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MRI of the scrotum: Recommendations of the ESUR Scrotal and Penile Imaging Working Group

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Abstract

Objectives The Scrotal and Penile Imaging Working Group (SPI-WG) appointed by the board of the European Society of Urogenital Radiology (ESUR) has produced recommendations for magnetic resonance imaging (MRI) of the scrotum.

Methods The SPI-WG searched for original and review articles published before September 2016 using the Pubmed and Medline databases. Keywords used were 'magnetic resonance imaging', 'testis or testicle or testicular', 'scrotum', 'intratesticular', 'paratesticular', 'extratesticular' 'diffusion-weighted', 'dynamic

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MRI'. Consensus was obtained among the members of the subcommittee. The expert panel proposed recommendations using Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence.

Results The recommended MRI protocol should include T1-, T2-weighted imaging, diffusion-weighted imaging and dynamic contrast-enhanced MRI. Scrotal MRI can be clinically applied for lesion characterisation (primary), including both intratesticular and paratesticular masses, differentiation between germ-cell and non-germ-cell neoplasms (evolving), characterisation of the histological type of testicular germ cell neoplasms (TGCNs, in selected cases), local staging of TGCNs (primary), acute scrotum (in selected cases), trauma (in selected cases) and undescended testes (primary).

Conclusions The ESUR SPI-WG produced this consensus paper in which the existing literature on MRI of the scrotum is reviewed. The recommendations for the optimal imaging technique and clinical indications are presented.

Key points

- *This report presents recommendations for magnetic resonance imaging (MRI) of the scrotum.*
- *Imaging acquisition protocols and clinical indications are provided.*
- *MRI is becoming established as a worthwhile second-line diagnostic tool for scrotal pathology.*

Keywords Scrotum · Testis · Magnetic resonance imaging (MRI) · Protocols · Evidence-based medicine/standards

Abbreviations

3D	Three-dimensional
ADC	Apparent diffusion coefficient
CDUS	Colour Doppler ultrasonography
DCE	Dynamic contrast-enhanced
DWI	Diffusion-weighted imaging
ESUR	European Society of Urogenital Radiology
LCTs	Leydig cell tumours
LE	Levels of Evidence
MRI	Magnetic resonance imaging
OCEBM	Oxford Centre for Evidence-Based Medicine
SPI-WG	Scrotal and Penile Imaging Working Group
T1WI	T1-weighted
T2WI	T2-weighted
TGCNs	Testicular germ cell neoplasms
TSI	Testicular segmental infarction
TSS	Testis sparing surgery
US	Ultrasonography

Introduction

Imaging the scrotal contents has advanced significantly in the last decade, initially with improvements in ultrasound (US) techniques and latterly with the application of magnetic resonance imaging (MRI). The drive behind adoption of the new technologies has been to reduce the number of unnecessary radical surgical procedures by better lesion characterisation.

Ultrasonography, including conventional grey-scale and colour Doppler ultrasonography (CDUS), remains the first choice for diagnostic imaging of the scrotum [1–5]. However, changes in echogenicity may be nonspecific and a confident characterisation of the nature of scrotal masses is not always possible [6–21].

MRI has proved to be a diagnostic tool of high performance for morphological assessment and tissue characterisation in the evaluation of scrotal masses, and may be used to reduce the incidence of unnecessary surgical explorations, especially in cases of inconclusive US findings or in patients in which the US findings are inconsistent with the clinical examination [6–52]. MRI is less operator-dependent than US and has a wide field of view and multiplanar capabilities, demonstrating in exquisite anatomical detail the entire scrotum [6–52]. Advances in MRI using a multiparametric approach, which combines anatomical and functional data, help in narrowing the differential diagnosis in cases of both intratesticular [8, 11–21, 42, 53–67] and paratesticular [8, 14–20, 43, 48, 49] masses. MRI findings correlate well with the histological characteristics of testicular germ cell neoplasms (TGCNs) [8, 15, 30, 68–70]. Accurate preoperative imaging evaluation of the local extent of the disease is provided in patients with TGCNs who may be candidates for testis-sparing surgery (TSS) [7, 13, 16, 42]. The visualization of the tunica albuginea is another distinct advantage of MRI, allowing the assessment in cases of trauma (surgical or conservative management depending on integrity) or testicular neoplasms (T staging, up until now restricted to histological analysis) [8, 13, 19, 24, 26].

However, data regarding optimal acquisition protocols and clinical indications for MRI of the scrotum are lacking. The aim of this work was to produce recommendations on (1) minimal acquisition standards for MRI of the scrotum, and (2) clinical indications from the Scrotal and Penile Imaging Working Group (SPI-WG) of the European Society of Urogenital Radiology (ESUR).

Method

For these recommendations, the ESUR SPI-WG searched for original and review articles published before September 2016,

in the English-language literature, regarding studies on human subjects, using the Pubmed and Medline databases. Keywords used were ‘magnetic resonance imaging’, 'testis or testicle or testicular', 'scrotum', 'intratesticular', 'paratesticular', 'extratesticular', 'diffusion-weighted' and 'dynamic MRI'. Consensus was obtained among the members of the subcommittee through discussions at international congresses and by e-mail. When necessary, the body of scientific recommendations was supplemented by the combined expertise of the multinational group.

The expert panel proposed a final recommendation for each criterion using Oxford Centre for Evidence-Based Medicine (OCEBM) 2011 Levels of Evidence [LE] [71], defined as follows:

- LE1: systematic review of cross-sectional studies, with consistently applied reference standard and blinding
- LE2: individual cross-sectional studies, with consistently applied reference standard and blinding
- LE3: non-consecutive studies, or studies without consistently applied reference standards
- LE4: case-control studies, or poor or non-independent reference standard
- LE5: mechanism-based reasoning (expert opinion).

The following grades were attributed: Grade A, consistent LE1 studies; Grade B, consistent LE2 or LE3 studies or extrapolations from LE1 studies; Grade C, LE4 studies or extrapolations from LE2 or LE3 studies; and Grade D, LE5 studies or troubling inconsistent or inconclusive studies of any level.

Results

Technical requirements

1.5 Tesla versus 3.0 Tesla systems

The majority of published articles use a 1.5 Tesla system. No data on a 3.0 Tesla magnet exist.

Coil selection A circular surface coil is recommended for imaging the scrotum in most studies (LE2) [6, 8, 10, 12, 13, 15, 17, 25, 36, 38, 45, 55, 58, 60, 63]. Surface coils offer an increased signal-to-noise ratio, allowing thin-section imaging and small field of views (Fig. 1a). However, studies using phased-array multichannel coils also have reported satisfactory results in the evaluation of scrotal pathology (LE2) [19, 21, 24, 40, 41, 43, 59, 67], with the option of using parallel imaging methods. Phased-array coils also may be used to evaluate the abdomen and pelvis for staging testicular malignancies [12, 15].

Surface coils are recommended in the evaluation of the scrotum (Grade B). Phased-array coils also provide diagnostic information (Grade B).

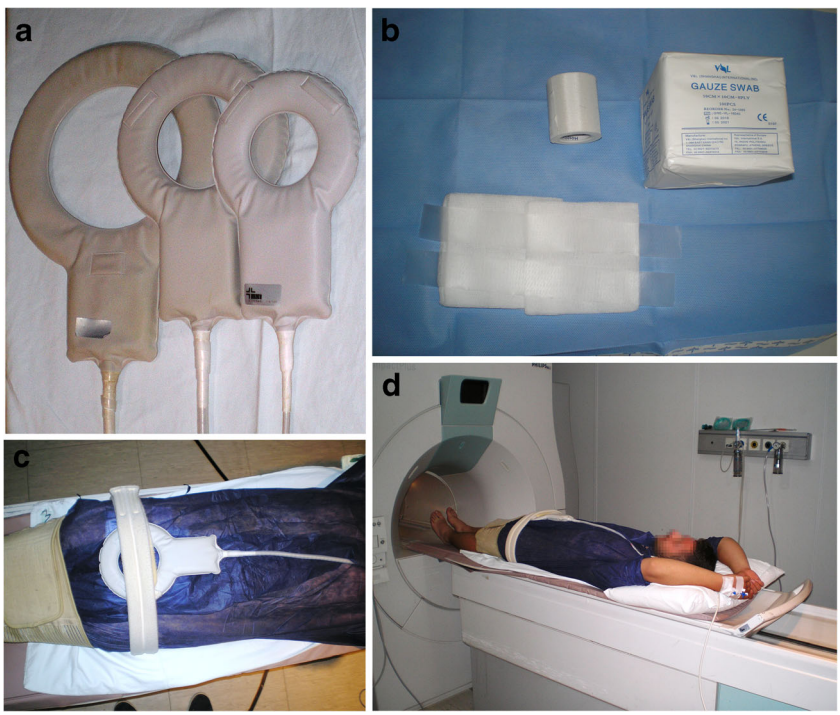

Fig. 1 Technical requirements for MRI of the scrotum: (**a**) Various circular surface coils 17, 11 and 8 cm in diameter. In the choice of a surface coil, patient's age, size of scrotum and imaging coverage should be taken into consideration. (**b**) Adhesive tape and gauge. (**c**) Surface coil is placed over the scrotum. (**d**) Patient positioning

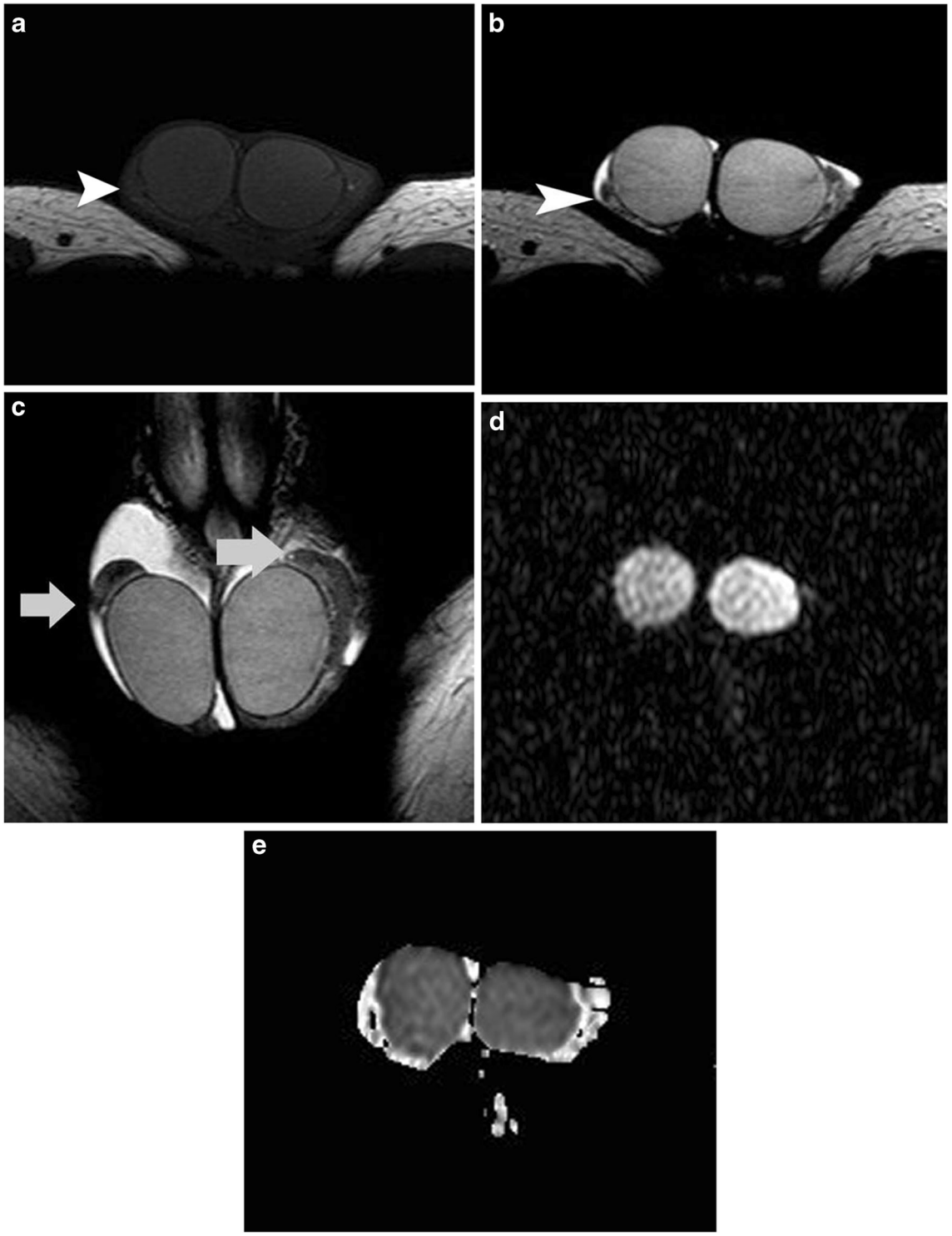

Fig. 2 Normal MRI findings in a 22-year-old man. Transverse (**a**) T1-weighted (T1WI) and (**b**) T2-weighted (T2WI). Normal testes are seen as sharply demarcated, homogeneous oval structures, with intermediate T1 and high T2 signal. The tunica albuginea appears as a thin hypointense halo, clearly defined on T2WI. The epididymis is slightly heterogeneous, isointense and hypointense (arrowhead) to the testis on T1WI and T2WI, respectively. (**c**) Coronal T2WI shows both epididymal heads (arrow), hypointense compared to normal testes. Bilateral small hydrocoele is also seen (normal finding). (**d**) Transverse diffusion-weighted image (DWI) ($b = 900$ s/mm^2) and (**e**) the corresponding apparent diffusion coefficient (ADC) map. Normal testes are hyperintense and slightly hypointense on high b value DWI and ADC maps, respectively, due to the histological complexity of the normal testicular parenchyma. The ADC of normal testis has been reported to vary from 1.08 to 1.31 × 10^{-3} mm^2/s, with an increase with advancing age [61]

Patient preparation and positioning Adequate support and correct positioning of the scrotum is essential (LE2) [8, 12, 13, 15, 17, 19, 21, 45, 55, 58, 63]. The penis should be raised, covered with a light cloth such as gauze, and fixed to the lower abdominal wall. Scrotum should be elevated by placing a towel between the thighs. A second towel is placed over the scrotum and the coil is placed on top of the second towel. The towels ideally should be warm to reduce scrotal muscular contractions that would degrade the images. Bands may be used to appose the thighs as close as possible to maintain the scrotum on the thighs. A peripheral intravenous line with a 19-gauge needle is placed into the subcutaneous veins of the forearm or antecubital fossa. Finally, the patient is placed into the MRI unit in the supine position with the feet first (Figs. 1b-d).

Adequate support and correct positioning of the scrotum are essential key elements in performing MRI of the scrotum (Grade B).

Conventional (anatomical) imaging The testes should be examined in at least two orthogonal planes, along the testicular length and transverse axes. The coronal and axial plane is recommended. Both T1-weighted (T1WI) and T2-weighted (T2WI) sequences are essential (Fig. 2). T1WI provides information about scrotal anatomy and demonstrates increased signal in certain tissues, such as fat and methaemoglobin. T1WI in transverse orientation is recommended (LE2) [8, 12, 13, 15, 17, 19, 21, 45, 55, 58, 63]. MRI protocol in some studies included fat-saturated T1WI (LE4) [15, 17, 19] and dual-echo (in-phase and out-of-phase) sequences (LE4) [17].

T2WI in at least two planes, including the transverse and the coronal plane, should follow (LE2) [8, 12, 13, 15, 17, 19, 21, 45, 55, 58, 63]. These images are best for lesion detection, localisation and characterisation. Sagittal T2WI is optional, but is recommended in the following cases: evaluation of the epididymis; lesion localisation; depiction of small-sized lesions close to the anterior or posterior testicular surfaces (LE4) [6]; testicular rupture (L32) [8, 13, 15, 19, 24]; and local staging of testicular carcinomas (LE2) [7, 13, 15, 16, 42].

T2WI obtained with TE of 100–140 ms provides satisfactory T2 contrast between the testis, the epididymis, the spermatic cord and the surrounding fat tissue (LE2) [8, 12, 13, 15, 17, 19, 21, 45, 55, 58, 63]. Some studies have used chemical-

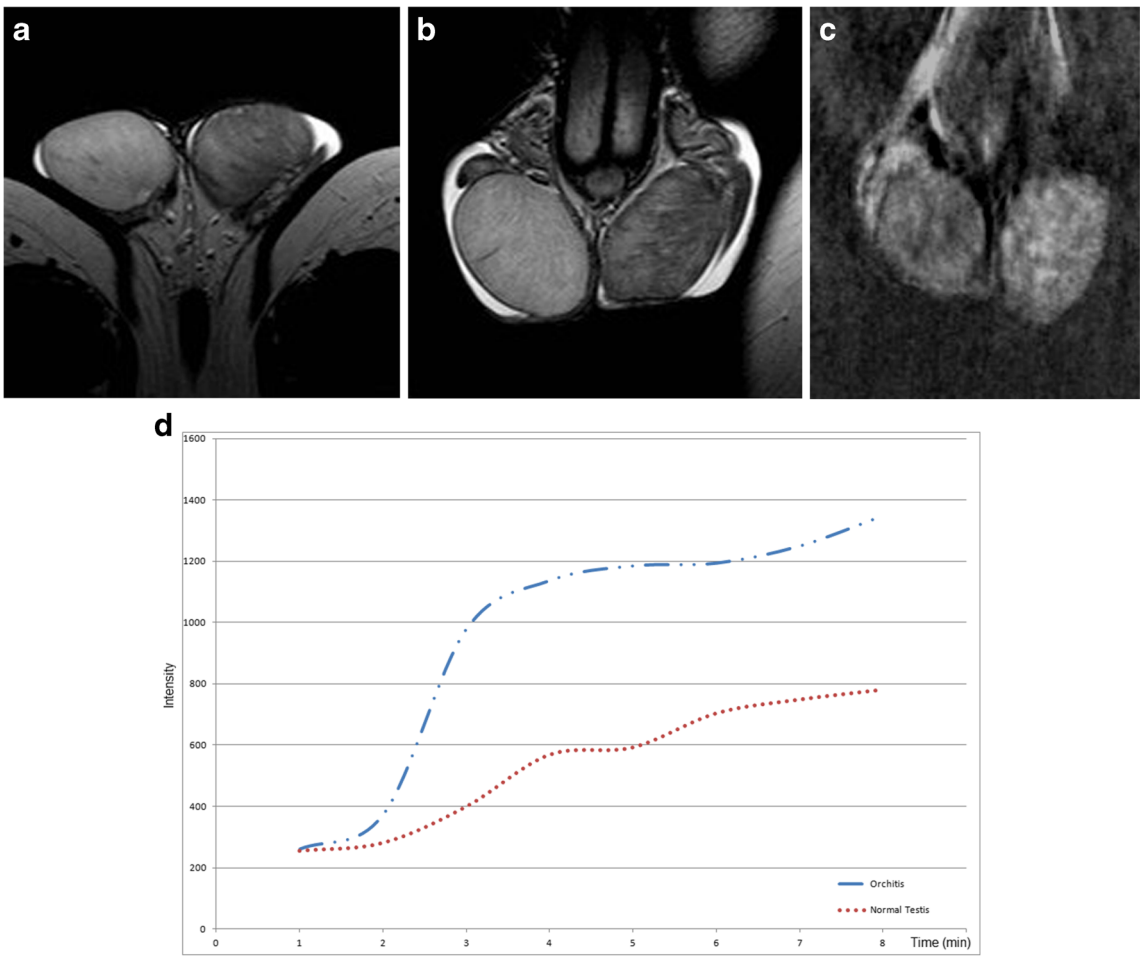

Fig. 3 Left acute epididymo-orchitis in a 40-year-old man. T2-weighted image (T2WI) in (**a**) transverse and (**b**) coronal orientation show heterogeneity and hypointensity of the left testicular parechyma. (**c**) Coronal subtracted dynamic contrast-enhanced (DCE) image (early phase) depicts left testis avidly and heterogeneously enhancing. (**d**) TSI curves of acute orchitis (type II, blue) and contralateral normal testis (type I, red)

selective fat-suppression T2WI (LE2) [19, 38, 45, 55, 59, 63], instead of conventional T2W1. Heavy T2WI also has been proposed for the evaluation of scrotal pathology (LE5) [45]. T2*-weighted gradient echo sequence has been advocated in patients suspected of testicular torsion due to their sensitivity in the detection of blood products (LE2) [45, 55, 63].

Optimal coverage is provided by thin sections (3–4 mm) without any gap and a 10- to 28-cm field of view. For very small testes, 2.5 mm without any gap can be performed. Superior and inferior saturation bands should be applied to eliminate ghosting artefacts from blood flow along the phase-encoding axis [12]. Respiratory compensation is not necessary [51]. Axial T1WI of the abdomen is recommended to search for metastatic lymphadenopathy [12], and as an overview in cases of testicular pain looking for causes of referred pain.

Axial T1WI, axial and coronal T2WI with thin sections are the minimum requirements for conventional MRI of the

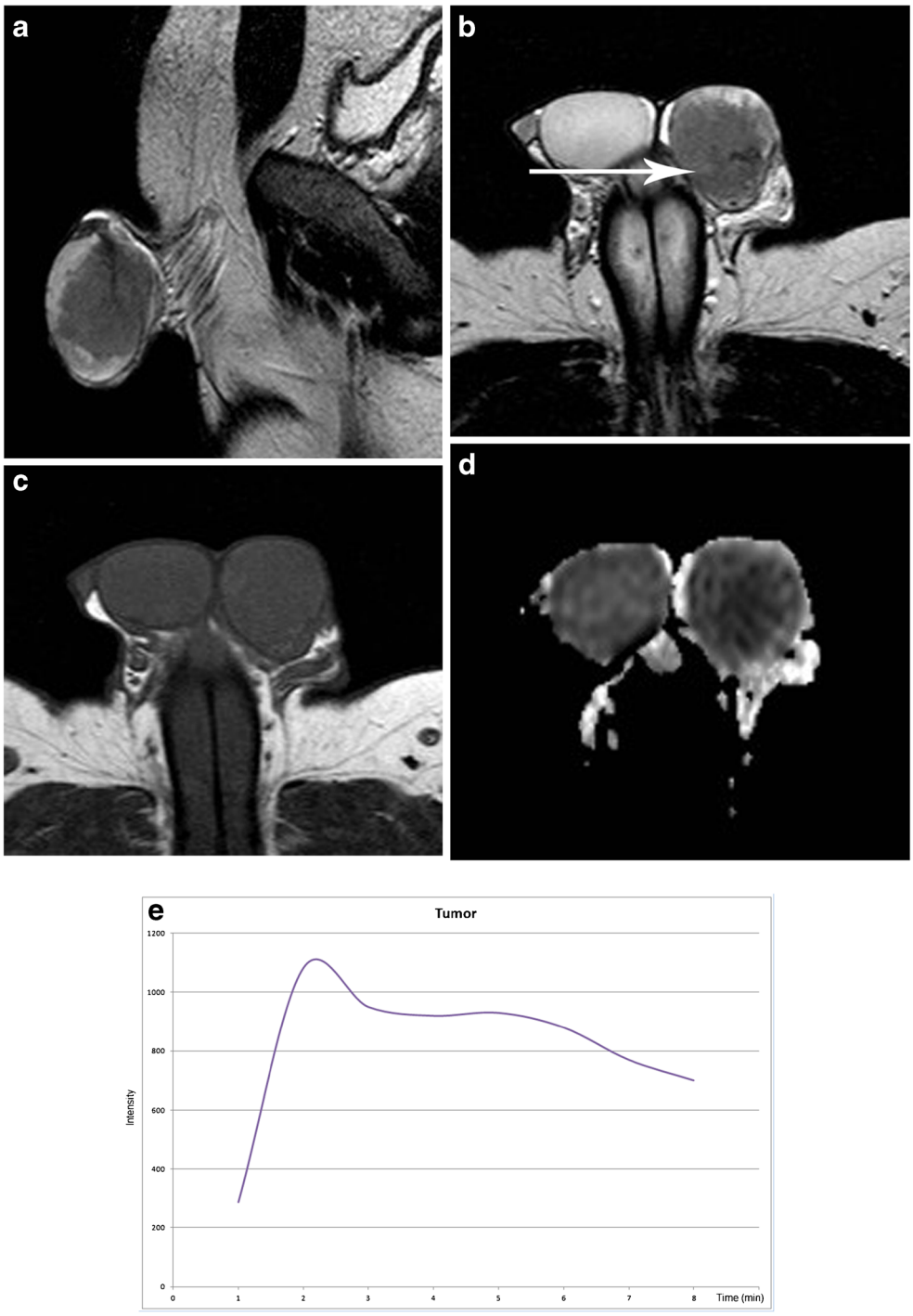

Fig. 4 Left testicular seminoma in a 27-year-old man. T2-weighted image (T2WI) in sagittal (**a**) and axial (**b**) planes depict left intratesticular mass, mainly homogenous, of low signal intensity. The tumour invades the testicular tunicae and extends into the paratesticular space (long arrow), findings which subsequently were confirmed on pathology. (**c**) Transverse T1-weighted image (T1WI). The neoplasm is detected isointense compared to the contralateral testis. (**d**) Transverse apparent diffusion coefficient (ADC) ($b = 900$ s/mm^2) map shows hypointense tumour, due to restricted diffusion. The ADC (x 10^{-3} mm^2/s) of the neoplasm is 0.53. (**e**) TSI of the tumour (type III)

scrotum (Grade B). Fat-saturated T1WI and fat-saturated T2WI may be used as alternatives to standard sequences (Grade B). The addition of T2*-weighted gradient echo sequence is proposed in acute scrotum (Grade B).

Diffusion-weighted imaging A few recent studies reported improvement in the characterisation of intratesticular lesions with the addition of diffusion-weighted imaging (DWI) (LE2) [58, 59]. The apparent diffusion coefficient (ADC) of testicular carcinomas has been reported to be lower than that of normal testis and various benign intratesticular lesions [58, 59]. DWI also has been reported useful in the diagnosis of testicular torsion (LE2) [63], the detection and localisation of nonpalpable undescended testes (LE2) [65], and the detection of fibrosis in testes with varicocele [67].

DWI should be acquired in the axial plane with an echo planar diffusion pulse sequence. At least three different *b* values should be acquired, including 0, 400–500 and 800–1,000 s/mm^2. ADC maps can be generated on the MRI console, and should be analysed both qualitatively and quantitatively (Figs. 2d,e). For qualitative assessment, high *b* value (800–1,000) DWI and ADC maps should be used, evaluated in combination with T1WI and T2WI.

DWI is recommended in the evaluation of scrotal pathology (Grade B).

Dynamic contrast-enhanced MRI Dynamic contrast-enhanced (DCE) MRI of the scrotum can be used when further tissue characterisation is needed or when patients present with acute scrotal symptoms (LE2) [21, 25, 45, 55, 56, 63]. The technique is useful in the diagnosis of testicular torsion (LE4) [23, 64] and the characterisation of scrotal lesions (LE2) [21, 55]. In a retrospective study of 44 men with various testicular lesions [56] three types of contrast enhancement were described according to the shape of time-signal-intensity (TSI) curves: type I, a gradual linear increase of enhancement throughout the examination, corresponding to the enhancement of normal testis; type II, a brisk upstroke enhancement, followed by either a plateau or a slight further increase of enhancement, representing benign lesions (Fig. 3); and type III, a brisk enhancement, followed by gradual washout of the contrast medium, representing malignancies (Fig. 4).

Although more technically demanding and time-consuming, subtraction DCE-MRI following the administration of gadolinium-based contrast medium is recommended for the evaluation of the scrotum (LE2) [21, 25, 45, 55, 56, 63]. The technique consists of a series of coronal three-dimensional (3D) fast field-echo sequences performed after a bolus injection (1–2 ml/s) of gadolinium-based contrast medium. The rapid injection of contrast agent should be performed within 5 s, followed by flush of 20 ml of physiological saline. Five to seven imaging sets should be consecutively acquired 15 s after the injection of contrast material. The actual examination time is 8 min and the duration of each set 50–60 s. Then, the slice-by-slice subtraction is performed to obtain subtraction DCE images. The data set obtained immediately before administration of contrast agent is used as a mask and subtracted section by section from each of the data sets obtained after contrast administration by using commercially available software.

Some studies have used post-contrast conventional TIWI with (LE4) [15, 19] and without fat saturation (LE4) [17, 60], in the axial and coronal plane, instead of DCE-MRI.

Subtracted DCE-MRI is recommended in the evaluation of scrotal diseases (Grade B). Conventional contrast-enhanced T1WI may be used as an alternative (Grade C).

Table 1 summarises the minimum requirements for MRI of the scrotum.

Clinical indications

Lesion localisation

The primary goal in the evaluation of a palpable scrotal mass is to determine its intra- or extratesticular origin. US remains the initial imaging modality in assessing the location of a scrotal mass. However, when the exact location is uncertain with US, MRI may be helpful (LE4) [12, 15–17, 19, 48, 49], especially in differentiating masses arising from the tunica albuginea rather than from the peripheral seminiferous tubules (Fig. 5). The delineation of the tunica albuginea, seen as a thin hypointense rim between the mass and the adjacent testis, helps to indicate the origin of the mass in these cases [19]. T2WI in three planes is recommended.

MRI of the scrotum is recommended when differentiation between intratesticular and paratesticular masses is not possible, based on US findings (Grade C).

Table 1 MRI protocol for the evaluation of the scrotum: minimum requirements

Fast <30 min multiparametric protocol. Imaging can be performed on a 1.5-T system using a circular surface coil. Images should cover the entire scrotum and include T1WI, T2WI, DWI and DCE-MRI
• **Patient positioning**: Supine position, feet first. Both testes are placed at a similar distance from the coil and the penis is draped on the anterior abdominal wall
• **T1WI** axial (3–4 mm slice thickness, no intersection gap)
• **T2WI** axial + coronal (3–4 mm slice thickness, no intersection gap)
• **DWI**: axial (3–5 mm slice thickness, 0.5 mm intersection gap). At least three *b* values should be acquired: 0, 400–500 and 800–1,000 s/mm^2. The highest *b* value should be used (800–1,000 s/mm^2) for the calculation of ADC
• **Subtraction DCE-MRI**: coronal 3D fast field-echo sequence (4 mm slice thickness, 2 mm overlapping sections). Five to seven consecutive imaging sets, each of 50–60 s duration should be acquired, 15 s following a bolus injection (1–2 ml/s) of contrast agent. Imaging acquisition should be continued for 8 min to evaluate washout

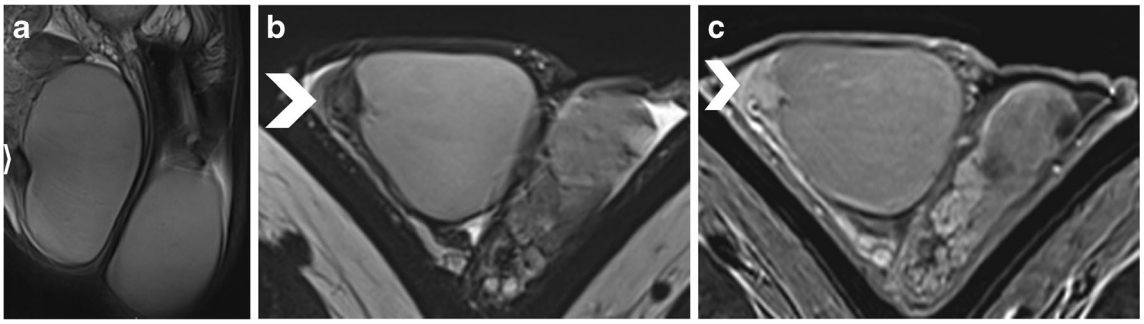

Fig. 5 T2-weighted image (T2WI) in (**a**) coronal and (**b**) transverse orientation show small right paratesticular mass lesion (arrowhead), in close proximity to the testicular tunicae and the ipsilateral testis. The lesion appears slightly hypointense on T2WI. (**c**) Axial contrast-enhanced T1WI depicts lesion enhancing after gadolinium administration. Histology reported adenomatoid tumour attached at the visceral layer of the tunica vaginalis

Lesion characterisation

Intratesticular masses The recommended MRI protocol for characterisation of intratesticular masses should include T1WI, T2WI, DWI and subtracted DCE-MRI.

Benign versus malignant Although most intratesticular masses are malignant, a possible diagnosis of various benign entities based on imaging features may improve patient care and decrease the number of unnecessary radical surgical procedures. In these cases, follow-up, biopsy, tumour enucleation and TSS may be justified [6–20, 39, 42]. MRI may provide important information in the preoperative characterisation of the histological nature of various benign intratesticular mass lesions in terms of morphological information and by showing the presence of fat, fluid, haemorrhage, fibrous tissue and solid contrast-enhancing tissue (LE2) [39, 42]. The technique can be used mainly as a problem-solving tool when US findings are equivocal (LE4) [6–8, 10–20, 42].

In patients with equivocal US, MRI is recommended as a second-line technique for characterisation of intratesticular masses (Grade C).

Germ cell neoplasms versus non-germ cell neoplasms The conventional MRI criteria used to characterize TGCNs have been described [7, 8, 10, 12, 17, 20, 30, 39, 42] (Appendix 1).

The widespread use of US has resulted in an increase of incidentally discovered nonpalpable small solid testicular masses, which are up to 80% are benign, with Leydig cell tumours (LCTs) being the most frequent [72]. TSS is recommended in small LCTs [73]. Although the preoperative characterisation of these tumours is difficult, MRI features may be helpful (LE2) [21]. TSS is also recommended in small-sized Sertoli cell tumours [73]. No adequate data are available on MRI for the characterisation of these neoplasms [21, 42, 54].

MRI may be used to suggest the diagnosis of primary testicular lymphoma in the presence of a hypointense T2 mass, strongly and heterogeneously enhancing, detected over 60 years of age (LE4) [74].

MRI may help in the characterisation of LCTs (Grade B).

Seminomas versus nonseminomatous tumours Radical orchidectomy is the therapy of choice in men with TGCNs and usually should be carried out without any delay. However, in cases of disseminated disease and/or life-threatening

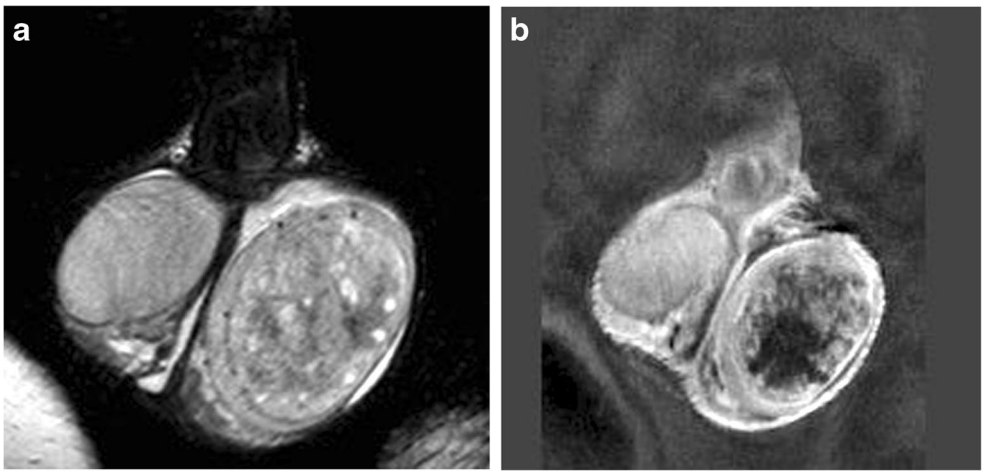

Fig. 6 Nonseminomatous germ cell neoplasm of the left testis (embryonal carcinoma, teratoma and yolk sac tumour) in a 20-year-old man. Coronal (**a**) T2-weighted image (T2WI) and (**b**) subtracted dynamic contrast-enhanced (DCE) images demonstrate large heterogeneous left testicular mass, strongly and inhomogeneously enhancing

metastases, chemotherapy is the first treatment, followed by orchidectomy when the patient's clinical condition improves [73]. In these cases, the preoperative differentiation between seminomas and nonseminomatous tumours is helpful. MRI features have been found to closely correlate with the histopathological characteristics of TGCNs (LE4) (Fig. 6) (Appendix 1) [8, 15, 17, 68–70]. ADC may be used as an additional tool (LE4) for differential diagnosis [70].

MRI is recommended to differentiate seminomas from nonseminomatous testicular neoplasms in selected cases (Grade C).

Paratesticular masses Primary solid tumours of the paratesticular space are uncommon. A confident characterisation of their nature may obviate unnecessary radical orchidectomy in cases of benign lesions. US findings often overlap, precluding a specific diagnosis [48, 49]. MRI features with respect to tumour location, morphological findings and tissue characteristics can help to narrow the differential diagnosis (LE4) [8, 14, 15, 17, 48, 49, 75]. In cases of malignancies, MRI can help in suggesting the diagnosis of an aggressive neoplasm, assessing the local extent and the presence or absence of distant metastases (LE4) [14, 15, 48, 49, 76].

MRI protocol should implement T1WI, T2WI in three planes, DWI and subtracted DCE-MRI.

MRI is recommended for characterisation of paratesticular masses (Grade C).

Local staging of testicular germ cell neoplasms (TGCNs)

Although radical orchidectomy is the treatment of choice for TGCNs, TSS can be attempted in special circumstances, including synchronous bilateral testicular tumours, metachronous contralateral tumours and a tumour in a solitary testis [73]. MRI performs well in the preoperative evaluation of the local stage T in TGCNs, in patients who are candidates for TSS. Accurate information regarding tumour dimensions, possible invasion of the rete testis, the paratesticular space and/or the spermatic cord and presence of a pseudocapsule helping in tumour enucleation are provided by MRI (LE4) [7, 16, 17]. MRI protocol should include T2WI in all three planes.

MRI is recommended for local staging of TGCNs (Grade C).

Acute scrotum

US with colour or power Doppler is the first imaging examination in the evaluation of acute scrotum, often allowing discrimination between causes that require emergency surgery, such as torsion from those that can be treated non-surgically [1–5, 77]. However, the detection of blood flow on US depends on the expertise of the investigator, and the sensitivity of the machine [11, 23, 26]. Patients with incomplete testicular torsion or those referred to a urologist several days after the onset of symptoms also represent problematic cases, both clinically and sonographically [8]. MRI may be used as a second-line examination in cases of inconclusive US findings or as a confirmatory study, helping plan appropriate treatment (LE2) [22, 25, 55, 63].

Segmental testicular infarction (STI) is a rare testicular disease, usually presenting with acute scrotal pain. CDUS findings are often diagnostic. MRI is excellent in suggesting the diagnosis of STI, when US findings are atypical (LE4) [15, 26, 41].

Despite satisfactory results, the disadvantages of MRI in an emergency setting should be acknowledged, including long examination time, high cost, frequent unavailability and need for sedation of young patients [25, 45].

The recommended MRI protocol should include T1WI, T2WI, DWI and subtracted DCE-MRI (LE2) [22, 25, 55, 63]. When the affected testis shows absent or diminished enhancement, T2*WI can be added to help in the diagnosis of haemorrhagic necrosis (LE4) [64].

MRI may be used as a complimentary examination in acute scrotal diseases (Grade B).

Trauma

Accurate characterisation of the type of injury in cases of blunt scrotal trauma is mandatory, so that appropriate treatment could be planned. US is the first-line diagnostic tool for the evaluation of blunt trauma, accurately assessing the integrity of the tunica albuginea in most cases [3]. In equivocal cases, MRI represents a useful alternative imaging modality [LE2] [24]. In cases of trauma, MRI protocol should implement T1WI, T2WI in all three planes and subtracted DCE-MRI [8, 13, 15, 19, 24, 26].

MRI is recommended as a second-line imaging examination in cases of scrotal trauma and non-diagnostic US findings (Grade B).

Undescended testes

US does not always reliably localize nonpalpable undescended testes and does not rule out an intra-abdominal testis [78]. Many studies have addressed on the diagnostic efficacy of MRI in locating undescended testes [LE2] [50–52, 79, 80]. Krishnaswami et al. [81] in a systematic review concluded that conventional MRI, including T1WI and T2WI, is poor at locating both atrophied and intra-abdominal testes but performs modestly well in locating those in the inguino-scrotal regions. However, the addition of fat-suppressed T2WI (LE2) [65] and DWI (LE2) [65, 66] improves the diagnostic performance of the technique in detecting nonpalpable testes.

The recommended protocol includes T1WI, axial and coronal fat-suppressed T2WI and DWI. In cases of intra-abdominal testis, coverage should be extended to the lower

Table 2 Clinical indications for MRI of the scrotum

Clinical indications	When to perform MRI?	MRI sequences
Lesion localisation: differentiating intratesticular from paratesticular masses	**Rarely needed. Recommended** to differentiate lesions arising from the tunical surface of the testis from those from the peripheral seminiferous tubules	T2WI in all three planes should be added to the routine MRI protocol
Lesion characterisation: **intratesticular masses**		
• differentiating benign from malignant	**Mainly as a second-line examination**, **when US findings**, **including B-mode imaging and CDUS**, **are equivocal or non-diagnostic** (**work in progress**)	T1WI, T2WI, DWI, subtracted DCE-MRI
• differentiating testicular germ cell neoplasms from non-germ cell neoplasms	**Work in progress**	T1WI, T2WI, DWI, subtracted DCE-MRI
• differentiating seminomas from nonseminomatous tumours	**Recommended in cases of disseminated disease and/or life-threatening complications**, **where chemotherapy is the first treatment**	T1WI, T2WI, DWI, subtracted DCE-MRI
Lesion characterisation: **Paratesticular masses**		
• differentiating benign from malignant	**Recommended**. US does not always allow a confident characterisation	T1WI, T2WI, DWI, subtracted DCE-MRI. T2WI in three planes helps lesion localisation
Local staging of TGCNs	**Recommended in patients planned for TSS**	T1WI, T2WI, DWI, subtracted DCE-MRI. T2WI in all three planes is recommended
Acute scrotal diseases	**Rarely needed. Recommended in cases** of inconclusive US findings, incomplete testicular torsion, referred with delayed torsion, or as a confirmatory study, for appropriate treatment planning	T1WI, T2WI, DWI, subtracted DCE-MRI. Addition of T2*WI in cases of absent or diminished enhancement by the affected testis.
Scrotal trauma	**In cases of inconclusive US findings**	T1WI, T2WI, subtracted DCE-MRI. T2WI in all three planes is recommended
Undescended testes	**Recommended. Role of DWI** (**work in progress**)	T1WI, axial and coronal fat-suppressed T2WI, DWI. In cases of intraabdominal testis, coverage should be extended to the lower poles of the kidneys

poles of the kidneys. MRI is recommended for locating nonpalpable undescended testes (Grade B).

Table 2 summarises clinical indications for MRI of the scrotum.

Conclusion

These recommendations show that MRI of the scrotum, including a multiparametric protocol, represents a valuable and efficient supplemental imaging technique in the evaluation of scrotal pathology. This is of great clinical importance because more precise treatment strategies can be determined and surgical explorations or orchidectomy avoided for more patients. The minimal requirements for the acquisition of MRI can be applied with the generally available 1.5 T MR systems.

Compliance with ethical standards

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Methodology Guidelines based on literature review and expert opinion.

Appendix 1: MRI findings of TGCNs

Table 3 MRI findings suggestive of testicular germ cell neoplasms

Primary	Secondary
mainly isointense on T1WI, low or heterogeneous T2 signal, restricted diffusion, low ADC, heterogeneous enhancement, type III TSI curve	areas of haemorrhage and/or necrosis, invasion of the testicular tunicae, extension to the paratesticular space and/or the spermatic cord

Table 4 MRI findings useful to differentiate seminomas from nonseminomatous germ cell neoplasms

Seminomas	Nonseminomas
• multinodular • mainly isointense on T1WI • relatively homogenous and hypointense on T2WI • bandlike structures of low T2 signal (corresponding to fibrovascular septa on pathology) • septa enhancing more that the remaining tumour • lower ADC, compared to nonseminomas	• often surrounded by a low signal intensity halo (proved to correspond to fibrous capsule on pathology) • heterogeneous on T1WI • markedly heterogeneous on T2WI • heterogeneous enhancement

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