ISMRM 2011- Hot Topics in Body MRI

Clinical Intensive Education Option - Male and Female Pelvis

Non-Oncological Imaging of the Male Pelvis

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Introduction

Although the role of magnetic resonance imaging (MRI) of the male pelvis has been defined best for various malignant neoplastic conditions, i.e., as an imaging modality applied in oncological imaging, other pathological conditions have been described where MRI may be used to the advantage of the patient and his diagnosis. Broad categories of pathology to be considered include congenital anomaly or disorder, trauma, inflammatory, and benign neoplastic (i.e., non-oncological) conditions. Male pelvic organs and anatomic structures to be examined by means of MRI include the urinary bladder, the prostate and seminal vesicles, the penis and urethra, and the scrotum and its contents.

Although patient preparation, selection of MRI scanner type, MRI coils, imaging protocols and sequences may vary according to the respective clinical setting and pathological condition of the patient, some general principles apply that can be followed as easy measures of quality assurance in MRI of the male pelvis.

The lecture strives to provide an overview of principal imaging techniques and categories of non-oncological pathological imaging findings in MRI of the male pelvis, provided by examples of MRI examinations in different non-oncological pathological conditions.

Principal MRI Techniques

Patient positioning and patient preparation

MRI examinations of the male pelvis are usually being performed with the patient in supine position. For improved patient comfort, the knees and lower legs may be slightly elevated by means of a leg rest, and the head and neck supported by a neck rest, such that the patient's spine and pelvis are in a comfortable and relaxed position which makes lower back pain less likely to occur than when the patient lies flat.

Fixing external surface coils in the region of the pelvis provides additional support for the patient and may help to decrease motion artefact. Patient comfort may be increased by the application of blankets that both separate the external surface coil slightly from the body, which decreases sweating, and cover the patient's pelvis and legs from sight and draft. Since organs of the male pelvis are somewhere half way between head and toes, there is essentially choice of placing the patient head first or feet first. However, it may be more comfortable for the patient to be examined feet first. As part of patient safety measures for the MRI examination, ear protection against MRI noises and an alarm bell should be offered to every patient.

Preparation of the patient for an MRI examination of the urinary bladder includes bladder distension. Unless there is disease or disorder which has severely decreased bladder capacity, the urinary bladder of an adult man should contain at least 150 ml, better 200-300 ml, of fluid for the MRI examination. In cases of disease of the urinary bladder suspected of affecting the rectum or sigmoid colon, it may be useful to distend the rectum and sigmoid colon by means of water or ultrasonography gel (for negative contrast on T1-weighted images and positive contrast on T2-weighted images) or water doted with small amounts of positive contrast media for MRI (for positive contrast on T1-weighted images).

For MRI of the prostate, the patient may have to be prepared for the application of an endorectal surface coil (ERC). Bowel preparation may be requested to include a cleansing enema of the sigmoid colon and rectum; however, in clinical practice, it is most often sufficient that the patient empties his bowels and urinary bladder on the toilet prior to the MR examination. In all instances, digital rectal examination (DRE) should precede placement of an ERC, to detect or rule out severe narrowing or other lesions of the anus and rectum potentially harmful to the patient when an ERC is applied.

MRI of the penis includes placement of the penis in such position that it can be examined by means of an external surface coil. Stretching the penis such that the glans penis points toward the patient's navel, the corpus spongiosum is ventral to the corpora cavernosa, and the penis does not overly the scrotum appears to be most advantageous. If need be, the shaft of the penis can be fixed to the skin of the lower abdomen by means of band aids or hospital adhesive tape. Another option is to stretch out the penis such that the glans penis points toward the patient's toes, and the corpora cavernosa are ventral to the corpus spongiosum.

Preparation of the patient for MRI of the scrotum is similar to preparation for MRI of the penis. However, when a surface coil is to be applied, elevating the scrotum and supporting it

with a foam rubber block or similar device, which is placed between the patient's inner thighs, may improve imaging results.

Application of butylscopolamide (Buscopan®) or glucagone has been recommended to decrease bowel motion in MRI of the urinary bladder or prostate; however, contraindications have to be observed. In MRI of the prostate at 1.5T, it is usually sufficient to inflate the balloon of the ERC with 80 to 100 ml of air once it has been entered into the empty rectum.

Selection of coils

MRI examinations of the male pelvis should be performed in whole-body high-field MR scanners. Recent, scientifically evaluated studies were mostly performed at a magnetic field strength of 1.5 T or 3.0T. While historically, the body coil was used as both transmitter and receiver, multi-channel phased array surface coils (PASC) with at least 4 independent elements have since been applied to the advantage of signal-to-noise ratio and image homogeneity. Parallel imaging techniques are available for some MRI scanners for use with dedicated PASCs and may primarily decrease examination time.

In MRI of the prostate, using the body coil or a PASC is usually sufficient if the aim is to determine prostate volume, e.g., in patients with benign prostatic hyperplasia, BPH, prior to and after therapy. However, the application of an ERC, particularly when integrated into a phased array that includes body or pelvic surface coils, has been shown to improve prostate imaging significantly at 1.5T. Currently, it remains unclear if an ERC is necessary at 3.0T.

When an ERC is being used in MRI of the prostate, the balloon of the ERC should be completely placed within the rectum, such that its concave part covers the dorsal aspect of the prostate from base to apex.

In MRI of the penis or scrotum, small surface coils with diameters of 15-20 cm (6-8 inches) or less may be used as receivers instead of PASC. However, when abdominal or pelvic lymph nodes are to be included in the examination, it is advantageous to use a PASC.

Examination sequences

MRI protocols for the urinary bladder, the prostate, the penis, and the scrotum are based on T1-weighted spin-echo- (SE)- and T2-weighted turbo- or fast-spin-echo- (TSE- or FSE-) sequences. SE-sequences with T1-weighting may replaced by three-dimensional gradient echo MR imaging in some instances, such as a magnetization-prepared rapid gradient echo (MPRAGE) sequence.

As an add-on to the protocol, short-tau inversion recovery (STIR) MR images may be helpful for the detection of tissue or bone marrow oedema in the pelvis, and for fluid collections

within the pelvis or scrotum, e.g., seromas, lympoceles, urinomas, hydroceles, spermatoceles, or pus collections.

Fat signal suppression techniques may be particularly useful with T1-weighted images to distinguish between fat and blood remnants in unenhanced MR images, and to increase the conspicuity of contrast-enhancing structures after intravenous administration of Gadolinium chelates. In the penis and scrotum, however, fat signal suppression is usually not advantageous, since there is naturally very little fat tissue anyway.

There are no published data to compare the respective diagnostic accuracies of T2-weighted HASTE/SSFSE and TSE/FSE MR sequences in diseases of the urinary bladder the prostate, the penis, and the scrotum. However, functional MRI of the urinary bladder and pelvic floor, based on rapid, T2-weighted MR sequences, such as HASTE and True FISP, has been applied in pelvic floor insufficiency, in patients with status post prostatectomy, and in children with various congenital anomalies of bladder and pelvic floor morphology and function. With the urinary bladder filled with urine or water, and the rectum and vagina filled with ultrasound gel, median sagittal MR images are obtained at intervals of one second. Changing strain on the urinary bladder and pelvic floor by alternating between contraction, pressing, and relaxation shows both respective positions of pelvic organs in different functional situations and evacuation of intraluminal contents of respective hollow organs. MRI examinations of micturition may be performed either with rapid, T1-weighted MR images with or without contrast enhancement of urine, or with rapid, T2-weighted sequences.

Application of intravenous contrast media

In MRI of the urinary bladder, dynamic contrast-enhanced (DCE-MRI) studies with short TR / short TE sequences repetitively acquired after intravenous bolus injection of Gd-chelates appear to improve test quality parameters, at least for oncologic cases. The role of DCE-MRI of the prostate has not sufficiently been defined yet. The most severe problems of DCE-MRI lie in the trade-off between the number of slices per scan and the repetition rate and in the lack of standardized post-processing protocols. Intravenous application of Gd-chelates are helpful in MRI examinations of the penis for two reasons. Contrast enhancement of the blood filling the corpora cavernosa and the bulbus and corpus spongiosum helps to delineate structures that do not enhance, such as fibrotic tissue or blood clots after longstanding priapism. Also, some penile lesions may be hypervascularized, such that they take up more contrast than healthy, surrounding tissue and delineate better on post-contrast MR images. Intravenous Gd-chelates have been applied in the majority of MRI studies of the scrotum.

Preferred coverage

In MR examinations of the urinary bladder and the prostate and seminal vesicles, preferred coverage extends from the aortic bifurcation to the pelvic floor, to cover both the primary region of interest, i.e., the urinary bladder and its adjacent organs and tissues, and the regional lymph nodes and skeleton. However, for sequences with 3 mm section thickness that focus on the prostate and seminal vesicles, coverage is limited to the prostate and seminal vesicles in axial images. Coronal and sagittal images are obtained with fields of view that cover the entire pelvis in cranio-caudal direction, but are limited in extent to the urinary bladder or to prostate and seminal vesicles and their immediate surroundings in the anterior-posterior (coronal) or lateral (sagittal) dimension, respectively.

When the MRI examination is limited to the penis or the scrotum and its immediate surroundings, respectively, it is sufficient to apply a small surface coil whose coverage is restricted to its diameter. As a rule of thumb, the depth of tissue penetration in a (circular) surface coil is limited to its radius from the center of the coil at each point. Thus, for covering the penis, adjacent scrotum and perineum, and pubic bone close to the midline, it is sufficient to apply a ring-shaped surface coil of 15-20 cm (6-8 inches) in diameter. The immediate surroundings of the scrotum include the inguinal part of the spermatic cord and the inguinal lymph nodes. However, with a PASC, it may be possible to cover both the primary region of interest, i.e., the penis or the scrotum and its adjacent organs and tissues, and the pelvis and lower abdomen, possibly to the level of the renal hilus, to include inguinal, para-iliac, and para-aortic lymph nodes.

Preferred fields of view and section thickness

Fields of view and section thickness are adapted to the respective organ and clinical question. For two-dimensional sequences, typical ranges are FOV from 28 to 36 cm, matrix size from 128 x 256 to 320 x 512, and section thickness 0.8 cm (0.5-1.2 cm), with intersection gap 0.2 cm (0-1.0 cm) for the urinary bladder and large pelvis, while FOV from 12 to 20 cm, section thickness 0.3 cm, and intersection gap 0 to 0.06 cm are usual for the prostate and seminal vescicles, the penis, and the scrotum.

Non-Oncological Pathology of the Male Pelvis

Broad categories of non-oncological pathology to be considered include congenital anomaly or disorder, trauma, inflammatory, and benign neoplastic conditions.

Congenital anomaly or disorder

MRI provides immediate visualization of pelvic floor muscles and continence organs and their respective functional and anatomical relationship in urinary and fecal incontinence or constipation associated with complex congenital malformations in children and young adults, such as anorectal malformation, bladder exstrophy, and cloacal exstrophy.

Predominant anomalies of the prostate and seminal vesicles include congenital cysts, which may be associated with other anomalies of the urogenital system, and with infertility. Congenital cysts are located at or close to the midline of the dorsal aspect of the prostate, with utricle cysts and cysts of the ejaculatori ducts being located inside the prostate, and Mullerian duct cysts being paraprostatic, at the base of the prostate. Simple cysts of the prostate and seminal vesicles demonstrate with homogeneous signal intensity, which is low at T1-weighted MRI and high at T2-weighted MRI; haemorrhage may cause signal heterogeneity, with high signals at T1-weighted MRI and any signal intensity at T2-weighted MRI.

Frequent congenital anomalies affecting the penis include hypospadia, with the urethral orifice opening on the dorsal side of the penis, and epispadia, with the urethra opening to the ventral side of the penis, usually in between the corpora cavernosa. Epispadia is frequently associated with other defects of lower anterior midline closure, such as bladder exstrophy (epispadia-exstrophy complex). Other anomalies include aplasia or hypoplasia of the corpora cavernosa or corpus spongiosum, and vascular defects associated with erectile dysfunction.

Frequent congenital anomalies affecting the scrotum include missing or supernumerary testes, such as in anarchism (absence of both testes), monorchism (absence of one testis), polyorchism (presence of more than two testes), and cryptorchidism (undescended testis). The incidence of cryptorchidism may be as high as 33% in premature neonates, 3% in full-term neonates, and 1% in boys and young adults. MRI has been favoured as the method of choice to detect the testis in low-lying undescended testis close to the inguinal canal, while. higher up in the abdominal cavity, differentiation of undescended testes from loops of bowel or lymph nodes may be impossible. Undescended testes may show normal signal at MRI unless they are atrophied, the latter being associated with decreased signal intensity relative to normal, particularly at T2-weighted MRI. Differential diagnosis includes ectopy of the testis, e.g., to

the perineum or thigh. Since such ectopic testes are usually readily found on physical examination, MRI is usually not necessary. Polyorchism has been associated with increased risks of inguinal hernia, testicular torsion, undescended or maldescended testis, and malignant testicular tumour, such that imaging, primarily by means of US, and secondarily by MRI, is warranted to find additional testicular tissue. Intraperitoneal testes occur when the tunica vaginalis testis maintains a large aperture toward the peritoneal cavity or is ectopic, or in cases of gastroschisis, where the testis may protrude through the periumbilical defect along with bowel. Bell clapper testis refers to a capacious tunica vaginalis testis that completely envelops both the testis and the epididymis and promotes testicular torsion.

Trauma

Organs typically injured by blunt and penetrating trauma to the urinary tract include kidneys, bladder, male urethra, penis, and scrotum, while the ureter is hardly ever involved. While cases of penetrating trauma usually are not primarily being referred to MRI, the assessment of (blunt) genitourinary tract trauma by means of ultrasound, CT and MRI, including contrast-enhanced magnetic resonance angiography, has recently gained clinical significance and determines decision making with regard to conservative and surgical management. MRI can help to detect occult pelvic fractures, especially in elderly patients. Detection of bladder rupture and sources of occult or overt pelvic haemorrhage is left to other means of imaging, including cystography, and angiography, which also guides therapeutic embolization.

Although pelvic trauma may alter the position of the prostate, particularly when the membranous urethra is disrupted, MRI is hardly ever being applied to investigate trauma to the prostate.

Unless traumatic force partially or completely separates the penis from the body, trauma to the penis usually results in haematoma that affects the subcutaneous compartment alone or involves one or more of the penile corpora. When blunt trauma occurs to the erect penis, it is frequently most severe at the base of the penis, close to the pubic bone. MRI findings in blunt penile trauma include a visible, subcutaneous, haemorrhagic mass whose signal is intermediate to high at both T1-weighted and T2-weighted MRI in the acute and subacute phases of haemorrhage and may become heterogeneous later on.

Fracture of the penis requires immediate surgical therapy for complete recovery and good functional results. Imaging is used in unclear and atypical cases and may include cavernosography, urethrography, ultrasonography, and MRI. When trauma involves rupture of one or more of the penile corpora, the low-signal-intensity layer of the tunica albuginea is

obscured or disrupted. Haematoma within the corpora is usually associated with a decrease of signal intensity at T2-weighted and contrast-enhanced, T1-weighted MRI.

Post-traumatic alterations in the penile corpora include scarring, which may change the width and shape of the tunica albuginea, and the occurrence of pathologic septations within the penile corpora that may partially or completely interrupt the continuity of the blood-containing compartment. Thrombosis may result from haemostasis when blood flow within the penile corpus is compromised. It has been discussed that partial priapism may be the consequence of post-traumatic septation of a penile corpus, and that both straddle injury and repetitive micro-trauma to the base of the penis may be the underlying cause.

Patients with large or complex blunt trauma of the scrotum may be referred to MRI. Blunt trauma is frequently associated with haemorrhage into one or more of the scrotal compartments, with subcutaneous haemorrhage resulting in haematoma, while blood loss into the scrotal cavity induces a haematocele. Intra-testicular haematoma results from contusion of the testis, while rupture of the tunica albuginea testis with or without fracture of the testis may cause a combination of both testicular haematoma and haematocele.

At T1-weighted MRI, acute haematoma and haematocele show with intermediate to high signal intensity, while at T2-weighted MRI, acute haemorrhage in the scrotum is associated with signal increase. At both T1-weighted and T2-weighted MRI, chronic haematocele demonstrates with high signal intensity. A breech of the low-signal-intensity layer of the tunica albuginea implies rupture, which is frequently associated with parenchymal haematoma within the testis.

Inflammatory disease

A variety of rare, non-neoplastic disorders of the urinary bladder may cause focal masses or diffuse mural thickening and mimic malignancy. In turn, findings at MRI of focal masses or diffuse mural thickening of the urinary bladder are suggestive of, but not specific for malignant neoplasm. Inflammatory pseudotumor of the urinary bladder is a non-neoplastic entity that is poorly understood, produces ulcerated, bleeding polypoid masses which may have an extravesical component, and may show at T1-weighted MRI with intermediate signal, at T2-weighted MRI with prominent, high signal intensity, and at contrast-enhanced, T1-weighted MRI with marked enhancement. Cystitis of the urinary bladder resulting from chemotherapy or radiation therapy may require imaging to determine severity and to assess complications. Idiopathic cystitis of the urinary bladder (cystitis cystica, cystitis glandularis, and eosinophilic cystitis) requires pathologic diagnosis. Extrinsic inflammatory disease, such

as Crohn's disease or colonic diverticulitis, may be associated with fistulas to the bladder and subsequent focal bladder wall abnormality. The extravesical findings determine the diagnosis, and MRI may be applied to assess severity and extent of disease. Bladder infection with tuberculosis and schistosomiasis produces non-specific bladder wall thickening and ulceration in the acute phase and should be suspected in patients who are immuno-compromised or have been exposed to the respective microorganisms.

Prostatitis in itself usually does not represent an indication for MR imaging of the prostate and seminal vesicles. Patients with acute prostatitis (category I of the NIH classification of 1995) may present with voiding problems and general symptoms of severe infectious disease, with severe pelvic pain rendering MRI involving an ERC impossible. Chronic prostatitis may be infectious (category II of the NIH classification of 1995) or non-infectious, with different clinical and laboratory findings (categories III, IIIa, IIIb, and IV of the NIH classification of 1995) and is frequently encountered in patients undergoing MRI of the prostate to rule out cancer. Increase in thickness of intraprostatic septa, and inhomogeneity of intraprostatic tissue texture, with and diffuse signal decrease, respectively, at T2-weighted MRI are signs associated with, but not uniformly found in chronic prostatitis. Occasionally, chronic prostatitis may be associated with volume decrease of one side of the prostate. Differentiation on T2-weighted MR images may be difficult between chronic prostatitis and prostate cancer in such cases. The inflammatory reaction within the peripheral zone in focal, granulomatous prostatitis mimics an intraprostatic mass, which may be indistinguishable from prostate cancer at T2-weighted MRI. Abscess of the prostate is usually detected and localized by transrectal ultrasonography. However, the liquefied, necrotic center shows high T2- and low T1-signal, while the edematous, inflammatory wall is bright at both T2-weighted and contrast-enhanced, T1-weighted MRI. Chronic inflammation or infection of the seminal vesicles frequently results in tissue shrinkage and loss of signal intensity within the glandular lumen at T2-weighted MRI. However, it is not possible by means of unenhanced MRI to distinguish between post-inflammatory changes and the consequences of previous hormone deprivation therapy of the prostate, previous radiation therapy, longstanding diabetes mellitus, amyloidosis, and alcoholism.

Induratio penis plastica or Peyronie Disease is an inflammatory condition of unknown aetiology in which elastic connective tissue of the tunica albuginea is replaced by fibrous or hyaline scar tissue, whose appearance may be sheet-like or plaque-like. At T2-weighted MRI, plaques of induratio penis plastica may show with decreased signal intensity when compared with adjacent, normal tunica albuginea; acute plaques may demonstrate contrast enhancement

at post-contrast, T1-weighted MRI. Infection of the penis, perineum, and scrotum may result from trauma or as a sequel of underlying inflammatory disease, e.g., Crohn's disease, and usually involves penetration into the subcutaneous tissue or deeper tissue layers of pathologic micro-organisms.   Consequences include inflammatory reaction, and, eventually, pus-containing, localized abscess or phlegmonous spread. In Crohn's disease, fistulous tracts may connect the skin surface or the mucosal surface of the intestinal tract with subcutaneous or deeper tissue layers of the penis and perineum. On T2-weighted images, Tissue oedema, inflammatory reaction, fistulae and abscess usually appear intermediate to bright at T2- and dark at T1-weighted MRI, unless there are blood remnants. Contrast uptake and resulting signal usually is high in the inflammatory reaction and surrounding oedema at post-contrast, T1-weighted MRI.

Benign neoplastic conditions

Benign neoplastic conditions are not frequent and oftentimes require histopathology for a diagnosis. MRI may be acquired to detect and localize lesions suspected in or around the urinary bladder and to determine their respective extent. Neurofibromatosis (von Recklinghausen disease) is a congenital, hereditary dysplasia that rarely involves the urogenital system, with neurofibromas usually showing signal intensities similar to that of skeletal muscle at T1-weighted MRI, while signal is high at both T2-weighted and contrast-enhanced, T1-weighted MRI. Nodular or diffuse bladder wall involvement may be accompanied by pelvic sidewall and adjacent soft tissue alterations. Leiomyomas may indent the posterior bladder wall as an extravesical tumorous lesion. Endometriosis may demonstrate with submucosal masses of the urinary bladder with MRI features including haemorrhagic foci and reactive fibrosis.

Benign prostatic hyperplasia (BPH) is frequently associated with voiding problems, usually affects men of more than 50 years of age, and is associated with pathologic increase in volume of the transitional zones of the prostate. BPH may be glandular and cystic, with predominant increase of gland tissue associated with heterogeneously high signal at T2-weighted MRI, fibro-muscular, with predominant increase of stromal components of the transitional zones and heterogeneously low signal at T2-weighted MRI, or both.

MRI imaging of the testes may help in the evaluation of male patients with congenital adrenal hyperplasia (CAH) caused by 21-hydroxylase deficiency, both to detect and to follow up on testicular adrenal rest tumour (TART), which is typically located around the mediastinum testis. TART tumours present with intermediate to high signal at T1-weighted MRI, low

signal at T2-weighted MRI, and with remarkable contrast enhancement when compared to normal testicular parenchyma. Testicular epidermoid cyst typically presents as a testicular mass of high signal intensity surrounded by rim of low signal intensity, with or without foci of low signal intensity at T2-weighted MRIwhile it usually does not show enhancement on contrast-enhanced T1-w MR images. Testicular hydrocele refers to an unusually large collection of serous transudate with low protein content within the tunica vaginalis testis. Hydrocele found along the processus vaginalis peritonei, the extension of the peritoneum toward the cavum scroti, is being referred to as funiculocele. Testicular hydroceles and funiculoceles show with low signal at T1-weighted MRI and high signal at T2-weighted MRI. The contents do not enhance with contrast media.

Other non-neoplastic conditions

Penile implants or prostheses offer a dependable way of restoring erection in many patients. However, although infrequent, complications of penile implant surgery may be clinically significant and include infection, perforation of the tunica albuginea, deformity of the penis, erosion of a component, and mechanical malfunction of the implanted device. While diagnosis of complication is based on clinical history and physical examination, imaging may be required to explore the prosthesis and decide on the clinical approach. MRI is considered to be most valuable for the diagnosis of penile prosthesis complications, since it demonstrates penile anatomy in three orthogonal planes with superior definition of soft tissue contrast.

Conclusion

Although overall, MRI is seldom applied under non-neoplastic pathological conditions in the male pelvis its use appears to be decisive in many instances. MRI techniques derive from experience made with neoplastic disease of the male pelvis and provide a safe basis to adaequately depict the pathology. Since some MRI findings appear to be specific for certain disease entities, referring to pertinent literature and case reports usually helps to narrow down the differential diagnosis.

Recommendations for Further Reading

For more extensive coverage of the subject and a list of references, please refer to

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