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Revised 2015 (Resolution 4)*

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 care¹. 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 in light of 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 the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also 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 sole 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, ___ N.W.2d ___ (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:

- Section 1. [Detection, Staging and Recurrence Assessment of Gynecologic Malignancies: Uterus, Cervix, Ovaries, Vulva, and Vagina](#)
- Section 2. [Evaluation of Pelvic Mass or Pain, Including Detection of Adenomyosis, Ovarian Cysts, Torsion, Tubo-Ovarian Abscesses, Benign Solid Adnexal Masses, Obstructed Fallopian Tubes, Endometriomas, and Fibroids](#)
- Section 3. [Assessment of Pelvic Floor Defects Associated with Urinary or Fecal Incontinence](#)
- Section 4. [Determination of Fibroid Number, Location, Size, and Type Prior to Intervention](#)
- Section 5. A. [Detection, Staging, and Recurrence Assessment of Urologic Malignancy: Bladder](#)
- Section 5. B. [Detection, Staging, and Recurrence Assessment of Urologic Malignancy: Prostate](#)
- Section 5. C. [Detection, Staging, and Recurrence Assessment of Urologic Malignancy: Scrotum and Penis](#)
- Section 6. [Evaluation of Complications Following Pelvic Surgery, Including Abscess, Urinoma, Lymphocele, Radiation Enteritis, and Fistula Formation](#)
- Section 7. [Identification of Source of Lower Abdominal Pain in Pregnant Women: Appendicitis, Ovarian and Uterine Masses, and Urological Conditions](#)
- Section 8. [Identification and Classification of Perianal Fistulas](#)
- Section 9. [Identification and Characterization of Congenital Anomalies of the Female and Male Pelvis](#)

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 pelvic pain or mass, including detection of adenomyosis, ovarian cysts, torsion, tubo-ovarian abscesses, benign solid adnexal masses, obstructed fallopian tubes, endometriomas, and fibroids ([See section 2.](#))
3. Identification and characterization of congenital anomalies of the male and female pelvic viscera ([See section 9.](#))
4. Determination of number, location, size, and type (nondegenerating or degenerating) of fibroids for treatment selection and planning ([See section 4.](#))
5. Assessment of pelvic floor defects associated with urinary or fecal incontinence ([See section 3](#))
6. Detection and staging of malignancies of the prostate, bladder, penis, testis, and scrotum ([See section 5b, section 5a, and section 5c.](#))
7. Assessment for recurrence of tumors of the bladder, prostate, or gynecologic organs following surgical resection or exenteration ([See section 1, section 5b, section 5a, and section 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. Planning and guidance for minimally invasive surgery and brachytherapy ([See section 1 and section 5b.](#))

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the [ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging \(MRI\)](#) [22].

IV. SAFETY GUIDELINES AND POSSIBLE CONTRAINDICATIONS

See the [ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging \(MRI\)](#) [22], the [ACR Guidance Document on MR Safe Practices](#) [23], and the [ACR Manual on Contrast Media](#) [24].

Peer-reviewed literature pertaining to MR safety should be reviewed on a regular basis [25,26].

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 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 components of the pelvis should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). 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's scope of practice requirements. (ACR Resolution 35, adopted in 2006)

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 \[27\].](#)).

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 \[28\]](#).

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 fast spin-echo 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 post-dynamic intravenous 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 magnets (>1.0 T), 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 women in the second and third trimester. For pregnant women 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 Adolescents and Women with Ionizing Radiation \[29\]](#). 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 to 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 \[30\]](#).

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.

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 Position Statement on QC & Improvement, Safety, Infection Control, and Patient Education on the ACR website (<http://www.acr.org/guidelines>).

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 should be provided that deal with potential hazards associated with MRI examination of the patient as well as to others in the immediate area [25,26,31-36]. Screening forms must also be provided to detect those patients who may be at risk for adverse events associated with the MRI examination [25,33].

Equipment performance monitoring should be in accordance with the [ACR Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance Imaging \(MRI\) Equipment \[37\]](#).

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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:

In the past 3 to 5 years, diffusion-weighted MR imaging and dynamic contrast-enhanced MR imaging have become useful adjuncts to standard anatomic MR sequences [38]. 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. Parallel imaging techniques increase SNR with reasonable specific absorption rates while markedly speeding up acquisition at 3T body imaging [39].

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 [40,41]. 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. Optional: 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 have been reported to achieve high-resolution images focally, but with a small field-of-view (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 [42].

In staging for gynecologic malignancy, large FOV T1-W images are used to evaluate the abdomen and pelvis for lymphadenopathy, hydronephroureterectasis, and bone lesions. High-resolution long and short axis T2-W imaging of the uterine body is used for localization of endometrial cancer and depth of myometrial invasion and shows zonal anatomy to advantage [4]. Long and short axis imaging of the cervix is performed to show the local extent of the cervical cancer to search for parametrial invasion and to assess candidacy for trachelectomy (a fertility-sparing procedure) [43].

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 [44]. In patients with biopsy proven adenocarcinoma involving both the lower uterine segment and cervix, dynamic contrast-enhanced scans are useful in differentiating correct primary site of origin [45].

DWI with both low and high b-values, respectively, combined with use of ADC maps and correlated with anatomic imaging can demonstrate restricted diffusion in malignancy. DWI assists in lesion detection and extent of disease evaluation, including metastases to the peritoneum or adnexa [46], myometrial invasion in endometrial cancer [47], and tissue characterization of ovarian masses [48]. Limitations of this technique include false-positive results from inflammatory conditions and other benign processes such as benign masses with high cellularity [42]. Use of DWI for detection of pelvic lymphadenopathy is controversial [39].

For evaluation of vulvar and vaginal cancers, MRI is excellent, especially with T2-W images, and MRI is better than physical examination for determining tumor size, extent, and perivaginal spread [49]. Installation of vaginal gel to separate the walls of the vaginal canal can improve visualization of a vaginal mass [50]. 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 [51].

High-resolution orthogonal T2-W FSE images in the axial and coronal planes are used for evaluation of the primary tumor. Dynamic contrast-enhanced 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. Dynamic contrast-enhanced scans with fat suppression are useful to detect small lesions and show involvement of the urethra and anus by vulvar cancer [52].

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 [53] and aids in differentiating post-treatment changes from active tumor [54]. Eligibility for pelvic exenteration requires exclusion of metastatic disease, which is best achieved by PET/CT [55]. The examination technique has not been standardized. Suggested sequences include the following:

- i. 2-plane orthogonal T2-W FSE
- ii. Precontrast and postcontrast fat-suppressed 3-D T1-W gradient echo
- iii. Optional: 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 [56].

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

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

C. Technical Advances:

Perfusion and DWI MR imaging sequences increase the diagnostic accuracy of conventional MR imaging with the overall accuracy for MR imaging greater than 90% for adnexal mass characterization [48]. If dynamic contrast-enhanced MR imaging 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 [57]. Susceptibility-weighted imaging shows hemosiderin deposition in extraovarian endometriosis and adenomyosis with increased sensitivity compared to conventional MR imaging [58]. ADC measurements on DWI may show quantitatively differences between fibroids and adenomyosis [59]. 3-D T2-W MR imaging 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 [60].

D. Examination Technique:

1. Detection and Characterization

The workup of adnexal masses is particularly challenging because the prevalence of ovarian malignancy is low compared to 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 field-of-view (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 [61]. 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. 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 post-contrast fat-suppressed 3-D T1-W gradient echo
- iv. Optional DWI with ADC map

Fluid, fat, blood, and fibrous tissues can be differentiated based upon MR signal characteristics that are often indeterminate on US. For solid adnexal masses, low T2 SI is usually correlated with benignity [61]. Most cystic ovarian masses are benign. Incidental functional ovarian cysts found on initial MRI do not require further workup if they are <3 cm in size in women of childbearing age, or <1 cm if postmenopausal [62]. In women of childbearing age with simple cysts >3 cm and ≤5 cm, cysts should be described and yearly US follow-up performed to ensure stability [62,63]. In postmenopausal women, simple cysts >1 cm and ≤7 cm can be described and yearly US follow-up performed to ensure stability. For simple cysts >7 cm in premenopausal or postmenopausal patients detected by initial pelvic US, pelvic MR may be performed to search for occult enhancing elements, or surgery may be considered [63].

Serous cystadenomas (the most common benign epithelial ovarian neoplasm) have fluid signal and thin walls [64]. Mucinous neoplasms are multilocular with varying MR signal intensities (“stained glass appearance”) [65]. The presence of papillary projections, wall thickening, and/or enhancement is worrisome for malignancy [66]. Restricted diffusion may be seen in malignancy, but there are many causes of false-positive findings [56].

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 contiguous with a paraovarian or paratubal cyst, or the normal ovary embedded into the wall of peritoneal inclusion cyst [66].

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 in patients who are refractory to medical therapy. Although CT usually is performed after equivocal pelvic US, MR, if performed in nonspecific cases, may show inflammation on contrast-enhanced scans and edema on fat-suppressed T2-W images [67].

Solid or mixed cystic and solid lesions are also characterized based upon morphology and tissue signal characteristics. Fat-suppressed or chemical shift MR techniques can be used to differentiate between bright signal from fat within mature cystic teratomas, or blood within hemorrhagic cysts or endometriosis. Fat signal in mature cystic teratomas and/or chemical shift artifact at the fat-fluid interface confirms the diagnosis [68]. 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 [69,70]. Ovarian fibromas have low T1 and T2 signal similar to skeletal muscle due to fibroblasts and collagen. Fibromas may enhance [71].

Because acute ovarian torsion is a gynecologic emergency 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) [67,72].

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 due to degeneration. Identification of separate normal ovaries, continuity of the mass with uterine myometrium, and enhancing bridging vessels arising from the uterus supplying the mass [73] 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 2 may coexist. Small hemorrhagic foci seen to best advantage on susceptibility-weighted images are helpful to identify adenomyosis and endometriosis [58]. MR can localize any associated macroscopic pelvic endometriosis. Cystic adenomyosis and subserosal polypoid adenomyomas can mimic an adnexal mass but typically are contiguous with myometrium forming a “beak sign,” indicating uterine origin [58].

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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 combining high-resolution anatomic imaging and functional evaluation. MRI is most helpful in patients with multicompartiment physical examination findings or symptoms, posterior compartment abnormalities, severe prolapse, or recurrent pelvic floor symptoms after surgical repair [74-76].

Prior to beginning the examination, it is important to reassure patients about privacy and coach appropriately of the maneuvers to ensure full patient cooperation. Patients are asked to empty bladder and rectum within 1 hour prior to the examination, and rectal enema is optional prior to the examination. Although a recent study has shown superiority of the physiologic sitting position for the evaluation of defecography [77], 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 [78].

The patient is placed on a water-resistant pad on the MRI table, and approximately 100–120cc of warmed US gel is instilled into the rectum. 10–20cc of gel may also be used to opacify the vaginal canal. . The patient is then positioned in the supine position and loosely wrapped in waterproof incontinence pad. A multi-element 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 single-shot FSE (SSFSE)
- iii. Sagittal midline rest and straining cine T2-W SSFSE
- iv. Optional axial or coronal rest and straining cine T2-W SSFSE
- v. Optional sagittal balanced steady-state free precession

Axial and coronal small field-of-view (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 is then obtained of the entire pelvis from sidewall to sidewall to determine resting organ positions. Functional evaluation is performed by acquiring a single midsection sagittal SSFSE 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 exercise can also be performed in the axial or coronal plane sequence to evaluate prolapse and effect on supporting structures [74,79]. Cine evaluation is then performed in the defecography phase until complete evacuation of rectal contrast is achieved. However, continuous imaging during defecation has shown greater degrees of prolapse with a balanced acquisition with steady-state precession than with a SSFSE sequence given the improved temporal resolution [80]. 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 MR imaging 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 [60].

DWI reflects water mobility and tissue cellularity. Apparent diffusion coefficients (ADCs) can be calculated from images with different b-values [81]. This technique can be useful when attempting to differentiate typical fibroids from uterine sarcomas [82]. ADC values may also show quantitative differences between fibroids and adenomyosis [59].

D. Examination Technique:

Although US remains the initial imaging modality in the workup of women with suspected symptomatic fibroids, MRI is the most accurate imaging technique for fibroid detection and localization [83]. It is increasingly performed in symptomatic patients being evaluated for minimally invasive uterine-sparing therapies such as uterine fibroid embolization (UFE) [84] and more recently magnetic resonance-guided focused US (MRgFUS) [85]. For UFE candidates, MRI provides additional information compared with US and affects clinical management in a significant number of patients [86]. Single institution and multicenter randomized controlled trials report significant decrease in symptoms and improved health related quality of life following UFE [87,88]. MR imaging 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. Patients are asked to void before 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

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 to 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 to 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 homogeneously.

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 [89-91]. DWI and ADC values may also add complementary information [92,93].

MR imaging features pertinent to the outcome of UFE include location, size, viability, ovarian arterial collateral supply to the uterus, and comorbid conditions.

Following successful UFE, fibroids undergo hemorrhagic infarction. Imaging features of an infarcted fibroid post embolization include hyperintense T1-W SI, increasing hyperintense T2-W SI over time, and no enhancement following intravenous contrast administration [94]. 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 [95].

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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, can be complementary to conventional imaging. Additionally, MR cystography relies on 3-D T2-W datasets 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 multi-element surface coil, thin section, and large matrix. Moderate bladder distention is necessary, and patients are asked to void approximately 2 hours prior to imaging. Administration of an antiperistaltic agent can reduce bowel peristalsis for assessment for extravesical disease [96]. Suggested sequences include the following:

- i. 3-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. Optional: DWI with ADC maps
- iv. Optional: 3-D MR cystography

Non-fat-saturated small field-of-view (FOV) high-spatial resolution (3–4 mm slice thickness) 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 sat 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 intravoxel resolution and signal-to-noise (SNR) are slightly reduced. Recent advances have made 3-D T2-W imaging feasible with the introduction of shorter acquisition times, volumetric acquisition, and improved SNR.

3-D fat-suppressed gradient-echo T1-W imaging is obtained prior to and following contrast material administration. 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 [97,98]. Preliminary studies using dynamic contrast-enhanced MRI for quantitative analysis have shown correlation with T stage, tumor angiogenesis, and prediction of tumor response to neoadjuvant therapy [97,99,100].

Several recent 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 [101-106]. ADC values for bladder tumors are less than surrounding normal tissues. Given significant variation in ADC measurements, changes in SI in DWI must also be taken into consideration [107].

There has been interest in 3-D rendering techniques with MR datasets (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) [108].

2. Therapy Response and Pelvic Recurrence

MRI technique is similar to that described for pre-operative 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 [109]. Recent studies report DWI to be superior to contrast-enhanced MRI for differentiation between tumor recurrence from postoperative fibrosis and inflammation [110,111].

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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 dynamic contrast-enhanced (DCE) imaging is complementary to conventional anatomic T2-W imaging. MR spectroscopy (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) [112]. Mp-MRI refers to the use of T2-W imaging in combination with functional imaging techniques; DWI, DCE MRI (DCE-MRI), and MRSI [112,113]. 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 [114,115].

Imaging should be performed at either 1.5T or 3T. The fundamental advantage of 3T over 1.5T is increased SNR, which improves the spatial, temporal, and spectral 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 [116-119]. 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 [120,121]. 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 consistent image quality.

To minimize the artifacts introduced from biopsy-related hemorrhage, which can interfere with lesion detection and staging, imaging can be delayed to 8–12 weeks after the biopsy procedure [110]. However, detection of clinically significant cancer at a site of postbiopsy hemorrhage without a corresponding abnormality on mp-MRI is low, and a recent study has shown the presence of extensive hemorrhage and short delay after biopsy did not negatively impact accuracy for tumor detection using MP-MRI [122]. So if 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 [123]. 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 [124]. 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. Orthogonal high resolution T2-W FSE of the prostate
- ii. DWI with ADC map
- iii. Precontrast fat-suppressed 3-D T1-W gradient echo and DCE T1-W
- iv. Large field-of-view (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 <1.5 -mm slice thickness may be used as an adjunct to orthogonal T2-W FSE sequences, although soft-tissue contrast is not identical [125].

DWI improves the diagnostic performance for cancer detection when combined with T2-W images and provides information about tumor aggressiveness [126-130]. DWI should be acquired in the axial plane with motion-probing gradients applied in 3 orthogonal planes. Although the optimal b-values have not been determined, it is agreed that b-values (s/mm^2) should include low (0 -100), medium (400-500) and high b-values (800-1000). A meta-analysis has shown mixed results with higher b-values (>1000) to suppress normal prostate tissue background signal [129]; however, in recent studies, acquired high b-values, 1400–2000, can have added value for tumor localization, although field strength and coil selection, technical parameters, and analysis of trace DWI and/or ADC maps will impact the utility of these higher b-values [129,131-139]. Alternatively, calculated high b-values from the acquired lower b-values can be used to create the ADC map to create images of high diagnostic value without added imaging time [140,141]. An ADC map is recommended, but b=0 value, if possible, should be excluded from the calculation. Axial slice thickness should be ≤ 4 mm and 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 [112,142,143]. Serial imaging of the gland should be performed prior to and following intravenous gadolinium administration (injection rate 2–4cc/s), and a rapid T1-W 3-D gradient-echo sequence with fat suppression is the preferred acquisition [112,142]. Pharmacokinetic features require a high temporal resolution ($<10s$ per phase) with an observation period of at least 5 minutes to evaluate for washout. 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 [112,143-145]. However, a recent 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 [146]. The volume of interest (VOI) is aligned to 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, a 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 [147-149]. 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 [150-152]. However, studies evaluating

DCE-MRI, DWI, and T2-W imaging following EBRT (external beam radiation therapy) have shown no added benefit if DCE-MRI is added to DWI and T2-W imaging for recurrence [151,153]. 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 [147].

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 [154]. 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

VI. 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 [155-157].

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 multi-element pelvic coil is centered over the scrotum. MRI sequences of the scrotum should be performed with small field-of-view (FOV) and high spatial resolution (slice thickness ≤ 4 mm). Suggested sequences include the following:

- i. Axial T1-W without and with fat suppression
- ii. Axial T1-W in-phase and opposed phase
- iii. 3-plane orthogonal T2-W FSE
- iv. Optional contrast-enhanced fat-suppressed T1-W 2-D SE or 3-D gradient echo

Axial T1-W spin-echo sequence with and without fat suppression, followed by axial, coronal, and sagittal T2-W FSE imaging differentiates tumor from normal structures. In-phase and opposed-phase imaging of the scrotum can identify fat-water interface and can help depict hemorrhage due to the T2* effects of hemosiderin. Intravenous gadolinium can be administered when indeterminate pathologies are found using fat-suppressed 2-D spin-echo or 3-D gradient-echo T1-W imaging in 2 orthogonal projections.

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 [158].

2. Penis

MRI is the most sensitive imaging modality for the local staging of penile carcinomas due to 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 [159]. A small surface coil placed on the penis is optimal for high-spatial resolution images (FOV 14–16 cm), although a multi-element pelvic coil can be used and enables a larger FOV to assess for inguinal and pelvic lymphadenopathy [159,160]. Suggested sequences include the following:

- i. 3-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 intravenous gadolinium has not shown to improve detection or local staging or to be advantageous to standard T2-W sequences [159,161-163]. 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 [161,164]. 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 [165]. The use of negative endoluminal bowel-contrast agents (such as ferumoxsil oral suspensions or barium suspensions) reduce the SI in the bowel lumen, thereby increasing the conspicuity of high signal inflammation and abscess on T2-W images [166]. DWI may assist in the differentiation between cystic lesions from abscesses [167,168].

D. Examination Technique:

CT is usually the first study performed in searching 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 women of child-bearing age and children [169].

MRI is performed with a pelvic phased array coil. Suggested sequences include the following:

- i. T2-W fat-suppressed FSE or 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 bowel conditions (such as Crohn disease, appendicitis, diverticulitis, radiation enteritis, and pelvic inflammatory disease). On both CT and MR, an abscess is a collection of pus, usually with rim enhancement, that may contain air from gas-forming organisms [170]. Air may cause blooming artifact on dual-echo gradient echo in-phase images [171]. MR shows inflammation on T1-W contrast-enhanced scans (especially if subtraction is performed following a 3-D acquisition) and edema on fat-suppressed T2-W images [67]. 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 [172]. 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 have the appearance of simple fluid on all MR sequences without enhancement, the MR appearance of hematoma varies with the age of the blood [173,174].

Urinomas usually result from obstructive uropathy but may also occur after trauma or surgery or may occur iatrogenically after instrumentation [173]. MRI does not play a role in acute urinary tract injuries [175], 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 intravenous 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 repair of tears or damage, in addition to percutaneous drainage of the collection.

Lymphoceles, usually a complication of lymphadenectomy, are managed differently than other postoperative fluid collections if refractory to medical therapy, as the former may undergo catheter drainage with or without sclerotherapy [172]. Uncomplicated lymphoceles are unilocular with fluid signal on all MR sequences and are located in the distribution of previous lymph node dissection [176]. 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 thickening of bowel wall, 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 [177].

MR enterography using ultrafast or turbo spin-echo sequences to reduce artifacts from peristalsis with intravenous contrast enhancement can demonstrate radiation changes such as bowel-wall thickening and dilation, mucosal edema, fatty stranding in the adjacent mesentery, and an abrupt transition point from adhesions. These studies involve administration of intravenous glucagon to reduce peristalsis and ingestion of up to 1.5 L of negative 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 intravenous contrast administration in the coronal and axial planes [178]. For more information, see the [ACR-SAR-SPR Practice Parameter for the Performance of Magnetic Resonance \(MR\) Enterography](#).

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 (short tau inversion recovery [STIR]) images may show a fistulous tract to advantage. Air-filled tracts produce low SI on all MR pulse sequences [179].

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 air-fluid levels. In patients with contraindications to iodinated intravenous contrast material, MR is preferred to noncontrast CT [179].

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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. Apparent diffusion coefficients (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 \[22\]](#)).

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 [180].

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. Ultrasound remains the initial imaging modality for evaluating pelvic pain. However, the advent of widespread motion-insensitive MR sequences, coupled with absence of ionizing radiation, has led to an increase of MR exams in pregnant patients, especially when US is equivocal or limited [20,24,181-187].

Patients should fast 4–6 hours prior to imaging to decrease bowel peristalsis. Women can be imaged in the supine or left lateral decubitus position using a multicoil array and a large field-of-view (FOV) (38–44 cm). Suggested imaging sequences include the following:

- i. 3-plane orthogonal T2-W SSFSE images
- ii. Axial fat-suppressed T2-W SSFSE images Short Tau Inversion Recovery (STIR)
- iii. Axial T1-W in-phase and out-of-phase gradient echo images

The above sequences should allow a diagnosis to be made or excluded in most instances. Optional sequences include the following:

- iv. Coronal T1-W
- v. 2-D time-of-flight (TOF)
- vi. Orthogonal T2-W fast imaging with steady-state free precession images
- vii. DWI with ADC maps
- viii. Negative oral contrast

(See the [ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation \[29\]](#).)

1. Gastrointestinal Disease

The MRI features of acute appendicitis parallel that for CT: a fluid-filled, dilated appendix >6 mm with a thickened wall and periappendiceal inflammation 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 images 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 dermoids 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 a follicular stroma with peripherally displaced follicles [72]. 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. Pelvocaliectasis 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].

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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 [190]. Dynamic contrast-enhanced (DCE) 2-D T1-W images with time-signal intensity curves provide information on fistula activity [191]. This technique may be useful to identify a subgroup of patients with perianal Crohn 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 resulting in high accuracy for detecting perianal fistulas [192-195]. This is especially true for patients with Crohn disease who are prone to distant fistulous extensions and abscesses. Some centers rely on an endoluminal coil alone or in combination with an external coil and report good imaging results [196]. Suggested sequences include [197] 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 axial fat-suppressed T2-W FSE
- iv. Oblique axial fat-suppressed T1-W fat
- v. Oblique axial and oblique coronal postcontrast fat-suppressed 3-D T1-W gradient echo
- vi. Optional: oblique coronal fat-suppressed T2-W FSE
- vii. Optional: short tau inversion recovery (STIR) images
- viii. Optional: DWI with ADC maps
- ix. Optional: digital subtraction MR-fistulography
- x. Optional: DCE 2-D T1-W images with time-signal intensity 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 disease and can be seen in up to a quarter of patients with longstanding (20 years) disease [198,199].

MRI is superior to digital rectal exam and anal endosonography in classifying fistulous tracts and identifying their internal opening [200,201]. 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 disease [202,203]. The most accepted MRI fistula classification system is the St. James University Hospital classification [204], which is a modification of the Parks classification [205]. 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: Trans-sphincteric fistula

- iv. Grade 4: Trans-sphincteric fistula with abscess or secondary tract within the ischioanal or ischiorectal fossa
- v. Grade 5: Supralelevator and translevator disease

On unenhanced T1-W images, fistulous tracts, inflammation, and abscesses are 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) are 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 disease patients. Time-signal intensity 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 [206].

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Section 9. Identification and Characterization of Congenital Anomalies of the Female and Male Pelvis

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

C. Technical Advances:

3-D T2-W MR imaging 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 [60]. High-resolution images of the seminal vesicles can be obtained with endorectal MR and/or by acquiring images on a 3T system. When evaluating nonpalpable undescended testes, DWI is complementary to conventional imaging [207].

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 ultrasound (US), especially 3-D US, is often the initial imaging exam and performs well in experienced hands [208,209], MRI is the most accurate modality to characterize and classify MDAs [210]. Hysterosalpingography (HSG) is best suited to evaluate synechiae and fallopian tube patency.

The original 1979 Buttram and Gibbons classification of MDAs [211] was modified in 1988 by the American Society of Reproductive Medicine [212]. Accurate classification is critical as treatments vary by subtype, thus underscoring the role of diagnostic imaging. A comprehensive MRI exam evaluates the uterine corpus, uterine cervix, vagina, and adnexa [213]. 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 and/or a 3-D volumetric T2-W acquisition
- ii. Axial T1-W with and without fat suppression
- iii. Coronal large field-of-view (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

Intravenous contrast is not indicated.

During organogenesis, the paired Müllerian ducts undergo a 3-stage process: 1) development (elongation and descent); 2) fusion; and 3) reabsorption of the uterovaginal septum. The goal of high-resolution T2-W images 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: Seminal Vesicle Anomalies

Ultrasound is often the initial imaging modality for evaluating the seminal vesicles 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 [214] 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 [215]. US is often the initial modality in the workup of a nonpalpable testis and has moderate success [216]; however, a meta-analysis found that US rarely impacts treatment while at the same time increases health care costs [217]. 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.
- 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 intravenous 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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