Revised 2020 (Resolution 28)*

ACR–SAR–SPR PRACTICE PARAMETER FOR THE PERFORMANCE OF MAGNETIC RESONANCE IMAGING (MRI) OF THE SOFT-TISSUE COMPONENTS OF THE PELVIS

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner considering all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by variables such as the condition of the patient, limitations of available resources, or advances in knowledge or technology after publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document may consider documenting in the patient record information sufficient to explain the approach taken.

The practice of medicine involves the science, and the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The purpose of this document is to assist practitioners in achieving this objective.

[1] Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing 831 N.W.2d 826 (Iowa 2013) Iowa Supreme Court refuses to find that the *ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures* (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

ABOUT THIS DOCUMENT

This collaborative practice parameter has undergone extensive revision and has been divided into sections with links as indicated below:

I. INTRODUCTION

Magnetic resonance imaging (MRI) of the pelvis is a proven and useful tool for the evaluation, assessment of severity, and follow-up of diseases of the male and female pelvic organs. It should be performed only for a valid medical reason.

MRI of the pelvis is the imaging modality of choice for many clinical situations involving pelvic pathology. This technique has superb soft-tissue contrast and has the advantage of providing multiplanar and 3-D depiction of anatomy and pathology. Additional benefits include absence of ionizing radiation and exposure to iodinated contrast material. Careful attention to patient comfort prior to beginning the MR examination will result in improved diagnostic quality. MRI for the detection, staging, and recurrence of rectal cancer is not considered in this parameter.

II. INDICATIONS

Indications for MRI of the pelvis include, but are not limited to, the following:

1. Detection and staging of gynecologic malignancies, including those originating in the vulva, cervix, uterus, ovaries, and fallopian tubes (see Section 1).
2. Evaluation of acute or chronic pelvic pain or pelvic mass, including detection of adenomyosis, ovarian cysts, torsion, tubo-ovarian abscesses, benign solid adnexal masses, obstructed fallopian tubes, endometriomas, and uterine fibroids (see Section 2).
3. Assessment of pelvic floor defects associated with urinary or fecal incontinence (see Section 3).
4. Determination of number, location, size, and type (nondegenerating or degenerating) of fibroids for treatment selection and planning (see Section 4).
5. Planning and guidance for minimally invasive surgery and brachytherapy (see Sections 1 and 5b).
6. Assessment for recurrence of tumors of the bladder, prostate, or gynecologic organs following surgical resection or exenteration (see Sections 1, 5b, 5a, and 5c).

7. Detection and staging of malignancies of the prostate, bladder, penis, testis, and scrotum (see Sections 5b, 5a, and 5c).
8. Evaluation of complications following pelvic surgery, including abscess, urinoma, lymphocele, radiation enteritis, and fistula formation (see Section 6).
9. Identification of the source of lower abdominal pain in pregnant women, including appendicitis, ovarian condition or adnexal torsion, or uterine mass (see Section 7).
10. Identification and classification of perianal fistulas (see Section 8).
11. Identification and characterization of congenital anomalies of the male and female pelvic viscera**,** including the anatomic evaluation of ambiguous genitalia and disorders of sexual development (see Section 9).

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging (MRI) [1].

IV. SAFETY GUIDELINES AND POSSIBLE CONTRAINDICATIONS

See the ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging (MRI) [1], the ACR Guidance Document on MR Safe Practices 2020 [2], and the ACR Manual on Contrast Media [3].

Peer-reviewed literature pertaining to MR safety should be reviewed on a regular basis [4,5].

V. GENERAL SPECIFICATIONS OF THE EXAMINATION *(additional specifications will be discussed in the relevant section)*

The supervising physician should have a complete understanding of the indications, risks, and benefits of the examination as well as of alternative imaging procedures. The physician must be familiar with potential hazards associated with MRI, including potential adverse reactions to contrast media. The physician should be familiar with relevant ancillary studies that the patient may have undergone. The physician performing MRI interpretation must have a clear understanding and knowledge of the anatomy and pathophysiology relevant to the MRI examination.

The written or electronic request for MRI of the soft-tissue pelvis should provide sufficient information to demonstrate the medical necessity of the examination and allow for the proper performance and interpretation of the examination.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). The provision of additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient's clinical problem or question and consistent with the state scope of practice requirements. (ACR Resolution 35 adopted in 2006 – revised in 2016, Resolution 12-b)

The supervising physician must also understand the pulse sequences to be used and their effect on the appearance of the images, including the potential generation of image artifacts. Standard imaging protocols may be established and varied on a case-by-case basis when necessary. These protocols should be reviewed and updated periodically.

A. Patient Selection

The physician responsible for the examination should supervise patient selection and preparation and be available in person or by phone for consultation. Patients must be screened and interviewed prior to the examination to exclude individuals who may be at risk by exposure to the MR environment.

Certain indications require administration of intravenous (IV) contrast media. IV contrast enhancement should be performed using appropriate injection protocols and in accordance with the institution's policy on IV contrast utilization (see the ACR–SPR Practice Parameter for the Use of Intravascular Contrast Media [6] and the ACR Manual on Contrast Media [3]).

Patients suffering from anxiety or claustrophobia may require sedation or additional assistance. Administration of moderate sedation may be needed to achieve a successful examination. If conscious sedation is necessary, refer to the ACR–SIR Practice Parameter for Sedation/Analgesia [7].

B. Facility Requirements

Appropriate emergency equipment and medications must be immediately available to treat adverse reactions associated with administered medications. The equipment and medications should be monitored for inventory and drug expiration dates on a regular basis. The equipment, medications, and other emergency support must also be appropriate for the range of ages and sizes in the patient population.

C. General Technique (additional technical advances will be discussed in the relevant section)

Whenever possible, a multicoil array should be used to allow for smaller fields of view (FOV) and higher spatial resolution. Fasting for 6 hours prior to the examination will diminish bowel peristalsis and improve quality. Alternatively, glucagon could be administered subcutaneously or intramuscularly to diminish artifacts from bowel peristalsis, unless contraindicated.

The majority of information is obtained using T2-weighted (T2-W) images. Fast spin-echo (FSE), turbo spin-echo, or their equivalents are recommended in the orthogonal planes (see relevant section) to clearly demonstrate the relevant anatomy. Ultrafast T2-W pulse sequences, such as single-shot FSE (SSFSE) or half-acquisition turbo spin-echo may be substituted, yielding a significant time savings at the cost of mildly diminished spatial resolution and with less T2-W imaging than comparable spin-echo technique. Anterior saturation bands over the anterior subcutaneous fat help minimize phase-encoding artifacts.

Contrast enhancement is often critical for detecting tumor extent. Rapid T1-weighted (T1-W) gradient-echo images should be obtained pre- and postdynamic IV bolus administration of a gadolinium chelate contrast material to highlight sites of disease. Images obtained during the arterial and venous phase of enhancement may be useful in determining the vascular supply and enhancement pattern of a pelvic mass. A 3-D sequence, particularly on high field strength platforms, yields superb thin-section contrast-enhanced images. Additional pulse sequences, for example diffusion-weighted imaging (DWI) with apparent diffusion coefficient (ADC) map, may be used as required for diagnosis and evaluation of extent of disease. In the case of advanced disease, MRI of the abdomen should be considered to search for distant metastases. Endoluminal coils (eg, endorectal) may be used for some indications.

1. MRI of the pelvis may be performed for pregnant patients in the second and third trimester. For pregnant patients in the first trimester, MRI of the pelvis is only recommended if the benefits outweigh any potential risks and then only as an adjunct to initial evaluation with ultrasound (US). See the ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients with Ionizing Radiation [8] and the ACR Manual on Contrast Media [3]. A multicoil array should be used with the patient fasting as tolerated to diminish fetal motion and bowel peristalsis. Diagnostic information can almost always be obtained using breath-hold (T1-W and T2-W) images. The patient may be imaged in the supine or left lateral decubitus position using a large FOV (38-44 cm).

D. Examination Technique (specific examination techniques will be discussed in the relevant section)

VI. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [9].

For detection and staging of prostate malignancy, the report should follow the guidelines for terminology, including descriptions of lesion features and location, as published in the Prostate Imaging Reporting and Data System (PI-RADS) v2.1 [10].

Specific policies and procedures related to MRI safety should be in place with documentation that is updated annually and compiled under the supervision and direction of the supervising MRI physician. Guidelines that deal with potential hazards associated with MRI examination of the patient as well as to others in the immediate area should be provided [4,5,11-16]. Screening forms must also be provided to detect those patients who may be at risk for adverse events associated with the MRI examination [4,13].

VII. EQUIPMENT SPECIFICATIONS

The MRI equipment specifications and performance must meet all state and federal requirements. The requirements include, but are not limited to, specifications of maximum static magnetic strength, maximum rate of change of the magnetic field strength (dB/dt), maximum radiofrequency power deposition (specific absorption rate), and maximum acoustic noise levels.

Equipment performance monitoring should be in accordance with the ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance (MR) Imaging Equipment [17].

VIII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading *ACR Position Statement on Quality Control and Improvement, Safety, Infection Control and Patient Education* on the ACR website (https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement).

ACKNOWLEDGEMENTS

This practice parameter was revised according to the process described under the heading *The Process for Developing ACR Practice Parameters and Technical Standards* on the ACR website (https://www.acr.org/Clinical-Resources/Practice-Parameters-and-Technical-Standards) by the Committee on Body Imaging (Abdominal) of the Commission on Body Imaging and by the Committee on Practice Parameters – Pediatric Radiology of the Commission on Pediatric Radiology, in collaboration with the SAR and SPR.

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Section 1. Detection, Staging, and Recurrence Assessment of Gynecologic Malignancies: Uterus, Cervix, Ovaries, Vulva, and Vagina

V. SPECIFICATIONS OF THE EXAMINATION *(general specifications were discussed earlier in the document)*

C. Technical Advances:

Diffusion-weighted MRI and dynamic contrast-enhanced (DCE) MRI are useful adjuncts to standard anatomic MR sequences [18]. High-field (3T) MRI has been more widely implemented for body-imaging applications, providing improved signal-to-noise ratio (SNR), spatial resolution, and anatomic detail as well as faster scanning techniques but with specific limitations due to magnetic susceptibility and motion artifacts and concerns about radiofrequency power deposition [19]. Parallel imaging techniques significantly increase acquisition speed, allowing for improved imaging efficiency, although this results in decreasing signal to noise.

D. Examination Technique:

1. Detection and Staging

MRI is most valuable for extent of disease evaluation and staging in patients with known or clinically suspected gynecologic malignancy. It is used in treatment planning to guide surgery and/or radiation therapy, to monitor treatment response, and to detect local and regional recurrence [20,21]. For ovarian neoplasms and masses, MRI is typically used for problem solving after inconclusive pelvic US and is not routinely performed for staging (see Section 2).

Suggested sequences include the following:

i. Axial T1-W
ii. Orthogonal high-resolution T2-W FSE (relative to the uterus or cervix)
iii. Long- or short-axis precontrast and dynamic postcontrast 2-D T1-W or 3-D T1-W acquisition (with fat suppression)
iv. Axial T2-W of the pelvis to include the perineum (vaginal and vulvar cancers)
v. DWI with ADC map
vi. Optional: Vaginal gel for vaginal cancer or cervical cancer with clinical suspicion of vaginal invasion

Endoluminal coils (endovaginal or endorectal) for localization of cervical cancers and evaluation of parametrial extension allow high-resolution imaging but are limited by the small FOV. These have not been widely adopted because of patient discomfort and limitations in imaging large tumors, extension to pelvic organs surrounding the primary site, and lymphadenopathy [22].

In staging for gynecologic malignancy, large FOV T1-W images are used to evaluate the abdomen and pelvis for lymphadenopathy, hydroureteronephrosis, and osseous lesions. High-resolution long- and short-axis T2-W imaging of the uterine body is used for localization of endometrial cancer and for determining the depth of myometrial invasion and clearly demonstrates zonal anatomy [23]. Long- and short-axis imaging of the cervix is performed to show the local extent of the cervical cancer to identify parametrial invasion and to assess candidacy for trachelectomy (a fertility-sparing procedure) [24].

Precontrast- and postcontrast-enhanced dynamic multiplanar multiphase imaging using either 2-D long- and short-axis or volumetric T1-W gradient-echo sequences have shown myometrial invasion from endometrial carcinoma to advantage [25]. In patients with biopsy-proven adenocarcinoma involving both the lower uterine segment and cervix, DCE scans are useful in differentiating correct primary site of origin [26].

DWI with both low and high b-values (800-1,000 s/mm^2) combined with use of ADC maps can demonstrate restricted diffusion in malignancy [18]. DWI assists in lesion detection and extent of disease evaluation, including metastases to the peritoneum or adnexa [27], myometrial invasion in endometrial cancer [28], and tissue characterization of ovarian masses [29]. Limitations of this technique include false-positive results from inflammatory conditions and other benign processes, such as benign masses with high cellularity [22]. Use of DWI for detection of pelvic lymphadenopathy is controversial [19].

For evaluation of vulvar and vaginal cancers, MRI is excellent, especially with multiplanar T2-W images, and MRI is better than physical examination for determining tumor size, extent, and perivaginal spread [30]. Installation of vaginal gel to separate the walls of the vaginal canal can improve visualization of a vaginal mass but is not required [31]. Axial T1-W FSE images with a large FOV are performed for detection of abdominopelvic lymphadenopathy and bone marrow abnormalities. Detection of regional lymphadenopathy is the most important prognostic factor that is correlated with depth of tumor invasion. Presence or absence of adenopathy guides decision making about the need for radical vulvectomy and inguinal lymphadenectomy, both of which are associated with significant morbidity but improved survival if inguinal nodes are involved [32].

High-resolution orthogonal T2-W FSE images in the axial and coronal planes are used for evaluation of the primary tumor. DCE sagittal T1-W images with fat suppression and small FOV high-resolution axial T2-W images should be obtained to include the entire perineum, including the vulva. DCE scans with fat suppression are useful to detect small lesions and show involvement of the urethra and anus by vulvar cancer [33].

2. Postsurgical Recurrence of Gynecologic Malignancy

Preoperative MRI is accurate in assessing tumor extent before pelvic exenteration for recurrent gynecological cancers and can guide the type of pelvic exenteration. In particular, MRI accurately assesses bladder and rectal wall invasion before major surgery [34] and aids in differentiating posttreatment changes from active tumor [35]. Eligibility for pelvic exenteration requires exclusion of metastatic disease, which is best achieved by PET/CT [36]. The MRI examination technique has not been standardized. Suggested sequences include the following:

i. Two-plane orthogonal T2-W FSE
ii. Precontrast and postcontrast fat-suppressed 3-D T1-W gradient echo
iii. DWI with ADC map

Conventional imaging serves as a surgical roadmap of recurrent disease. DWI is useful for detecting tumor recurrence, both in the pelvis and in areas of disseminated disease in the peritoneum [37].

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Section 2. Evaluation of Pelvic Mass or Acute or Chronic Pelvic Pain, Including Detection of Adenomyosis, Ovarian Cysts, Torsion, Tubo-Ovarian Abscesses, Benign Solid Adnexal Masses, Obstructed Fallopian Tubes, Deep Pelvic Endometriosis, Endometriomas, and Fibroids

V. SPECIFICATIONS OF THE EXAMINATION *(general specifications were discussed earlier in the document)*

C. Technical Advances:

Perfusion and DWI MRI sequences increase the diagnostic accuracy of conventional MRI with the overall accuracy for MRI greater than 90% for adnexal mass characterization [29]. If DCE-MRI using postprocessing subtraction techniques shows early enhancement in solid elements, then the mass is much more likely to be malignant. The absence of enhancing solid elements is more likely benign [38]. Susceptibility-weighted imaging shows hemosiderin deposition in extraovarian endometriosis and adenomyosis with increased sensitivity compared with conventional MRI [39]. ADC measurements on DWI may show quantitative differences between fibroids and adenomyosis [40]. 3-D T2-W MRI allows volumetric acquisition, providing submillimeter sections with multiplanar reformatting capability. There is a tradeoff between volume imaged, with both acquisition time and T2-weighting characteristics [41].

D. Examination Technique:

1. Detection and Characterization

The workup of adnexal masses is particularly challenging because the prevalence of ovarian malignancy is low compared with that of benign adnexal masses, and benign conditions frequently have an acute presentation. Because pelvic US is the initial study of choice for workup, MRI of the pelvis for adnexal mass or pelvic pain is useful after indeterminate pelvic US for problem solving. US is limited by its small FOV, obscuration of organs by overlying bowel gas, operator dependence, and limitations in patients with large body habitus. MR outperforms US with higher specificity due to its multiplanar imaging capabilities and excellent soft-tissue contrast for tissue characterization [42]. Adenomyosis is diagnosed when the junctional zone is thickened on T2-W images; however, less commonly, a myometrial contraction can mimic adenomyosis. Performing an additional sagittal T2-W sequence at the conclusion of the study can differentiate contraction from adenomyosis as the thickening will resolve with a contraction but will persist with adenomyosis [43]. The differential diagnosis of adnexal masses on MRI is based upon a systematic evaluation of their anatomic location, morphology (solid, cystic, or both), signal intensity (SI) characteristics, enhancement, and appearance on DWI. Deep pelvic endometriosis may present as an implant in the posterior, middle, and/or anterior pelvic compartments. MRI with vaginal and/or rectal gel may aid in detection of these implants but is considered optional [44]. Fasting 4 to 6 hours prior to imaging decreases artifacts from bowel peristalsis; alternatively, subcutaneous (SQ) or intramuscular (IM) glucagon may be administered if not contraindicated.

Suggested sequences include:

i. Orthogonal high-resolution T2-W FSE or a 3-D T2-W volumetric acquisition
ii. Axial in-phase, opposed-phase, and/or fat-suppressed T1-W gradient echo
iii. Pre- and dynamic postcontrast fat-suppressed 3-D T1-W gradient echo
iv. Optional: DWI with ADC map
v. Optional: T2-W with vaginal gel
vi. Optional: T2-W with rectal gel

Fluid, fat, blood, and fibrous tissues can be differentiated based upon MR signal characteristics that are often indeterminate on US. When differentiating between hemorrhagic ovarian cyst and endometrioma, the T2 dark

spot sign has high specificity for endometrioma compared with T2 shading but a lower sensitivity [45]. For solid adnexal masses, low T2 SI is usually correlated with benignity [42]. Most cystic ovarian masses are benign. Guidelines have been established for evaluation of adnexal cysts based on patient menstrual status and symptoms [46,47].

Serous cystadenomas (the most common benign epithelial ovarian neoplasm) have fluid signal and thin walls [48]. Mucinous neoplasms are multilocular with varying MR SIs ("stained glass appearance") [49]. The presence of papillary projections, wall thickening, and/or enhancement is worrisome for malignancy [50]. Restricted diffusion may be seen in malignancy, but there are many causes of false-positive findings [37].

Other fluid-containing extraovarian benign lesions have characteristic morphologies that suggest the correct diagnosis, such as the tubular shape and incomplete folds of a hydrosalpinx, the identification of a normal ovary or normal fallopian tube contiguous with a paraovarian or paratubal cyst, respectively, or the normal ovary embedded into the wall of peritoneal inclusion cyst [50].

In patients with acute pelvic pain from tubo-ovarian abscess, the diagnosis is usually evident clinically (cervical motion tenderness, discharge, leukocytosis). Further imaging is reserved for nonspecific clinical presentations or for patients who are refractory to medical therapy. CT is usually performed after equivocal pelvic US. However, MRI may be performed in nonspecific cases or in young females when decreasing radiation exposure is a priority. MR may show inflammation on contrast-enhanced scans and edema on fat-suppressed T2-W images [51].

Solid or mixed cystic and solid lesions are also characterized based upon morphology and tissue signal characteristics. Fat-suppressed and/or chemical shift MR techniques can be used to differentiate between bright signal from fat within mature cystic teratomas and blood within hemorrhagic cysts or endometriosis. Fat signal in mature cystic teratomas manifested by chemical shift artifact at the fat-fluid interface **(**or within the teratoma in cases of intracellular fat) confirms the diagnosis [52]. T2 shading (bright T1 and dark T2 signal) in endometriosis is typical and results from chronic bleeding containing high protein and iron concentrations and protein cross-linking, all of which decrease both T1 and T2 relaxation time [53,54]. Ovarian fibromas have low T1 and T2 signal, similar to skeletal muscle due to fibroblasts and collagen. Fibromas may enhance [55].

Because acute ovarian torsion is a gynecologic emergency that is usually first evaluated with pelvic US, MR is not generally utilized in the acute setting. The use of MR generally has been limited to imaging subacute or chronic torsion. MR findings are those of an enlarged ovary with central stromal edema and/or hemorrhage, ipsilateral deviation of the uterus, fallopian tube thickening, and enlarged congested vessels with twisting of the vascular pedicle (beak sign) [51,56].

When a uterine fibroid resides in the broad ligament, it projects laterally from the uterine contour. This can be difficult to distinguish from a solid ovarian neoplasm both clinically and by pelvic US. MRI is valuable for further characterization, especially when the typical low SI of fibroids becomes complex because of degeneration. Identification of separate normal ovaries, continuity of the mass with uterine myometrium, and enhancing bridging vessels arising from the uterus supplying the mass [57] are key features that make the diagnosis of pedunculated fibroid or broad ligament fibroid.

In patients with dysmenorrhea and menorrhagia from adenomyosis, MRI shows the characteristic low-signal lenticular-shaped junctional zone thickening >12 mm diffusely or focally that distinguishes this condition from fibroids on T2-W images. Sometimes the two may coexist. Small hemorrhagic foci seen to best advantage on susceptibility-weighted images are helpful to identify adenomyosis and endometriosis [39]. MR can localize any associated macroscopic pelvic endometriosis. Deep pelvic endometriosis can affect the anterior, middle, or posterior pelvic compartments. Most common sites are retrocervical region, vagina, ovaries, bladder dome, rectosigmoid colon, and round ligaments. Less common sites in the pelvis include the abdominal wall in a Caesarean section scar, inguinal region, and pelvic nerves [58]. Cystic adenomyosis and subserosal polypoid adenomyomas can mimic an adnexal mass but typically are contiguous with myometrium forming a "beak sign," indicating uterine origin [39].

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Section 3. Assessment of Pelvic Floor Defects Associated with Urinary or Fecal Incontinence

V. SPECIFICATIONS OF THE EXAMINATION *(general specifications were discussed earlier in the document)*

D. Examination Technique

MRI of pelvic floor dysfunction allows noninvasive, dynamic evaluation of all the pelvic organs in multiple planes with high soft-tissue and temporal resolution. Imaging consists of a 2-step process that combines high-resolution anatomic imaging and functional evaluation. MRI is most helpful in patients with multicompartment physical examination findings or symptoms, posterior compartment abnormalities, severe prolapse, or recurrent pelvic floor symptoms after surgical repair [59-61].

Prior to beginning the examination, it is important to reassure patients about privacy and coach them appropriately regarding the maneuvers to ensure full patient cooperation. Patients are asked to empty their bladder and rectum within 1 hour prior to the examination, and rectal enema is optional prior to the examination. Although a study has shown superiority of the physiologic sitting position for the evaluation of defecography [62], such equipment is not readily available, and most patients are imaged in the supine position using conventional closed or wide-bore platforms with equal outcomes reported for both sitting and supine positions [63].

The patient is placed on a water-resistant pad on the MRI table, and approximately 100–120 cc of warmed US gel is instilled into the rectum. A measure of 10–20 cc of gel may also be used to opacify the vaginal canal. The patient is then positioned in the supine position and loosely wrapped in a waterproof incontinence pad. A multielement coil is necessary to achieve high-resolution imaging and optimal SNR and should be centered low enough to visualize prolapsed organs.

Suggested sequences include the following:

i. Axial and coronal T2-W FSE
ii. Sagittal T2-W SSFSE
iii. Sagittal midline rest, straining, and defecography cine balanced steady-state free precession
iv. Optional: axial or coronal rest and straining cine balanced steady-state free precession
v. Optional: sagittal midline squeezing cine balanced steady-state free precession

Axial and coronal small FOV T2-W FSE is performed at rest to evaluate pelvic floor support structures. Following surgical repair, the superior aspect of the axial T2-W FSE image should begin at the level of the sacral promontory for patients who have undergone sacrocolpopexy. Sagittal half-Fourier SSFSE of the entire pelvis, from sidewall to sidewall, is then obtained to determine resting organ positions. Continuous imaging during straining and defecography has shown greater degrees of prolapse with a balanced acquisition with steady-state precession than with a SSFSE sequence given the improved temporal resolution [64]. Functional evaluation is performed by acquiring a single midsection sagittal balanced steady-state free precession sequence with the anorectum at rest. The image should include the symphysis, bladder neck/urethra, vagina, anus/rectum, and coccyx. Thereafter, serial (cine) imaging is repeated during the straining phase and repeated 2 to 3 times with increasing straining to achieve maximal Valsalva maneuver. Straining exercises can also be performed in the axial or coronal plane sequence to evaluate prolapse and its effect on the supporting structures [59,65]. Cine evaluation is then performed in the defecography phase until complete evacuation of rectal contrast is achieved. Knee flexion supported by a pillow and slight hip abduction can maximize strain maneuvers and complete defecation. Imaging can also be acquired during the “squeeze maneuver” (ie, squeezing the buttocks as if trying to prevent the escape of urine) to evaluate puborectalis muscle contraction. Throughout this process, the technologist must continuously interact with the patient to optimize the functional evaluation.

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Section 4. Determination of Fibroid Number, Location, Size, and Type Prior to Intervention

V. SPECIFICATIONS OF THE EXAMINATION *(general specifications were discussed earlier in the document)*

C. Technical Advances:

3-D T2-W MRI allows volumetric acquisition of the uterus, providing submillimeter sections with multiplanar reformatting capability. There is a tradeoff between volume imaged, acquisition time, and T2 characteristics [41].

DWI reflects water mobility and tissue cellularity. ADCs can be calculated from images with different b-values [66]. This technique can be useful when attempting to differentiate typical fibroids from uterine sarcomas [67]. ADC values may also show quantitative differences between fibroids and adenomyosis [40].

MR elastography (MRE) measures a tissue's stiffness. MRE of uterine fibroids can be correlated with T2-W imaging. Less-stiff fibroids appear more T2 hyperintense and more-stiff fibroids appear more T2 hypointense [68].

D. Examination Technique:

Although US remains the initial imaging modality in the workup of patients with suspected symptomatic fibroids, MRI is the most accurate imaging technique for fibroid detection and localization [69]. It is increasingly performed in symptomatic patients being evaluated for minimally invasive uterine-sparing therapies, such as uterine fibroid embolization (UFE) [70] and MR-guided focused US (MRgFUS) [71]. For UFE candidates, MRI provides additional information compared with US and affects clinical management in a significant number of patients [72]. Single-institution and multicenter randomized controlled trials report significant decrease in symptoms and improved health-related quality of life following UFE [73,74]. MRI following UFE and MRgFUS has also been used to monitor outcome and diagnose complications.

Imaging is performed with a pelvic phased array coil. Fasting 4–6 hours prior to imaging decreases artifacts from bowel peristalsis; alternatively, SQ or IM glucagon may be administered if not contraindicated. A moderately distended, half-full urinary bladder may be optimal for the examination.

Suggested sequences include the following:

i. Orthogonal T2-W FSE (at least one plane should be a high-resolution sequence and/or a 3-D T2-W volumetric acquisition)
ii. Axial T1-W with and without fat suppression
iii. Precontrast and dynamic postcontrast 3-D T1-W fat-suppressed gradient-echo images
iv. Optional: DWI with ADC maps
v. Optional: large FOV upper abdomen T2-W to assess kidneys for hydronephrosis and metastases in suspected malignancy

Before treatment, orthogonal T2-W images allow fibroid detection, localization (submucosal, intramural, or subserosal), measurement of size, and characterization. Other uterine pathology, if present (eg, adenomyosis), is also diagnosed on T2-W images. The T1-W images provide information on the relationship of the fibroid to the uterus and adnexa as well as identify blood and fat in fibroids and/or concurrent uterine or adnexal disease.

The majority of nondegenerated fibroids are well-circumscribed round or ovoid masses with homogeneous low SI on T2-W images compared with myometrium. These imaging features reflect whorls of smooth-muscle cells with various amounts of intervening collagen. Nondegenerated cellular fibroids exhibit different imaging features—high T2-W SI compared with myometrium—a function of compact smooth-muscle cells with a paucity of intervening

collagen. On T1-W images, nondegenerated fibroids are low or isointense in SI to myometrium. Following contrast, nondegenerated fibroids enhance homogenously.

Degenerated fibroids have variable appearance on T1-W, T2-W, and postcontrast T1-W images. Types of fibroid degeneration include hyaline, calcific, myxoid, cystic, necrosis (hyaline or coagulative), and red. Although a combination of imaging features may suggest a specific type of degeneration, overlap in imaging features exists. This is also true for distinguishing a degenerated fibroid from a uterine sarcoma. Imaging features that have been reported in sarcomas include, but are not limited to, irregular margins, extensive hemorrhage, and necrosis [75-77]. DWI and ADC values may also add complementary information [78,79].

MRI features pertinent to the outcome of UFE include location, size, viability, ovarian arterial collateral supply to the uterus, and comorbid conditions [70].

Following successful UFE, fibroids undergo hemorrhagic infarction. Imaging features of an infarcted fibroid postembolization include hyperintense T1-W SI, increasing hyperintense T2-W SI over time, and no enhancement following intravenous contrast administration [80]. Small amounts of gas within an infarcted fibroid may be normal. Although follow-up imaging may not be necessary in patients who become asymptomatic following UFE, MRI can be employed to diagnose complications such as fibroid passage or pyomyoma. Surveillance MRI can also be used to assess for residual fibroid enhancement in patients with continued symptoms [81].

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Section 5. Detection, Staging, and Recurrence Assessment of Urologic Malignancy
A. Bladder

V. **SPECIFICATIONS OF THE EXAMINATION** *(general specifications were discussed earlier in the document)*

C. Technical Advances:

DWI, which reflects the degree of tissue cellularity, is complementary to conventional imaging. Additionally, MR cystography relies on 3-D T2-W data sets amenable to postprocessing to simulate conventional cystography.

D. Examination Technique:

1. Detection and Staging

MRI is usually used for T staging once the cancer has been diagnosed and is considered superior to contrast-enhanced CT in demonstrating extent of bladder wall invasion (nonmuscle invasive from muscle-invasive bladder cancer). The study of the bladder requires high spatial resolution with a multielement surface coil, thin section, and large matrix. Moderate bladder distention is necessary, and patients are asked to void approximately 1-2 hours prior to imaging or to drink 500-1,000 mL of water in the 30 minutes prior to the examination [82]. Administration of an antiperistaltic agent can reduce bowel peristalsis for assessment for extravesical disease [83].

Suggested sequences include the following:

i. Three-plane orthogonal T2-W FSE or 3-D T2-W volumetric acquisition
ii. 3-D fat-suppressed gradient-echo T1-W perpendicular to the tumor
iii. Precontrast fat-suppressed 3-D T1-W gradient echo and DCE T1-W
iv. Whole-body or small FOV DWI with ADC maps
v. Optional: 3-D MR cystography

Non–fat-saturated small FOV high spatial resolution (slice thickness of 3–4 mm) FSE T2-W imaging is performed in 3 orthogonal planes to evaluate the detrusor muscle for tumor depth, extravesical disease, and invasion of surrounding organs. Anterior saturation bands should be applied for the axial and sagittal planes to minimize phase-encoding artifacts. SSFSE imaging may replace T2-W FSE sequences to decrease motion artifacts, although increased image blur and reduced intravoxel resolution and SNR can impair staging. Recent advances have made 3-D T2-W imaging feasible with the introduction of shorter acquisition times, volumetric acquisition, and improved SNR.

Multiphase dynamic 3-D fat-suppressed gradient-echo T1-W imaging is obtained prior to and following contrast material administration. The plane of imaging should be perpendicular to the implantation base of the tumor. The majority of bladder tumors enhance briskly in the early phase (≤20 seconds) following contrast injection with the detrusor muscle enhancing late (60 seconds), thus allowing detection of small tumors and differentiation of superficial from muscle-invasive tumors [84,85]. Preliminary studies using DCE-MRI for quantitative analysis have shown correlation with T stage, tumor angiogenesis, and prediction of tumor response to neoadjuvant therapy [84,86-88].

Several studies have reported high b-value DWI to complement T2-W and gadolinium-enhanced imaging in improving the diagnosis of organ-confined muscle-invasive disease, extravesical extension, and prediction of tumor grade [88-95]. ADC values for bladder tumors are less than those for surrounding normal tissues. Trace high b-value DWI often depicts tumor better than ADC maps as there is more contrast between tumor and surrounding structures, and there is significant signal variation in ADC measurements [96,97]. Reduced FOV

DWI has been shown to improve image quality, reduce artifacts, and yield high spatial resolution compared with whole-body DWI [98].

There has been interest in 3-D rendering techniques with MR data sets (including multiplanar reconstructions and creation of cystoscopy-like images) as a replacement for traditional cystoscopy and to assist in staging, where traditional cystoscopy may be contraindicated (urethral stricture) or suboptimal (narrow-necked bladder diverticula) [99].

2. Therapy Response and Pelvic Recurrence

MRI technique is similar to that described for preoperative staging evaluation regardless of whether the patient has undergone radical cystectomy, transurethral resection, or neoadjuvant chemotherapy. In particular, MRI can evaluate therapeutic response to induction chemoradiotherapy in patients with muscle-invasive bladder cancer; identify complete response; and optimize patient selection for bladder-sparing protocols as well as monitor recurrence [100]. Some studies report DWI to be superior to contrast-enhanced MRI and T2-W imaging for differentiation between tumor recurrence from postoperative fibrosis and inflammation [101,102].

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Section 5. Detection, Staging, and Recurrence Assessment of Urologic Malignancy
B. Prostate

V. SPECIFICATIONS OF THE EXAMINATION *(general specifications were discussed earlier in the document)*

C. Technical Advances:

Multiparametric MRI, which combines DWI and DCE imaging, is complementary to conventional anatomic T2-W imaging. MR spectroscopy imaging (MRSI) can aid lesion characterization and provide information about tumor biology but is currently not routine.

D. Examination Technique:

1. Detection and Staging

The recommended use of MRI in prostate cancer detection, localization, staging, characterization, and risk stratification consists of multiparametric MRI (mp-MRI) [103]. Mp-MRI refers to the use of T2-W imaging in combination with functional imaging techniques: DWI, DCE-MRI, and MRSI [103,104]. The optimal combination of anatomic and functional sequences has yet to be established. However, the more functional sequences are utilized, the better the accuracy seems to be [105,106].

Imaging should be performed at either 1.5T or 3T. The fundamental advantage of 3T over 1.5T is increased spectral resolution and improved SNR, that can be used to achieve better spatial and/or temporal resolution. However, certain situations warrant imaging at 1.5T, eg, implantable devices deemed incompatible at 3T, or the location of a device would compromise image quality at 3T. Several groups have reported comparable performance between multichannel phased array coil MRI of the prostate at 3T and endorectal phased array coil MRI at 1.5T [107-110]. At 3T, most of the benefits of MRI can be achieved with multichannel phased array coil (at least 8-16 channels), although use of an endorectal coil or endorectal phased array coil combination can incrementally improve detection and staging [111,112]. However, the use of an endorectal coil deforms the shape of the gland. Use of the endorectal coil may add both imaging time and cost and may diminish patient acceptance, which would need to be considered by the supervising radiologist. The supervising radiologist must strive to optimize MRI protocols to obtain the best and most consistent image quality.

To minimize the artifacts introduced from biopsy-related hemorrhage, which can interfere with lesion detection and staging, imaging can be delayed between 8 and 12 weeks after the biopsy procedure [101]. However, detection of clinically significant cancer at a site of postbiopsy hemorrhage without a corresponding abnormality on mp-MRI is low, and a study shows the presence of extensive hemorrhage and short delay after biopsy did not negatively impact accuracy for tumor detection using mp-MRI [113]. When the primary purpose of the examination is to detect and characterize clinically significant cancer after a negative transrectal US-guided biopsy, a delay in mp-MRI may not be necessary [114]. Conversely, postbiopsy hemorrhage may adversely affect image interpretation for staging in some instances, and an interval between biopsy and MRI is appropriate and should be considered [115]. An antiperistaltic agent should be administered prior to imaging to reduce motion from bowel peristalsis; however, incremental cost and potential for adverse drug reactions should be taken into consideration.

Suggested sequences (regardless of coil) include the following:

i. Three-plane orthogonal T2-W FSE of the prostate
ii. Whole-body or small FOV DWI with ADC map
iii. Precontrast fat-suppressed 3-D T1-W gradient echo and DCE T1-W
iv. Large FOV axial T1-W and T2-W of the pelvis
v. Optional MRSI

High spatial resolution T2-W FSE imaging is used for detection, localization, and staging of prostate cancer and should be obtained in 3 planes. The axial T2-W imaging should cover the prostate gland and seminal vesicles, and locations should be the same as those used for DWI and DCE-MRI. Phase-encoding direction should be right to left to minimize motion and pulsation artifact overlapping the prostate gland. Recommended slice thickness is ≤3 mm and no gap. 3-D T2-W acquisition with a slice thickness <1.5 mm may be used as an adjunct to orthogonal T2-W FSE sequences, although soft-tissue contrast is not identical [116].

DWI improves the diagnostic performance for cancer detection when combined with T2-W images and provides information about tumor aggressiveness [117-121]. DWI should be acquired in the axial plane with motion-probing gradients applied in 3 orthogonal planes. Diffusion kurtosis effect occurs at b-values > 1,000 s/mm^2; therefore, ADC maps should be calculated with b values that are ≤ 1,000 s/mm^2 [122]. Although the optimal b-values have not been determined for calculation of ADC map, it is agreed that at least two b-values are required and should include low (0-100 s/mm^2 and preferably 50-100 s/mm^2) and intermediate (800-1,000 s/mm^2) b values [10]. High b-values between 1,400–2,000 s/mm^2 have added value for tumor localization, although field strength and coil selection, technical parameters—including SNR—and analysis of trace DWI will impact the utility of these higher b-values [120,123-131]. A high b-value DWI (≥ 1,400 s/mm^2) should be acquired separately or calculated from the low and intermediate b-value images [10]. Axial slice thickness should be ≤4 mm with no gap, and the location should ideally match the axial T2-W and DCE-MRI images without sacrificing SNR.

The added value of DCE-MRI over the combination of T2-W and DWI is not certain and may be secondary with only modest improvement in tumor detection, localization, and local staging. DCE-MRI should always be used in combination with T2-W FSE imaging and at least one other functional parameter (DWI or MRSI) given the decreased specificity for central gland tumors, or in the setting of prostatitis and postbiopsy hemorrhage [103,132,133]. Serial imaging of the gland should be performed prior to and following IV gadolinium administration (injection rate 2-4 cc/s), and a rapid T1-W 3-D gradient-echo sequence with fat suppression is the preferred acquisition [103,132]. Pharmacokinetic features require a high temporal resolution (<15 seconds per phase) with an observation period of at least 5 minutes to evaluate for washout [134,135]. Unenhanced T1-W images from this sequence can be used to detect postbiopsy hemorrhage. Axial slice thickness should be ≤ 3 mm, no gap, and the location should match axial T2 and DWI axial images. Images can be evaluated qualitatively, semiquantitatively, or quantitatively.

MRSI has been shown to improve lesion detection and provide valuable information about lesion aggressiveness but requires expertise, use of an endorectal coil at 1.5T, and added time [103,133,136,137]. However, an American College of Radiology Imaging Network (ACRIN) multicenter trial showed no incremental benefit of MRSI in detection of cancer over 1.5T endorectal T2-W imaging [138]. The volume of interest (VOI) is aligned with the axial T2-W images to maximize coverage of the whole gland while minimizing surrounding tissue contamination. A multivoxel 3-D chemical shift imaging technique is preferred with a voxel size <0.5 cc.

Finally, T1-W or T2-W imaging of the pelvis with a pelvic phased array coil is performed to assess for nodal or osseous metastasis, albeit limited given the morphologic limitations of MRI for lymph node assessment.

2. Local Recurrence after Radiation Therapy and Radical Prostatectomy

MRI can accurately detect local recurrence after radiation therapy and radical prostatectomy, allowing salvage radiotherapy as potential treatment option [139-141]. DCE-MRI in combination with T2-W imaging is particularly accurate in detecting recurrence after radiation therapy and radical prostatectomy. DWI, in combination with T2-W imaging, has been shown to be sensitive for detection of local recurrence in patients following radiation therapy but is inconsistent following interstitial brachytherapy or prostatectomy given the susceptibility artifacts from seeds and surgical clips, respectively [142-144]. However, studies evaluating DCE-MRI, DWI, and T2-W imaging following external-beam radiation therapy have shown no added benefit if DCE-MRI is added to DWI and T2-W imaging for recurrence [143,145]. The role of MRSI is controversial, especially given the metabolic changes that occur in the normal gland following radiation therapy and the theoretical

undetectable citrate levels following prostatectomy, which complicates the metabolic criteria used for diagnosis. MRSI is also limited by spatial resolution and is sensitive to field inhomogeneity [139].

The multiparametric MRI technique can be tailored to the type of therapy with appropriate selection of functional parameters.

3. Ablative Therapy for Prostate Cancer

Ablative therapy techniques include cryotherapy, high-intensity modulated focused US, laser ablation therapy, radiofrequency ablation, and photodynamic therapy. Imaging criteria for focal therapy differ from imaging criteria for whole-gland treatment, as the objective of imaging is accurate localization and contouring of the index lesions [146]. Although research evidence for MRI in focal therapy is limited, mp-MRI may be the optimum approach needed to achieve the objectives for focal therapy.

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Section 5. Detection, Staging, and Recurrence Assessment of Urologic Malignancy
C. Scrotum and Penis

V. SPECIFICATIONS OF THE EXAMINATION *(general specifications were discussed earlier in the document)*

D. Examination Technique:

1. Scrotum

Although sonography remains the primary modality in the diagnosis of scrotal pathology, MRI provides valuable information in the detection and localization of scrotal masses (intratesticular versus paratesticular), morphology, and tissue characterization, especially when sonography is inconclusive [147-150]. MRI is also recommended for local staging of testicular germ cell tumors [150].

Patients are prepared by placing a towel under the scrotum to elevate both testes to a horizontal plane, and the penis is draped over the anterior abdominal wall. Either a small-diameter multipurpose or multielement pelvic coil is centered over the scrotum. MRI sequences of the scrotum should be performed with small FOV and high spatial resolution (slice thickness ≤4 mm and no gap).

Suggested sequences include the following:

i. Axial T1-W without and with fat suppression
ii. Axial T1-W, in-phase and opposed-phase
iii. Three-plane orthogonal T2-W FSE
iv. DCE fat-suppressed 3-D gradient-echo or fat-suppressed T1-W 2-D SE
v. Optional: Axial DWI with ADC maps

Axial T1-W spin-echo sequences with and without fat suppression, followed by axial, coronal, and sagittal T2-W FSE imaging, are optimal for lesion detection, characterization, and localization. T2-W sequence is best obtained with echo time (TE) of 100-140 ms to optimize contrast [150]. In-phase and opposed-phase imaging of the scrotum can identify the fat-water interface and can help depict hemorrhage due to the T2* effects of hemosiderin. DCE-MRI using 3-D gradient-echo T1-W imaging in 2 orthogonal planes has been shown to improve characterization of scrotal lesions [151,152]. Alternatively, postcontrast conventional 2-D spin-echo in 2 planes can be substituted [150].

Preliminary investigations report improvement in characterization of intratesticular lesions with ADC of carcinomas being lower than that of normal testes and some benign intratesticular lesions [153,154]. Axial DWI is recommended (slice thickness of 3-5 mm) with b-values including 0-100, 400-500, and 800-1,000 s/mm^2.

Staging is typically performed with CT for assessment of retroperitoneal nodes. However, MRI is an appropriate substitute with performance of either T1 or T2-W imaging to the level of the renal hila [155].

2. Penis

MRI is the most sensitive imaging modality for the local staging of penile carcinomas because of its high soft-tissue contrast and multiplanar capability. It is important for the penis to be placed in a position of comfort, not bent or rotated, and to remain fixed in position throughout the examination, which is typically achieved with the penis draped and taped to the anterior abdominal wall. However, artifacts from excessive abdominal wall motion during breathing can degrade image quality, and the penis may need to be positioned inferiorly [156]. A small surface coil placed on the penis is optimal for high spatial resolution images (FOV: 14-16 cm), although

a multielement pelvic coil can be used and enables a larger FOV to assess for inguinal and pelvic lymphadenopathy [156,157]. Suggested sequences include the following:

i. Three-plane orthogonal high-resolution T2-W FSE (optional fat suppression in one plane)
ii. Axial T1-W

High spatial resolution T2-W sequence (3-4 mm) provides excellent contrast resolution between the hypointense tunica albuginea and hyperintense corpora and urethra, and is most useful for local staging. Fat suppression may be used in one plane to increase the dynamic range. The use of IV gadolinium has not been shown to improve detection or local staging or to be advantageous to standard T2-W sequences [156,158-160]. Artificial erection by intracavernous injection of prostaglandins or combinations has been shown to increase diagnostic accuracy for invasion of the tunica albuginea and corpora but is rarely applied in practice given the risk of priapism [158,161]. Osseous structures can be assessed with a T1-W sequence and inguinal lymph node evaluation with either a T1-W or T2-W acquisition.

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Section 6. Evaluation of Complications Following Pelvic Surgery, Including Abscess, Urinoma, Lymphocele, Radiation Enteritis, and Fistula Formation (for parameter on performance of MRI for perianal fistulas, refer to the section **Identification and Classification of Perianal Fistulas**)

V. SPECIFICATIONS OF THE EXAMINATION *(general specifications were discussed earlier in the document)*

C. Technical Advances:

Fat-suppressed T2-W images are sensitive to edema, inflammation, and abscess formation [162]. The use of negative or biphasic endoluminal bowel-contrast agents (such as ferumoxsil oral suspensions or dilute barium suspensions) reduce the SI in the bowel lumen on T2-W images, thereby increasing the conspicuity of high signal inflammation and abscess [163]. DWI may assist in the differentiation between cystic lesions and abscesses [164,165].

D. Examination Technique:

CT is usually the first study performed in the search for an abscess, especially in the setting of postoperative complications or for nonspecific symptoms and signs of infection. Because MR has better soft-tissue contrast and lacks ionizing radiation, it sometimes has been used as an alternative to CT in patients of child-bearing age and children [166].

MRI is performed with a pelvic phased array coil.

Suggested sequences include the following:

i. Orthogonal planes (axial and coronal) or 3-D T2-W fat-suppressed FSE or short tau inversion recovery (STIR) to highlight inflammation and/or edema
ii. Axial T1-W
iii. Precontrast and dynamic postcontrast fat-suppressed 3-D T1-W gradient echo
iv. Optional: DWI with ADC maps
v. Optional: MR enterography (see below)

Abscesses may be caused by postoperative complications or infectious or inflammatory conditions (such as Crohn's disease, appendicitis, diverticulitis, radiation enteritis, and pelvic inflammatory disease). On both CT and MR, an abscess is a collection of purulent fluid, often with peripheral rim enhancement, that may contain gas [167]. Gas may cause blooming artifact on dual-echo gradient-echo in-phase images (longer TE images) [168]. MR shows inflammation as enhancement on T1-W contrast-enhanced scans and edema as fluid signal on fat-suppressed T2-W images [51]. In the acute setting, DWI may show high signal on the high b-value image and restricted diffusion on the ADC map in an abscess [169]. Abscesses may be treated by percutaneous drainage; however, imaging guidance is usually accomplished using US or CT.

Pelvic hematomas can be caused by trauma, surgery, and/or coagulopathy. Although seromas and lymphoceles have the appearance of simple fluid on all MR sequences and do not enhance , the MR appearance of hematoma varies with the age of the blood but is commonly hyperintense on T1-W images [170,171].

Urinomas can result from obstructive uropathy, trauma, or surgery, or may occur iatrogenically after instrumentation [170]. MRI does not play a role in acute urinary tract injuries [172], but resultant findings may be seen in MRI scans that were requested for other reasons. Urinomas have fluid signal on MR, with low signal on T1-W and high signal on T2-W images. Extravasation of urine can be directly demonstrated in the excretory phase after IV contrast administration from the genitourinary system. Management of urinomas differs from that of other

postoperative collections in that it usually involves treatment of the primary cause of urine extravasation—such as stent or nephrostomy tube placement, or operative repair of tears or damage—in addition to percutaneous drainage of the collection.

Lymphoceles, usually a complication of lymphadenectomy, may be managed by catheter drainage with or without sclerotherapy [169]. Uncomplicated lymphoceles are unilocular with fluid signal on all MR sequences and are located in the distribution of previous lymph node dissection [173]. DWI and ADC maps may help identify active disease.

Acute radiation enteritis occurs within days to weeks of exposure and is manifested by mucosal hyperenhancement and bowel wall thickening, usually affecting the small bowel as it is more sensitive to injury. Chronic radiation enteropathy usually presents with bowel obstruction due to stricture formation. MR also shows wall thickening, scarring, tethering, and abnormal or absence of peristalsis. T2-W sequences and contrast enhancement are used to differentiate active inflammation (bright signal) from fibrosis with stenotic disease (dark signal with luminal narrowing). Fistulas may form secondary to radiation injury with tissue breakdown [174].

MR enterography using ultrafast or turbo spin-echo sequences to reduce artifacts from peristalsis with IV contrast enhancement can demonstrate radiation changes, such as bowel-wall thickening and dilation, submucosal edema, fatty stranding in the adjacent mesentery, and an abrupt transition point from adhesions. These studies involve administration of IV or IM glucagon to reduce peristalsis and ingestion of up to 1.5 L of biphasic endoluminal contrast agents. Balanced gradient-echo sequences (such as FIESTA or true FISP) in axial and coronal planes with breath-holding best show mural abnormalities and findings surrounding the bowel loops. 3-D spoiled gradient-echo fat-saturated T1-W sequences are acquired before and serially after IV contrast administration in the coronal and axial planes [175]. For more information, see the ACR–SAR–SPR Practice Parameter for the Performance of Magnetic Resonance (MR) Enterography [176].

Imaging along with physical examination can identify the site of a fistula and map its course and extent. Fistulas may be caused by surgery, radiation, trauma, childbirth, infection, inflammatory bowel disease, and malignancies. In patients with a malignancy, fistulas may occur as a result of a primary or recurrent tumor or as a consequence of surgery or radiation therapy. On T2-W images, fistulas typically have high signal due to fluid. Short inversion time inversion-recovery (STIR) images may show a fistulous tract to advantage. Air-filled tracts produce low SI on all MR pulse sequences [177]. On DCE T1-W imaging, the fistulous tract often enhances.

The sagittal plane usually best delineates vaginal fistulas. For vesicovaginal fistulas, CT or MR with excretory phase imaging shows contrast material outlining the fistulous communication between the bladder and the vagina, and vaginal gas fluid levels. In patients with contraindications to iodinated IV contrast material, MR is preferred to noncontrast CT [177].

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Section 7. Identification of Source of Lower Abdominal Pain in Pregnant Women: Appendicitis, Ovarian and Uterine Masses, and Urologic Conditions

V. SPECIFICATIONS OF THE EXAMINATION *(general specifications were discussed earlier in the document)*

C. Technical Advances:

DWI reflects water mobility and tissue cellularity. ADCs can be calculated from images with different b-values.

D. Examination Technique: (Please also refer to the ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging [1]).

The etiology of acute pelvic pain in pregnant patients falls into one of 3 categories: gastrointestinal disease, gynecologic disease, or urologic disease. The most common cause is acute appendicitis [178]. Other common pelvic etiologies include degenerating fibroid and significant hydronephrosis [179].

The goal of imaging a pregnant patient with pelvic pain is to promptly identify the source of the pain. This information guides surgical and medical management. US remains the initial imaging modality for evaluating pelvic pain. However, the advent of widespread motion-insensitive MR sequences, coupled with the absence of ionizing radiation, has led to an increase of MR examinations in pregnant patients, especially when US is equivocal or limited [3,180-187].

Patients should fast between 4–6 hours prior to imaging to decrease bowel peristalsis. A 1.5T magnet strength (or lower) is suggested in pregnant patients to decrease specific absorption rates. Patients can be imaged in the supine or left lateral decubitus position using a multicoil array and a large FOV (38-44 cm).

Suggested imaging sequences include the following:

i. Three-plane orthogonal T2-W SSFSE images
ii. Axial fat-suppressed T2-W SSFSE images or STIR
iii. Axial T1-W in-phase and out-of-phase gradient-echo images
iv. Optional: Coronal T1-W
v. Optional: 2-D time-of-flight (TOF)
vi. Optional: Orthogonal T2-W fast imaging with steady-state free precession images
vii. Optional: DWI with ADC maps
viii. Optional: 2-D or 3-D balanced-steady-state-free-precession (b-SSFP) noncontrast MRA/MRV

(See the ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation [8].)

1. Gastrointestinal Disease

The MRI features of acute appendicitis parallel those of CT: a fluid-filled, dilated appendix with a thickened wall and periappendiceal inflammation and fluid. A diameter between 6 and 9 mm without secondary finding is indeterminate [187]. It is important to have an adequate imaging FOV to ensure identification of the entire appendix, which is displaced superiorly and medially by the enlarging uterus [182]. 2-D TOF imaging can help distinguish the appendix from adjacent engorged gonadal vessels.

Bowel-wall edema is common to many gastrointestinal diseases: inflammatory bowel disease, enteritis, colitis, enteropathies, and ischemia [188]. On T2-W and DWI, edema manifests as high SI [189]. Noting the segment

of bowel affected and any ancillary imaging features (eg, fibrofatty proliferation) aids in arriving at the correct differential diagnosis.

2. Gynecologic Disease

Fibroids may be a source of acute pain during pregnancy owing to rapid growth, torsion, and/or hemorrhagic infarction. Of these, hemorrhagic infarction may have characteristic imaging features: diffuse or peripheral high SI on T1-W images, central high SI on T2-W images, and restricted diffusion [182,188].

Pelvic mass origin and characterization can be challenging in pregnant patients, and MRI can be used as a problem-solving tool. MR can be used to delineate whether a mass is uterine or adnexal or to differentiate conditions such as mature cystic tertomas and endometriomas with confidence. Acute torsion may occur in pregnancy as the ovaries are lifted out of the true pelvis by the enlarging uterus. The enlargement and edema that accompanies torsion is readily apparent on fat-suppressed T2-W images and include afollicular stroma with peripherally displaced follicles [56]. Hemorrhage within the stroma is a later finding, and T1-W and T2-W SI reflects the age of the blood products [182]. A twisted pedicle, though specific, is not commonly identified.

3. Urologic Disease

Cystitis has bladder wall thickening with or without air and/or filling defects. Nondependent signal voids in the urinary tract in the absence of instrumentation suggest air, whereas dependent filling defects may be blood clots, and/or calculi, and/or fungus balls. Pelvi caliectasis and ureterectasis are common in late pregnancy and are differentiated from obstruction by noting ureteral tapering to the point where there is extrinsic compression by the gravid uterus anteriorly and the sacral promontory posteriorly. Ureteral calculi, in contrast, result in abrupt caliber change of the ureter and may have associated high SI on T2-W images due to inflammatory changes [182]. Pyelonephritis results in lower ADC values compared with normal renal cortex [190].

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Section 8. Identification and Classification of Perianal Fistulas (For parameters on performance of MRI for abscess, please refer to the section Evaluation of Complications Following Pelvic Surgery, Including Abscess, Urinoma, Lymphocele, Radiation Enteritis, and Fistula Formation)

V. SPECIFICATIONS OF THE EXAMINATION *(general specifications were discussed earlier in the document)*

C. Technical Advances:

Digital subtraction MR-fistulography and high-resolution precontrast and postcontrast fat-suppressed 3-D T1-W gradient-echo sequence with subtraction postprocessing have been reported to be an important complement to surgical exploration [191]. DCE 2-D T1-W images with time-SI curves provide information on fistula activity [192]. This technique may be useful to identify a subgroup of patients with perianal Crohn's disease at increased risk for complications. These patients may benefit from more frequent monitoring. DWI reflects water mobility and tissue cellularity and can improve diagnostic confidence.

D. Examination Technique:

Imaging with a pelvic phased array coil is standard practice that results in high accuracy for detecting perianal fistulas [193-196]. This is especially true for patients with Crohn's disease who are prone to distant fistulous extensions and abscesses. Some centers have utilized an endoluminal coil alone or in combination with an external coil and report good imaging results, but endoluminal coils are not routinely used [197].

Suggested sequences include [198] the following:

i. Sagittal T2-W SSFSE (localizer) to prescribe true axial and coronal images of the anal canal (oblique axial and oblique coronal)
ii. Oblique axial T2-W FSE
iii. Oblique coronal T2-W FSE
iv. Oblique axial fat-suppressed T2-W FSE
v. Oblique axial fat-suppressed T1-W
vi. Oblique axial and oblique coronal postcontrast fat-suppressed 3-D T1-W gradient echo
vii. Optional: oblique coronal fat-suppressed T2-W FSE
viii. Optional: STIR images
ix. Optional: DWI with ADC maps
x. Optional: digital subtraction MR-fistulography
xi. Optional: DCE 2-D T1-W images with time-SI curves

The majority of perianal fistulas are not associated with an underlying condition. They result from impaired drainage of the anal glands, leading to abscesses that subsequently fistulize. However, perianal fistulas frequently complicate Crohn's disease and can be seen in up to a quarter of patients with longstanding (20 years) disease [199,200].

MRI is superior to digital rectal examination and anal endosonography in classifying fistulous tracts and identifying their internal opening [201,202]. The objectives in performing and interpreting MRI for perianal fistulas are 3-fold: 1) to determine the relationship of the fistula to the sphincter complex; 2) to identify any secondary fistulae and/or abscesses; and 3) to monitor medical therapy for perianal fistulizing Crohn's disease [203,204]. The most accepted MRI fistula classification system is the St. James University Hospital classification [205], which is a modification of the Parks classification [206].

There are 5 grades:

i. Grade 1: Simple linear intersphincteric fistula
ii. Grade 2: Intersphincteric fistula with intersphincteric abscess or secondary fistulous tract
iii. Grade 3: Transsphincteric fistula
iv. Grade 4: Transsphincteric fistula with abscess or secondary tract within the ischioanal or ischiorectal fossa
v. Grade 5: Supralevator and translevator disease

On unenhanced T1-W images, fistulous tracts, inflammation, and abscesses have low to intermediate SI and may be difficult to distinguish from sphincters and normal muscles. On T2-W and STIR images, linear fistulas and their complications (secondary tracts and/or abscesses) have high in SI compared to surrounding structures. The use of contrast increases the conspicuity of the fistulous tracts and abscess cavity walls. Contrast-enhanced T1-W images can also help distinguish fluid from inflammatory tissue, common in Crohn's disease patients. Time-SI curves following dynamic contrast administration provide information about disease activity. Additionally, DWI improves diagnostic confidence and may be especially helpful as an adjunct to T2-W images in patients with a contraindication to IV contrast [207].

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Section 9. Identification and Characterization of Congenital Anomalies of the Female and Male Pelvis, Including the Anatomic Evaluation of Ambiguous Genitalia and Disorders of Sexual Development (DSD)

V. SPECIFICATIONS OF THE EXAMINATION *(general specifications were discussed earlier in the document)*

C. Technical Advances:

3-D T2-W MRI allows volumetric acquisition of the male and female pelvis, providing submillimeter sections with multiplanar reformatting capability. There is a tradeoff between volume imaged, acquisition time, and T2 characteristics [41]. When evaluating nonpalpable undescended testes, DWI is complementary to conventional imaging [208]. High-resolution images of the seminal vesicles can be obtained with endorectal MR and/or by acquiring images on a 3T system.

D. Examination Technique:

1. Müllerian Duct Anomalies

The workup of suspected Müllerian duct anomaly (MDA) is often undertaken in the setting of infertility, obstetric complications, primary amenorrhea, and/or endometriosis. Although US, especially 3-D US, is often the initial imaging examination and performs well in experienced hands [209,210], MRI is the most accurate modality to characterize and classify MDAs [211]. In young females who are not sexually active, MRI may be performed rather than transvaginal US [212]. Hysterosalpingography and hysterosalpingo contrast sonography are best suited to evaluate synechiae and fallopian tube patency.

The original 1979 Buttram and Gibbons classification of MDAs [213] was modified in 1988 by the American Society of Reproductive Medicine [214]. Accurate classification is critical as treatments vary by subtype, thus underscoring the role of diagnostic imaging. A comprehensive MRI examination evaluates the uterine corpus, uterine cervix, vagina, and adnexa [215]. Vaginal gel insertion may aid in evaluating cervical and/or vaginal involvement, such as by a vaginal septum [216]. The kidneys must also be assessed because there is a 30–50% prevalence of associated renal anomalies. Imaging is performed with a pelvic phased array coil. Fasting 4–6 hours prior to imaging decreases artifacts from bowel peristalsis; alternatively, SQ or IM glucagon may be administered if not contraindicated. Patients are asked to void before the examination.

Suggested sequences include the following:

i. Orthogonal high-resolution (long and short axis) T2-W FSE of the uterus and upper vagina. This should include a T2-W FSE coronal oblique view, oriented parallel to the long axis of the uterus, in order to assess the uterine fundal contour. Alternatively, a 3-D volumetric T2-W acquisition may be obtained
ii. Axial T1-W with and without fat suppression
iii. Coronal large FOV T2-W SSFSE that includes the renal fossae
iv. If a patient is unable to cooperate, orthogonal T2-W SSFSE of the uterine corpus, uterine cervix, and vagina may be performed, recognizing the more limited spatial resolution
v. Optional: T2-W FSE with vaginal gel to define the vaginal canal and/or cervix
vi. Optional: T2-W FSE that includes the abdomen in patients with disorders of sex development for presurgical planning of prophylactic gonadectomy or surveillance in those who choose gonad preservation
vii. Optional: DWI can help identify and characterize the gonads in patients with disorders of sexual development

IV contrast is not indicated.

The goal of high-resolution T2-W imaging is to identify abnormalities that may occur from the time the paired Müllerian ducts descend, elongate, and fuse to the time of reabsorption of the intervening tissue, the uterovaginal septum. The short-axis T2-W images provide information on the number of endometrial, endocervical, and/or endovaginal cavities, whereas the long-axis T2-W images provide information on the true fundal contour of the uterus. T2-W sequences also provide information on whether or not any 2 cavities communicate. T1-W images allow diagnosis of concomitant hematometra and/or endometriosis that may accompany certain MDAs. Finally, a large FOV coronal image assesses renal abnormalities that often accompany MDAs.

2. Male: Congenital Pelvis Anomalies

Congenital anomalies of the male pelvis includes a variety of cystic lesions such as ejaculatory duct cysts, Cowper gland duct cysts and syringoceles, prostatic utricle, and Müllerian duct cysts and seminal vesicle cysts [217]. Other anomalies include abnormalities of the seminal vesicle, cryptorchidism, and congenital absence of the vas deferens. US is often the initial imaging modality for evaluating the seminal vesicles, prostate gland, and/or cryptorchidism. CT and MRI are typically reserved for problem solving (eg, investigation of intra-abdominal undescended testes).

The seminal vesicles are extraperitoneal secretory glands that lie posterior to the bladder and cephalad to the prostate. They originate from the lower mesonephric ducts. Congenital anomalies include agenesis, hypoplasia, and cysts. Seminal vesicle agenesis and hypoplasia may be associated with cryptorchidism. Likewise, seminal vesicle cysts may be associated with renal anomalies, ectopic insertion of ureters, and/or agenesis of the vas deferens. Multiplanar MRI allows comprehensive evaluation of the seminal vesicles and their surrounding structures.

Suggested sequences include [218] the following:

i. Orthogonal T2-W
ii. Axial T1-W
iii. Contrast-enhanced T1-W images may be performed in complicated cases (eg, proteinaceous cyst)
iv. Optional coronal large FOV T2-W SSFSE that includes renal fossae

3. Male: Cryptorchidism

Imaging may help identify a nonpalpable testis by serving as a surgical roadmap in an effort to preserve testicular function and/or detect early malignant tumors [219]. US is often the initial modality in the workup of a nonpalpable testis and has moderate success [220]; however, a meta-analysis found that US rarely impacts treatment while at the same time increases health care costs [221]. MRI is usually reserved for patients with nondiagnostic US.

Sequences include the following:

i. Axial and coronal T1-W images
ii. Axial and coronal T2-W fat-suppressed images to include the abdomen.
iii. Optional: Orthogonal contrast-enhanced T1-W images may increase conspicuity of the nonpalpable testis
iv. Optional: Axial high b-value single-shot spin-echo echoplanar images with chemical shift selective fat suppression

The nonpalpable testis is typically hypointense to muscle on T1-W images, hyperintense to muscle on T2-W, and enhances following IV contrast. Although conventional imaging performs well in locating a nonpalpable

testis, a high b-value DWI can increase the preoperative sensitivity and accuracy of detection of nonpalpable testes. A nonpalpable testis is markedly hyperintense to muscle on high b-value DWI.

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∗Practice parameters and technical standards are published annually with an effective date of October 1 in the year in which amended, revised, or approved by the ACR Council. For practice parameters and technical standards published before 1999, the effective date was January 1 following the year in which the practice parameter or technical standard was amended, revised, or approved by the ACR Council.

Development Chronology for this Practice Parameter
2005 (Resolution 4)
Amended 2006 (Resolution 35)
Revised 2010 (Resolution 15)
Amended 2014 (Resolution 39)
Revised 2015 (Resolution 4)
Revised 2020 (Resolution 28)
Amended 2023 (Resolution 2c)