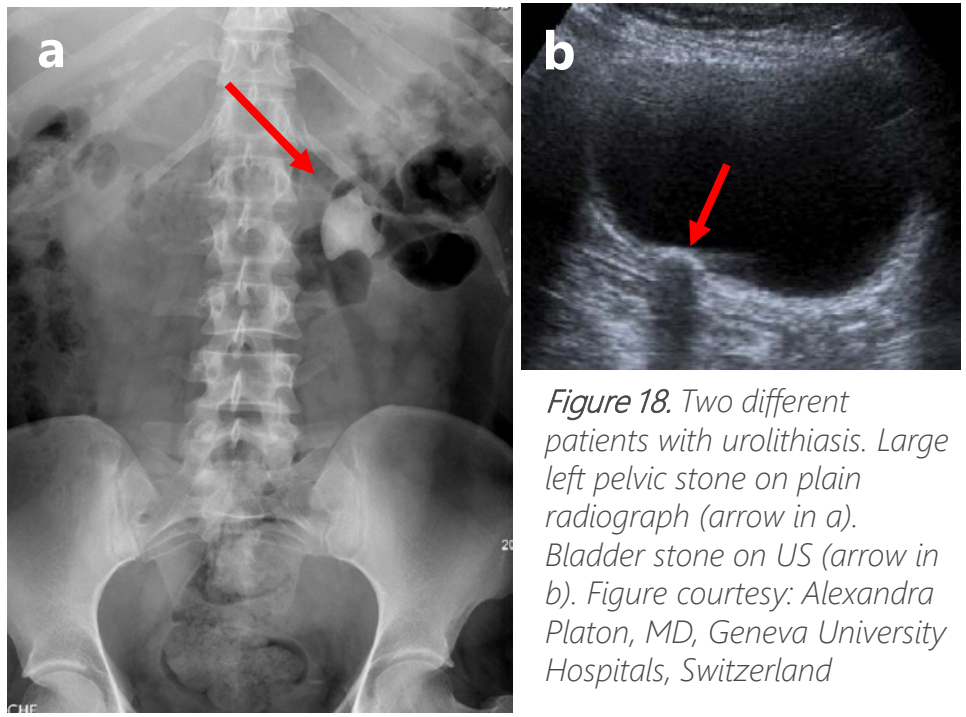

Figure 18. Two different patients with urolithiasis. Large left pelvic stone on plain radiograph (arrow in a). Bladder stone on US (arrow in b). Figure courtesy: Alexandra Platon, MD, Geneva University Hospitals, Switzerland

Chapter Outline

Urogenital Diseases

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 shows a dilated pelvicalyceal system. In long-standing hydronephrosis, the renal cortex may be thinned.
- CT enables not only the diagnosis of hydronephrosis but also the cause

Hydroureteronephrosis = hydronephrosis accompanied by ureter dilatation.

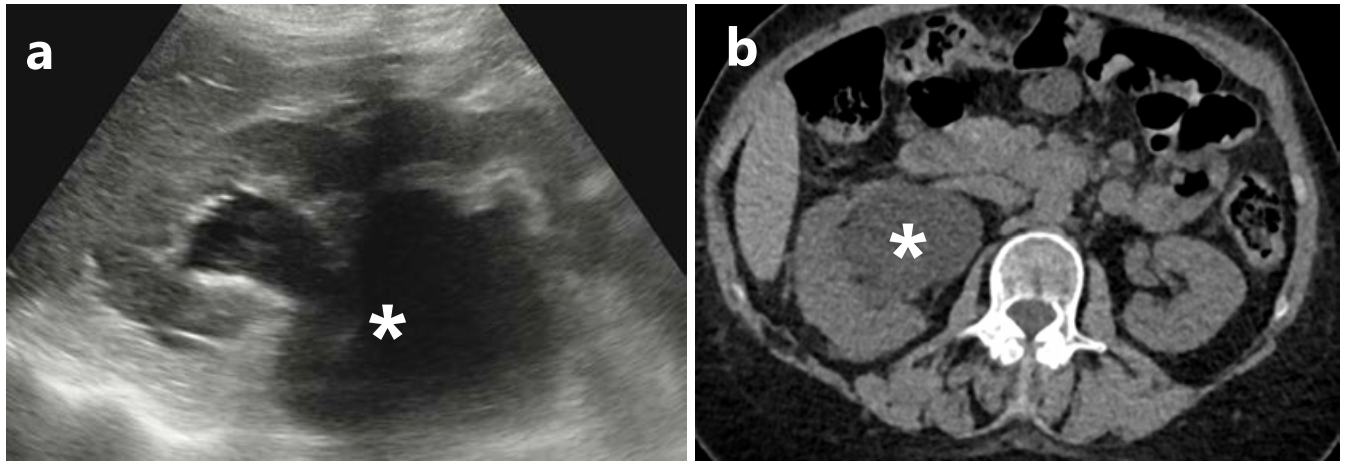

Figure 19. US image of the right kidney (a) showing characteristic features of hydronephrosis (asterisk). CT appearance of hydronephrosis (asterisk in b). Figure courtesy: Minerva Becker, MD, Geneva University Hospitals, Switzerland

Chapter Outline

Urogenital Diseases

Acute Pyelonephritis

= infection of the upper urinary tract (i.e., enal 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 mainly made clinically and on the basis of laboratory findings, imaging is indicated to exclude the cause of renal obstruction, as well as in immuno-compromised patients and in patients with underlying renal pathology (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 treated early.

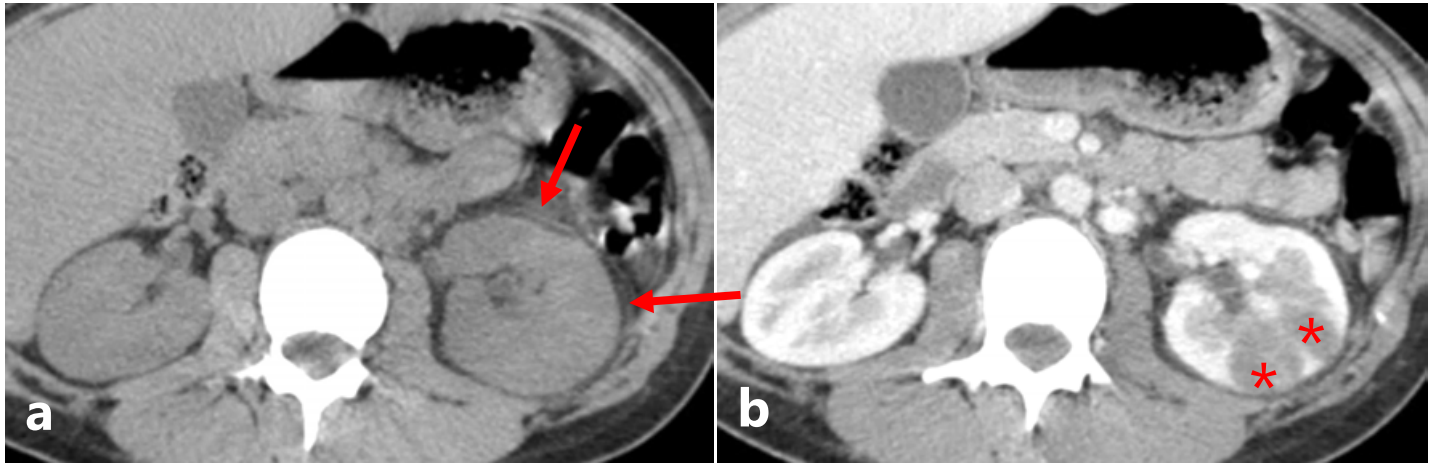

Figure 20. Acute pyelonephritis in a diabetic patient. Non-contrast enhanced CT shows swollen left kidney and perinephric fatty stranding (arrows). On the post-contrast CT image, a swollen wedge-like region involving the cortex periphery is seen (asterisks). Figure courtesy: Minerva Becker, MD, Geneva University Hospitals, Switzerland

Chapter Outline

Urogenital Diseases

Renal Masses

Renal masses are extremely frequent, and they are usually found as incidentalomas, during US, CT or MR exams performed for other 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 can show some specific alarm characteristics. In this scenario, the *Bosniak classification* (6) plays a key role to stratify the risk of malignancy in cystic renal masses, classifying them into five categories and assessing any appropriate follow-up (Bosniak IIF) or the need for surgery (Bosniak III and IV).

2. Solid Masses (Fig. 23):

Up to 80% are malignant and **renal cell carcinoma (RCC)** accounts for ~80% of all kidney cancers. Renal cell carcinomas arise from tubular epithelium, and include several distinct histological varieties (RCC subtypes):

- *Clear cell* (70- 80%)
- *Papillary* (10-15%)
- *Chromophobe* (5%)
- *Other* (< 1%, Collecting ducts and Medullary carcinoma).

Chapter Outline

1. Cystic Lesions: (Fig. 21)

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

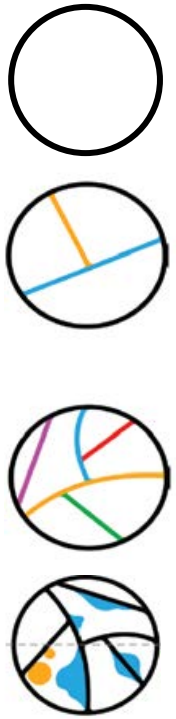

Figure 21. *Determination of wall and septa thickness/irregularity by using the Bosniak classification of cystic renal masses, version 2019*

Chapter Outline

1. Cystic Lesions

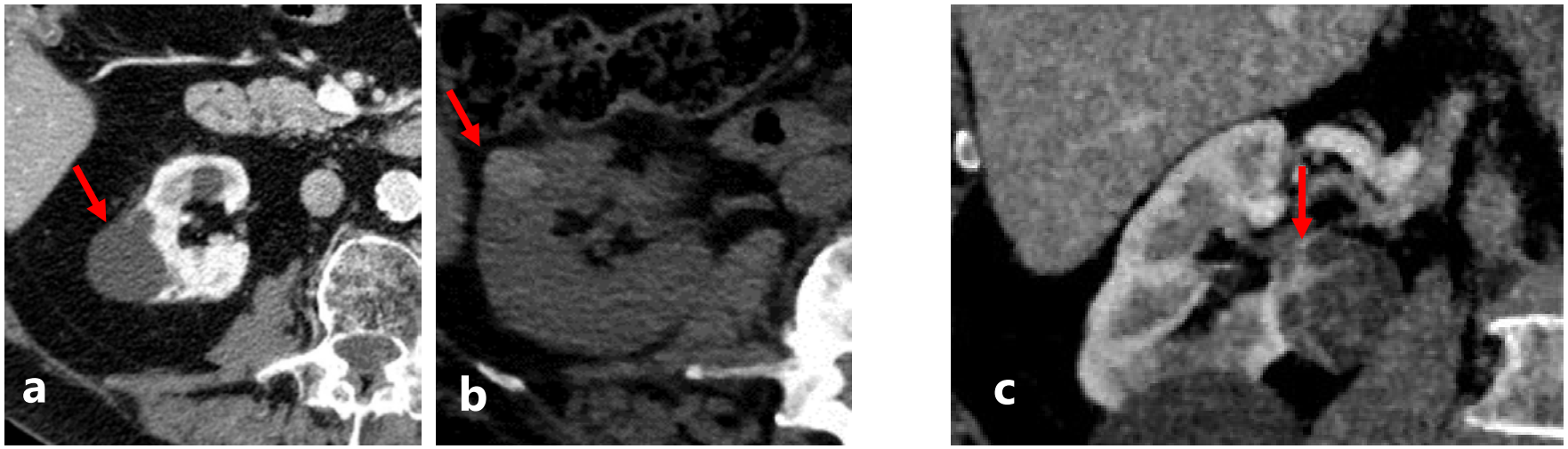

Figure 22. Spectrum of complex cystic lesions as categorised by the Basniak classification. Cystic lesion with homogeneous simple fluid (red arrow), Bosniak type I (a); hyperdense cystic lesion (red arrow) in non-contrast phase, Bosniak type II (b); enhancing nodule (red arrow) and multiple septa, Bosnkia type IV (c).

2. Solid Masses

Benign Lesions:

- Angiomyolipoma
- Oncocytoma
- Pseudotumor

Malignant Lesions:

- Renal Cell Carcinoma
- Urothelial Carcinoma
- Lymphoma

2. Solid Masses

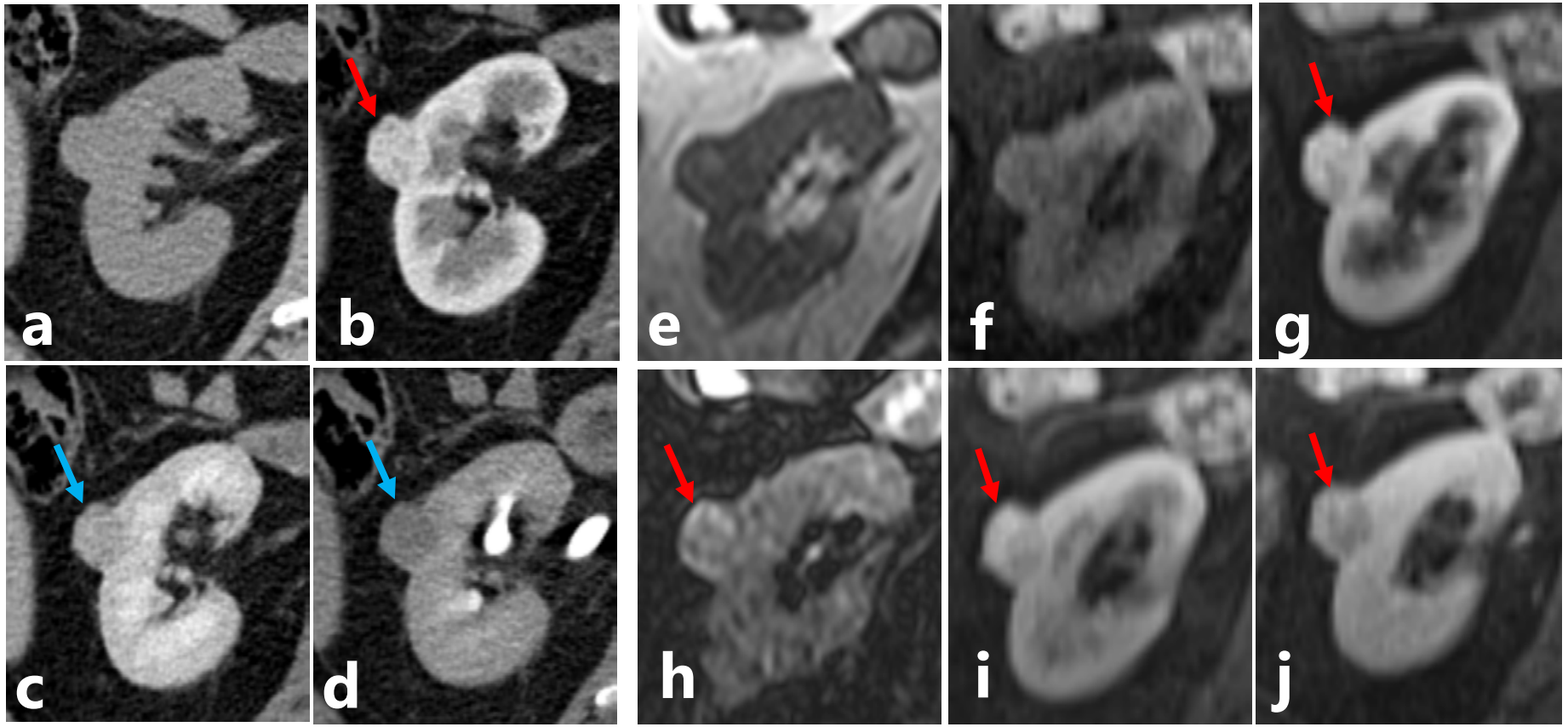

Figure 23. CT (a-d) and MRI (e-j) showing a hypervascular solid mass (red arrows), with «wash out» on delayed CT phases (c and d, blue arrows) and MRI sequences, corresponding to renal cell carcinoma. T2 WI (e), fat saturated T1 WI (f), arterial phase fat saturated T1WI (g), nephrogenic phase fat saturated T1WI (i), excretory phase saturated T1WI (j).

Several **anatomical aspects** of renal tumours are routinely considered in the preoperative imaging to categorize **renal masses** into low, intermediate, and high complexity, and to aid in **surgical planning**.

These include:

- Tumour *size*;
- Exophytic / endophytic tumour *growth pattern* and *exophytic rate*;
- *Nearness to the renal collecting system* or renal;
- Precise localisation (using **renal** *segmentation*);
- Presence of *feeding artery*.

Chapter Outline

Bladder Cancer

Bladder cancer (BCa) is one of the most frequent cancers diagnosed, and every year around 550000 new BCa diagnosis are made. *Urothelial cell carcinoma* is the most common histologic variety 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) undergoes TURBT, whereas *muscle-invasive BCa* (MIBC) (stage T2 or higher) undergoes radical cystectomy or radiotherapy and palliative chemotherapy (6).

The detrusor invasion represents the most important predictive and prognostic factor: *MIBC* presents an extremely poorer prognosis, compared to *NMIBC*. This point assigns a key role to pathologic and radiologic assessment of muscle invasion, with a significant impact on treatment strategies (3).

MRI represents the best imaging modality for BCa regional staging for its superior contrast resolution of soft tissues and its ability to evaluate the *muscolaris propria* and tumour infiltration grade in the bladder wall and the perivesical extension.

Chapter Outline

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 T2WI, the *muscularis propria* (detrusor muscle) appears as a low signal intensity line: the *muscularis propria* is a continuous hypointense line in NMIBC, while in MIBC there is an interruption of this low SI muscular line, suggesting muscle invasion.

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 DCE (7).

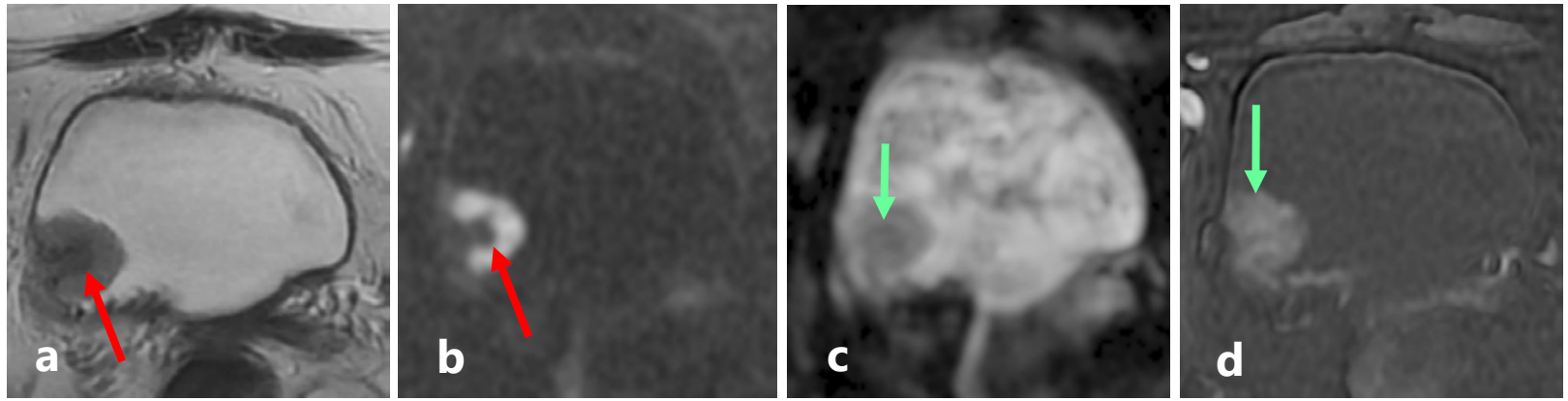

Figure 24. Bladder MRI (axial images) showing an exophytic lesion with a stalk (red arrow) on the right lateral wall (green arrows). T2 weighted image (a), DWI at b1000 image (b), ADC map (c), subtraction image T1 + Gd – T1 (d). Histology revealed non-muscle-invasive bladder cancer (NMIBC).

Chapter Outline

A new scoring system, the **VI-RADS (Vesical Imaging Reporting and Data System) score**, has been developed with the aim to standardize the approach to imaging and reporting of mpMRI for bladder cancer and to define the risk of BCa muscle invasion (8) as shown in **Fig. 25**.

The score is based on *T2* weighted images (T2WI), *DCE-MRI* and *DWI* findings. For each sequence, 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, expressing *the risk of muscle invasion*.

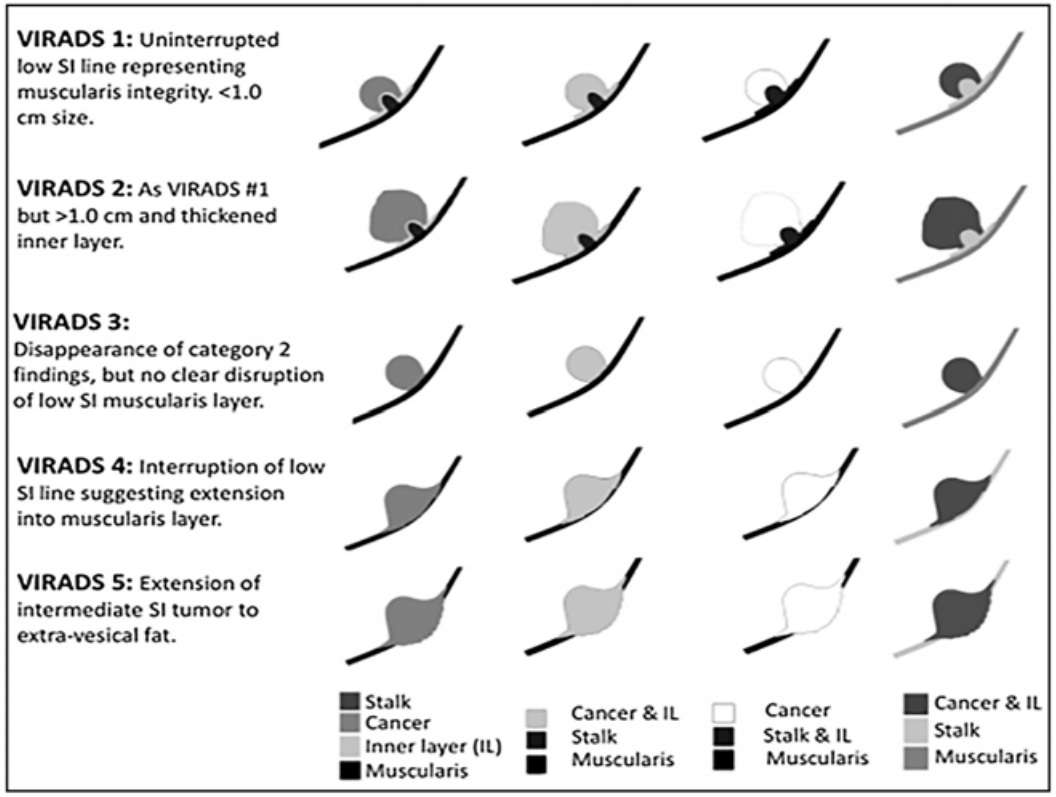

Figure 25. Visual representation of VI-RADS score

Chapter Outline

Prostate Diseases

The two most common prostate disease are:

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

When *benign prostatic hyperplasia (BPH)* develops, the Transition Zone will account for an increasing percentage of the gland volume. *Prostate cancer* most commonly develops from 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;
- It also can be used to guide procedures such as needle biopsies.

Standard TRUS (Transrectal ultrasound) is not reliable at detecting prostate cancer.

Chapter Outline

MRI Role for Prostate Cancer

Multiparametric MRI (mpMRI) combines anatomic T2W imaging with functional assessment, including diffusion-weighted imaging (DWI) and its derivative apparent diffusion coefficient (ADC) maps and dynamic contrast-enhanced (DCE) MRI.

MRI has good sensitivity and specificity for the detection and localisation of *prostate cancer* (Fig. 26), but clinical applications of prostate MRI have expanded to include also surveillance, assessment of suspected recurrence, and image guidance for biopsy, surgery, focal therapy and radiation therapy.

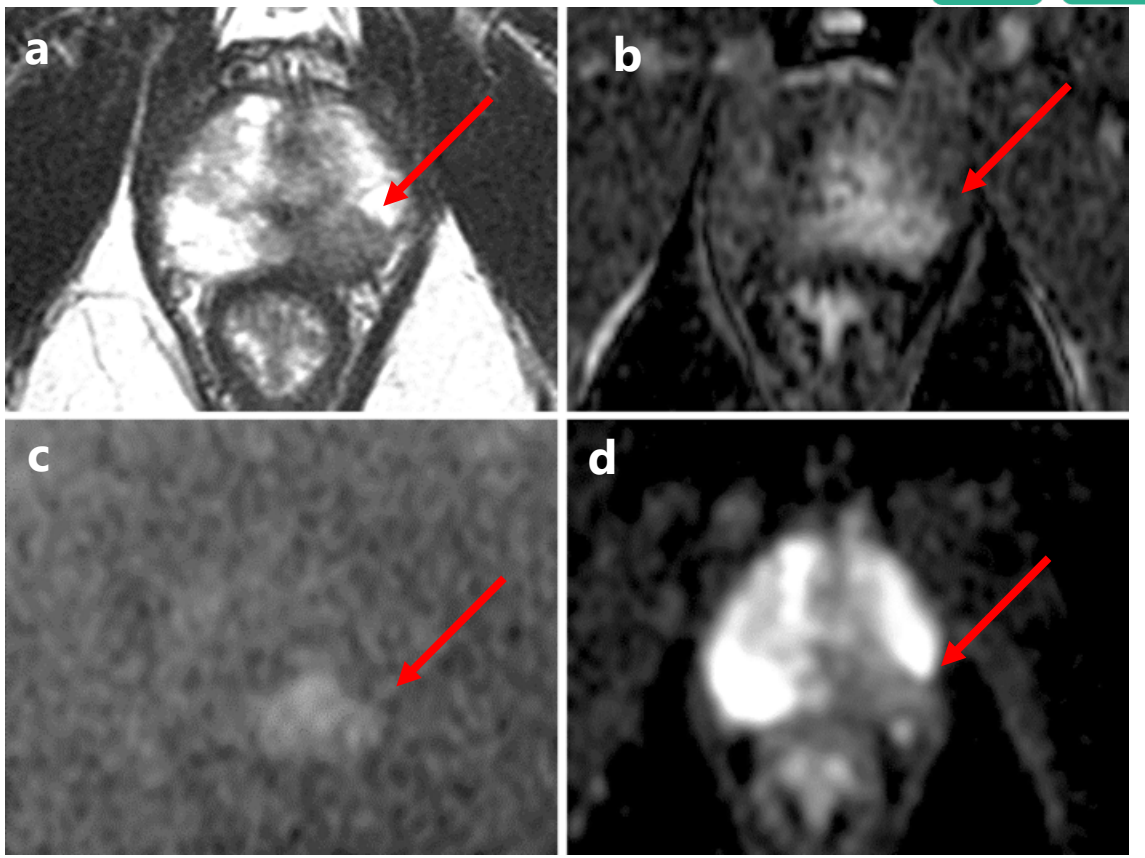

Figure 26. Prostate mpMRI (axial images) showing the typical behaviour of prostate cancer (arrows). T2 WI (a), DCE MRI image (b), ADC map (c) and DWI (d), b value of 2000. Figure a) shows an hypointense lesion in T2 WI localized in the peripheral zone (5 o'clock), with an early and focal enhancement (b) after administration of contrast medium (for the neoangiogenesis) markedly hyper-intense on high b-value DWI (c) and markedly hypo-intense on ADC(d) due to high cell proliferation.

Chapter Outline

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

Each lesion is assigned a PI-RADS Assessment Category using a 5-point scale based on the likelihood that findings on T2WI, DWI, & DCE correlates with the presence of a clinically significant prostate cancer (9).

If the lesion is classified as PI-RADS 4 or 5 the patient is directed to *targeted biopsy*.

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

Chapter Outline

Testicular Diseases

The two most common types of testicular disease are:

1. Testicular torsion: takes place when a testicle torts on the spermatic cord resulting in the cutting off the blood supply. The most common symptom is acute and intense pain.

The diagnosis is suspected clinically but needs to be confirmed by colour *Doppler US* (10) as shown in Fig. 28. Prompt diagnosis is essential to avoid testicular infraction.

If the diagnosis is made in<6h, the chance of salvage is 100%.

US is the modality of choice in suspected testicular torsion.

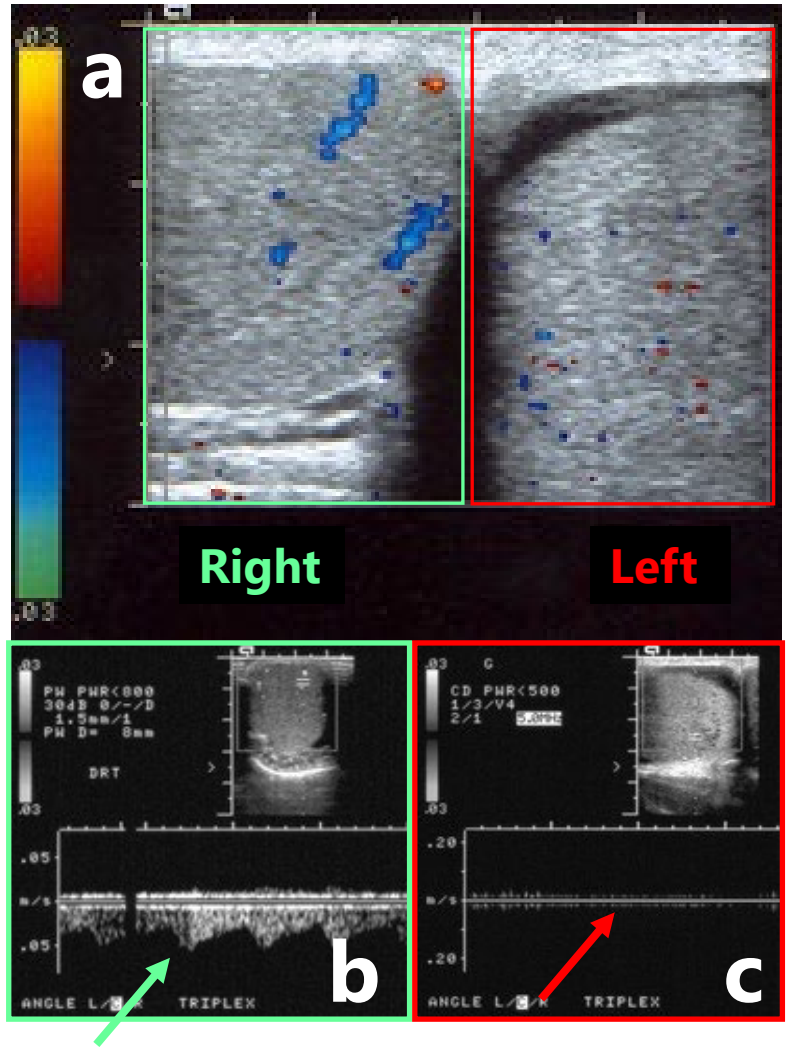

Figure 28. Testicular torsion as seen on colour Doppler US. The patient had intense pain in the left testis. Colour Doppler images (a, b and c) of the left and right testis showed massively altered blood flow on the left with increased resistive index. Note normal arterial flow curve on the right (b) and absent arterial flow curve on the left (c). Figure courtesy: Alexandra Platon, MD, Geneva University Hospitals, Switzerland

Chapter Outline

2. Testicular Cancer: represents 1% of male cancers and it is the most common type of cancer in men in the 3rd and 4th decade of life. Over 90% of testicular cancers are primary germ cell tumours. In patients older than 70 years, lymphoma is the most common testicular cancer type.

EAU (European Association of Urology) recommends to perform:

- *bilateral testicular US* in patients with suspicion of testicular cancer (Fig. 29)
- *contrast enhanced computerised tomography (CT)* scan chest, abdomen and pelvis for the staging.

MRI of the scrotum offers higher sensitivity and specificity than US in the diagnosis of testicular cancer, but its high cost does not justify its routine use for diagnosis.

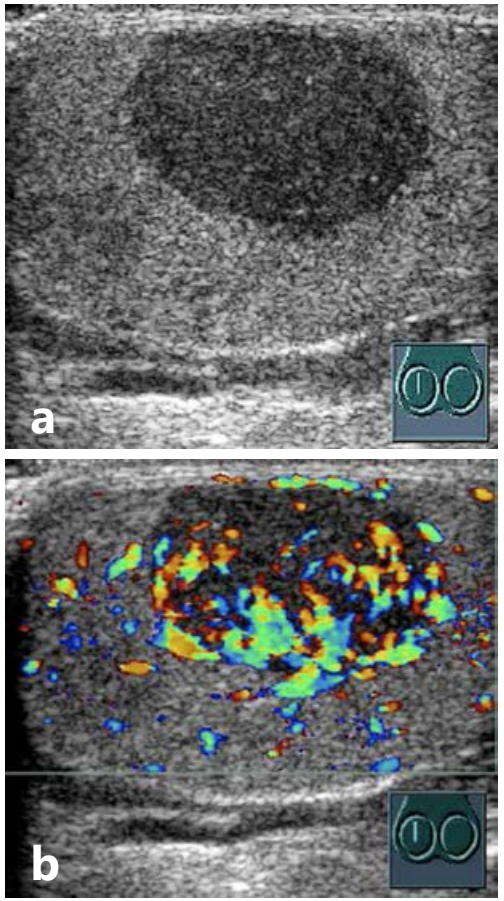

Figure 29. Example of a sagittal testicular US image showing a right, nodular, hypoechoic testicular tumour (a) with increased vascularity on the colour Doppler image (b). Image courtesy: Thomas de Perrot, MD, Geneva University Hospitals.

Chapter Outline

Penile Diseases

Penile cancer is a very rare tumour.

Penile fractures (Fig. 30) rarely occur but should be promptly diagnosed and treated as they represent a medical emergency:

It is a *rupture of penile tunica albuginea of the corpora cavernosa or spongiosum* caused by trauma to an erect penis, most commonly during sexual intercourse.

- *Emergency ultrasound with doppler* is usually the initial imaging modality, to verify the presence of a fracture and hematoma (a common complication).

- *MRI* of the penis (Fig. 30) is the most useful study to determine the extent of injury, the precise location and depth, and complications in order to decide the most appropriate therapeutic approach (NSAIDS or surgery).

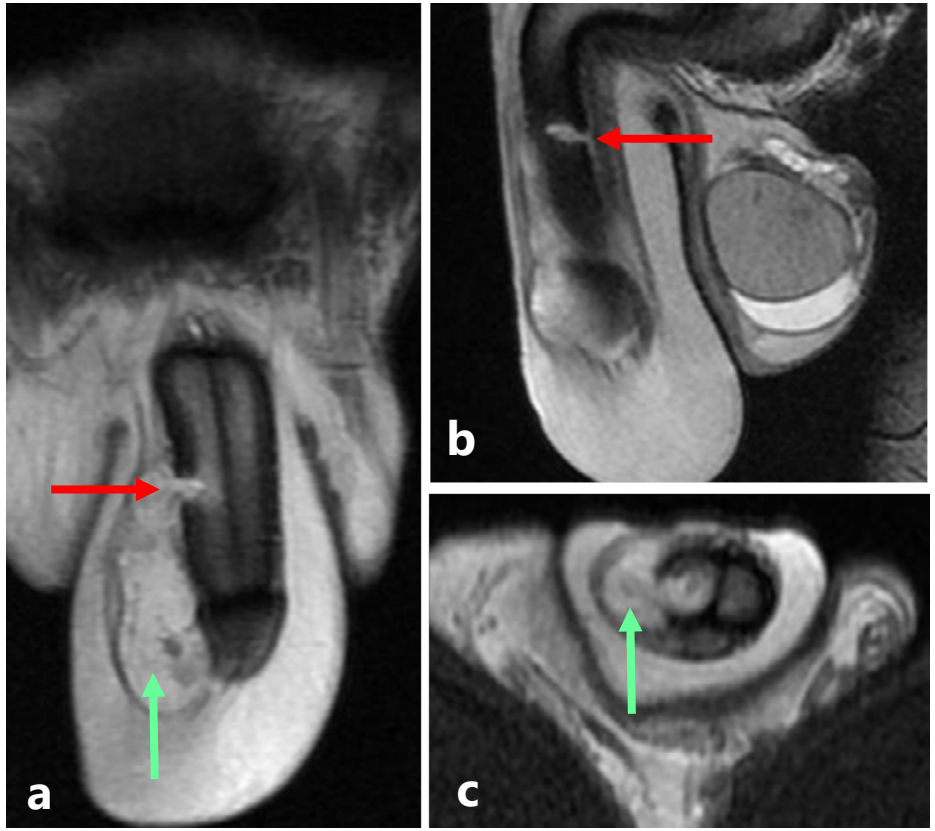

*Figure 30. Penile fracture on MRI. **Coronal (a), sagittal (b) and axial (c) T2 weighted images.**. Note the breach as red arrow in the band of fibrous tissue (tunica albuginea) and the hematoma alongside the breach (green arrow)*

Chapter Outline

Interventional Procedures

Renal Procedures

Even if radical and partial nephrectomy remain the gold standard for the treatment of renal cancer, interventional procedures (tumor ablation) are an alternative to surgery in patients with small renal masses (< 3cm). Tumor ablation (TA) includes two main techniques:

- CRYOABLATION (CA)
- RADIOFREQUENCY ABLATION (RFA)

A RENAL MASS BIOPSY prior to tumor ablation is mandatory!

These focal therapies have advantages for

- *kidney function preservation*
- *reducing bleeding*
- *shortening operating time*
- *shortening the time of hospitalization.*

Chapter Outline

Interventional Procedures

MRI Targeted – Transrectal Ultrasound Scan (TRUS) Biopsy «Fusion biopsy»

MRI targeted biopsy, differing from systematic biopsy, includes different types of procedures:
1. "*Fusion biopsy*": pre-biopsy MRI images are "fused" with "real time" transrectal ultrasound scan (TRUS) images as shown in Fig. 31 to guide biopsy sampling (11) (12).

- Higher accuracy for detecting cancer tissue
- Fewer number of sample core required
- Less painful and decreased risk of infection and bleeding
- Quicker post-biopsy recovery time

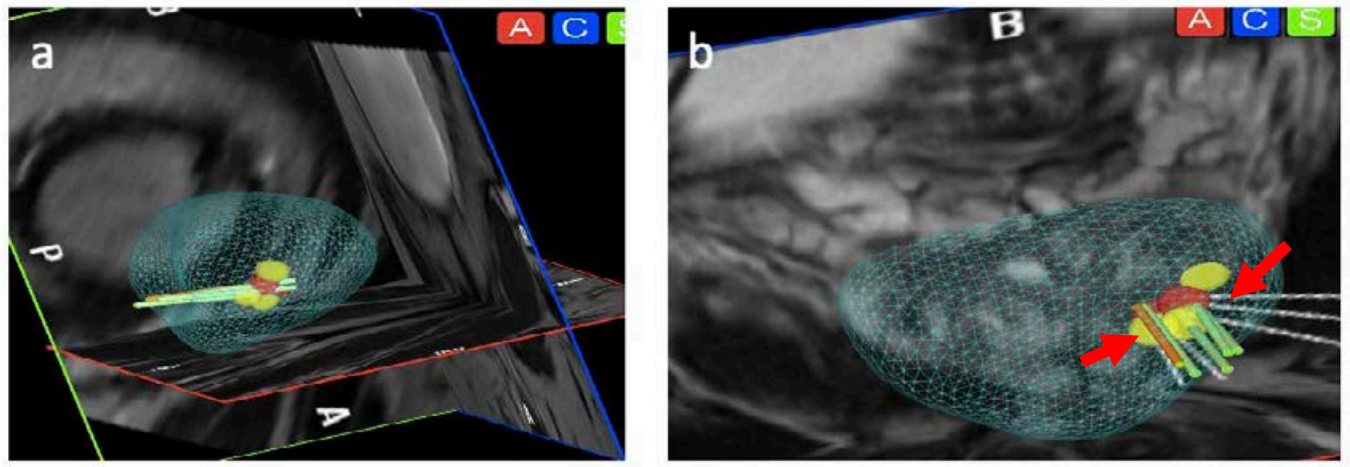

Figure 31. Virtual representation of a TRUS-biopsy. In particular, the figures show the co-registration of MRI and US images of the prostate, with the reconstruction of the biopsy targets and cores (red arrows).

Chapter Outline

Interventional Procedures

2. "In-bore" biopsy: with this approach prostate sampling is obtained directly under MR guidance, by means of a robotic system (Fig. 32). It allows to visualize the exact position of the needle in the lesion.

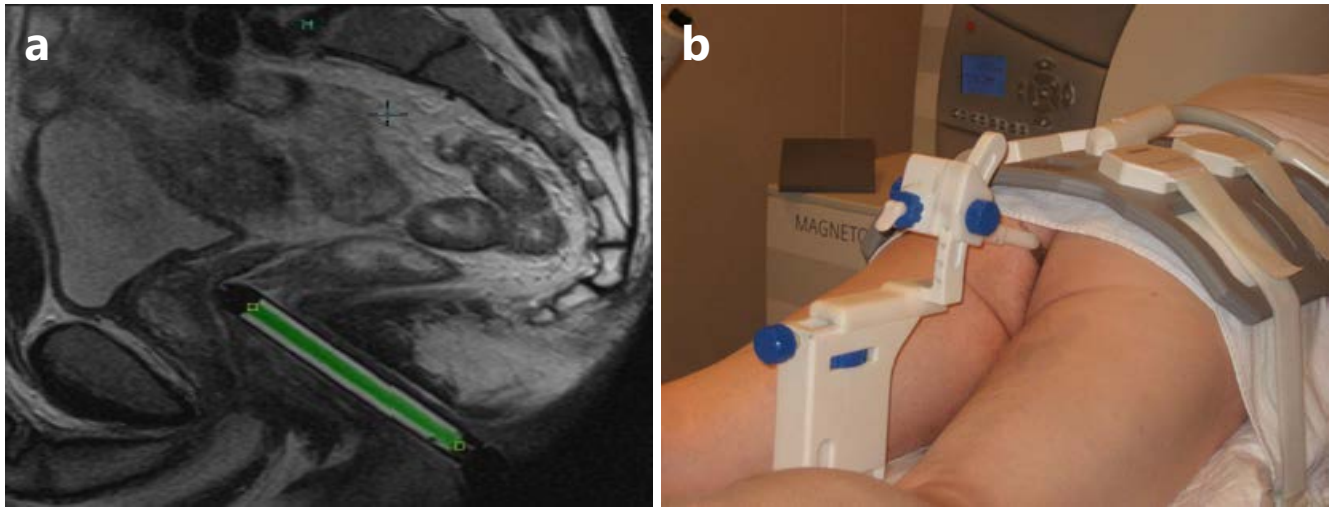

*Figure 32. In-Bore Biopsy. **Figure a)** shows a sagital T2-weighted image obtained before the biopsy to visualize the prostate and identify the target lesion. **Figure b)** shows the correct position of the patient and the device used in the procedure.*
The sequences are acquired along the axis of the amagnetic needle to assess the correct position with respect to the target lesion and establish its direction and depth.

Chapter Outline

Interventional Procedures

Focal Therapy in Prostate Cancer

Focal therapy is an alternative to surgery or radiotherapy. It uses a high dose of different kind of energy to kill cancerous cells (13). Two examples:

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

Chapter Outline

Interventional Procedures

Minimally Invasive Surgical Techniques (Mists) in BPH

There have been significant surgical advancements for the treatment of benign prostate hypertrophy (BPH), including an increasing development 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 displays arterial anatomy, and the appropriate prostatic arterial supply is selectively embolised (14).

However, current evidence of safety and efficacy of PAE supports the use of this procedure for men with moderate-to-severe lower urinary tract symptoms, but PAE remains under investigation.

Chapter Outline

Take-Home Messages (1)

Kidney

The role of the radiologist is:

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

Take-Home Messages (2)

Bladder

- If clinically suspected, perform an ultrasound of the bladder.
- MRI of the bladder is useful for local staging of disease and to differentiate NMIBC from MIBC

Prostate

- mpMRI of the prostate with morphological and functional sequences is recommended as first line test for Prostate Cancer diagnosis.
- PI-RADS score defines the probability of clinically significant disease.
- When MRI is suspicious, perform a targeted biopsy.

Take-Home Messages (3)

Testicles

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

Penis

- In the case of penile cancer or penile fracture, MRI is indicated, after US, to confirm the diagnosis and to determine treatment, for complications assessment.

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Chapter Outline

Test Your Knowledge

1 – Can Imaging distinguish between renal cortex and medulla?

- Yes
- No

Test Your Knowledge

1 – Can Imaging distinguish between renal cortex and medulla?

✓ Yes

- No

Test Your Knowledge

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

- There are 2 renal pelvis
- 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

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

✓ There are 2 renal pelvis

- 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

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

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

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

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

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

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

Test Your Knowledge

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

- Bosniak I
- Bosniak II
- ✓ Bosniak III
- ✓ Bosniak IV

Test Your Knowledge

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

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

Test Your Knowledge

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

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

Test Your Knowledge

7 – On the peripheral zone of the prostate there is a lesion of 10 mm of diameter with suspicious MRI-features; which PI-RADS score would you assign?

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

Test Your Knowledge

7 – On the peripheral zone of the prostate there is a lesion of 10 mm of diameter with suspicious MRI-features; which PI-RADS score would you assign?

- PI-RADS 2
- PI-RADS 3
- ✓ PI-RADS 4
- PI-RADS 5

Test Your Knowledge

8 – How can you perform a prostate biopsy?

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

Test Your Knowledge

8 – How can you perform a prostate biopsy?

- ✓ US-guided
- Fluoroscopy-guided
- ✓ MRI-guided
- CT-guided

Test Your Knowledge

9 - Male, 44 years old, with right testicular pain and enlargement without trauma: what would you do first?

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

Test Your Knowledge

9 - Male, 44 years old, with right testicular pain and enlargement without trauma: what would you do first?

- X-ray
- ✓ US
- MRI
- CT with CE

Test Your Knowledge

10 - US reveals testis enlargement with low signal on colour-Doppler; what do you suspect?

- Seminoma
- Testicular torsion
- Varicocele
- Acute orchitis

Test Your Knowledge

10 - US reveals testis enlargement with low signal on colour-Doppler; what do you suspect?

- Seminoma
- ✓ Testicular torsion
- Varicocele
- Acute orchitis

Chapter Outline