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

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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.

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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.*

I. INTRODUCTION

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 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
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. Detection, Staging, and Recurrence Assessment of Urologic Malignancy: Bladder
Section 6. Detection, Staging, and Recurrence Assessment of Urologic Malignancy: Scrotum and Penis
Section 7. Evaluation of Complications Following Pelvic Surgery, Including Abscess, Urinoma, Lymphocele, Radiation Enteritis, and Fistula Formation
Section 8. Identification of Source of Lower Abdominal Pain in Pregnant Women: Appendicitis, Ovarian and Uterine Masses, and Urological Conditions
Section 9. Identification and Classification of Perianal Fistulas
Section 10. 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)

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 before beginning the MR examination will result in improved diagnostic quality. MRI for the detection, staging, and recurrence of rectal and prostate cancer are 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 (see Sections 1 and 4).
6. Assessment for recurrence of tumors of the bladder or gynecologic organs following surgical resection or exenteration (see Sections 5a and 5b).
7. Detection and staging of malignancies of the bladder, penis, testis, and scrotum (see Sections 5a and 5b).
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 patients, 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 DSD (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 Manual on MR Safety [2], the ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients

with Ionizing Radiation [3] and the ACR Manual on Contrast Media [4]
Peer-reviewed literature pertaining to MR safety should be reviewed on a regular basis [5,6].

V. GENERAL SPECIFICATIONS OF THE EXAMINATION
(additional specifications are discussed in relevant sections)

The supervising physician should have an adequate 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.

V. GENERAL SPECIFICATIONS OF THE EXAMINATION
(additional specifications are discussed in relevant sections)

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 before 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 use (see the ACR–SPR Practice Parameter for the Use of Intravascular Contrast Media [7] and the ACR Manual on Contrast Media [4]).

Patients experiencing 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 [8]. For pediatric patients, support from child life specialists can be beneficial and may avoid sedation in some cases.

V. GENERAL SPECIFICATIONS OF THE EXAMINATION
(additional specifications are discussed in relevant sections)

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.

V. GENERAL SPECIFICATIONS OF THE EXAMINATION
(additional specifications are discussed in relevant sections)

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 (FOVs) and higher spatial resolution. Fasting for 6 hours before 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, including diffusion-weighted imaging (DWI) with apparent diffusion coefficient (ADC) map, are now essential for diagnosis and evaluation of extent of disease in many indications. In the case of advanced disease, MRI of the abdomen should be considered to search for distant metastases. Endoluminal coils (eg, endorectal) are now rarely used.

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 Manual on Contrast Media [4]. 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.

VI. DOCUMENTATION

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

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 [6,7,10-15]. Screening forms must also be provided to detect those patients who may be at risk for adverse events associated with the MRI examination [6,11].

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 [16].

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

A. Technical Advances:

DWI and dynamic contrast-enhanced (DCE) sequences are useful adjuncts to standard anatomic MR sequences [17-22]. 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]. Advanced acceleration techniques, such as parallel imaging, compressed imaging, and simultaneous multislice imaging, reduce the spatial encoding steps needed for an MR image without compromising spatial resolution. These techniques provide faster acquisitions, but at the cost of SNR. Noncartesian acquisition techniques are designed to oversample the center of k-space by using radial or rotating k-space trajectories, which leads to relatively motion-robust imaging such as PROPELLER (periodically rotated overlapping parallel lines with enhanced reconstruction) sequences. 3-D gradient-echo sequences can be used

for motion-robust dynamic or postcontrast imaging. Modern Dixon techniques can provide more uniform and complete fat suppression in the presence of moderate susceptibility. Deep learning reconstruction techniques are becoming available to reduce image noise, increase image sharpness, and reduce sampling artifacts. Artificial intelligence (AI) techniques are being developed for MR based detection and prognostication of gynecologic malignancies [23]. AI techniques have been able to differentiate between benign, borderline, and malignant ovarian lesions [24,25] and allow for risk stratification of high-grade serous ovarian cancers [26], detection of cervical cancer [27] and assessment for recurrence after chemoradiation [28], and diagnosis and evaluation for myometrial invasion with endometrial cancer [29-31].

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

B. Examination Technique

1. Detection and Staging

MRI is valuable for differentiating benign from malignant masses, assessing extent of disease and local staging in patients with known or clinically suspected gynecologic malignancy [17,32-35]. Recent literature supports the role of MRI in differentiating leiomyomas from leiomyosarcomas, which is essential for planning laparoscopic surgery and contained morcellation for fibroids [35]. It is used in treatment planning to guide surgery and/or radiation therapy for cervix, vaginal and vulvar cancers, to monitor treatment response, and to detect local and regional recurrence [17,32-34]. MRI along with Ovarian-Adnexal Imaging-Reporting-Data System (O-RADS) MRI risk stratification can help assess risk of malignancy with ovarian neoplasms [36]. Using O-RADS MRI lexicon, ovarian lesion features can be assessed allowing for differentiation between benign and malignant neoplasms. Enhancement characteristics of solid tissue can also allow for lesion stratification as low-risk, intermediate risk or high risk for malignancy [36].

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 fat-suppressed 3-D T1-W acquisition.For most female pelvic malignancies, postcontrast phase is recommended to be performed 30–40 seconds after the end of the contrast material injection. Dynamic contrast enhanced imaging for O-RADS MRI protocol is recommended to be performed with minimal temporal resolution < 15 seconds interval [36].
iv. Axial T2-W of the pelvis to include the perineum without fat suppression (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

Differentiation of atypical leiomyomas from leiomyosarcomas is suggested using appropriate FOV to include the entire uterine mass and pelvic side walls to assess for pelvic lymphadenopathy and peritoneal disease [35]. In staging for gynecologic malignancy, large FOV T2-W and T1-W images with and without contrast are used to evaluate the abdomen and pelvis for lymphadenopathy, peritoneal disease, hydroureteronephrosis, and osseous lesions [17,33]. 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 [17,37]. 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) [33].

Precontrast and postcontrast-enhanced dynamic multiplanar multiphase imaging using volumetric T1-W gradient- echo sequences have shown myometrial invasion from endometrial carcinoma to advantage [17,22,37]. 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 [38].
DWI with both low and high b-values (1000-1200 s/mm2) combined with use of ADC maps can demonstrate restricted diffusion in malignancy [22,35,36]. DWI assists in lesion detection and extent of disease evaluation, including metastases to the peritoneum or adnexa [17,37], myometrial invasion in endometrial cancer [17,37], and tissue characterization of ovarian masses [39]. Limitations of this technique include false-positive results

from inflammatory conditions and other benign processes, such as benign masses with high cellularity. Use of MRI features including short axis >8 mm, T2-W hypointense signal intensity (SI), rounded morphology and restricted diffusion has been shown to be helpful for detection of pelvic lymph node involvement, particularly in cervix cancer [40].

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 [34,41,42]. Installation of vaginal gel to separate the walls of the vaginal canal can improve visualization of a vaginal mass but is not required [34,41,42]. 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 [43]. 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 [43]. 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 [41,43].

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

B. Examination Technique

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 [44] and aids in differentiating posttreatment changes from active tumor [41,45,46]. Eligibility for pelvic exenteration requires exclusion of metastatic disease, which is best achieved by PET/CT [47]. The MRI examination technique for assessing recurrence for gynecologic cancers 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 (b-value of 1000–1200 s/mm2) 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 [41]. Recurrent disease evaluation with PET/CT may be beneficial compared to MRI, but additional large-scale studies are needed for definitive recommendations [48-50].

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

A. Technical Advances

Perfusion and DWI MRI sequences increase the diagnostic accuracy of conventional MRI with the overall accuracy for MRI > 90% for adnexal mass characterization [51]. 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 [37].

ADC measurements may show quantitative differences between fibroids and adenomyosis [52]. 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 [53]. The use of diffusion tensor imaging and MR neurography for detecting pelvic nerve involvement by deep endometriosis is being investigated [54,55].

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

B. 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 for problem solving after an indeterminate pelvic US. 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 [56]. Transvaginal US in trained hands can be used for detection and presurgical mapping of deep pelvic endometriosis [57]. Pelvic MRI improves global pelvic imaging while removing operator dependency in mapping deep pelvic endometriosis [58]. 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 [59]. The differential diagnosis of adnexal masses on MRI is based upon a systematic evaluation of their anatomic location, morphology (solid, cystic, or both), SI characteristics, enhancement, and appearance on DWI. Deep pelvic endometriosis may present as an implant in the posterior, middle, and/or anterior pelvic compartments and use of a compartmental approach with structured reporting is shown to improve patient care [60].

MRI for pelvic endometriosis can be performed at any time during the menstrual cycle, on a 1.5T or 3T magnet. Use of an endorectal coil, fasting or bowel preparation, and oral contrast are not recommended. Vaginal and rectal gel are optional. Moderate urinary bladder filling is conditionally recommended, and use of an antiperistaltic agent is highly recommended [61].

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 (small and large FOV)

iv. DWI (b-values of 0 or 50 sec/mm2 and 1000–1200 sec/mm2) 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 [62]. For solid adnexal masses, low T2-W SI is usually correlated with benignity [56]. Most cystic ovarian masses are benign. Guidelines have been established for evaluation of adnexal cysts based on patient menstrual status and symptoms [63,64].

Serous cystadenomas (the most common benign epithelial ovarian neoplasm) have fluid signal and thin walls [65]. Mucinous neoplasms are multilocular with varying MR SIs ("stained glass appearance") [66]. The presence of papillary projections, wall thickening, and/or enhancement is worrisome for malignancy [67]. Restricted diffusion may be seen in malignancy, but there are many causes of false-positive findings [68-72].

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 [67].

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 patients when avoiding radiation exposure is a priority. MRI may show inflammation on contrast-enhanced scans and edema on fat-suppressed T2-W images [73].

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 [74]. 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 [75,76]. Ovarian fibromas have low T1 and T2 signal, similar to skeletal muscle due to fibroblasts and collagen. Fibromas may enhance [77].

Because acute ovarian torsion is a gynecologic emergency that is usually first evaluated with pelvic US, MRI is not generally used in the acute setting. The use of MRI generally has been limited to imaging subacute or chronic torsion. MRI 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) [73,78].

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 on T2-W images 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 [79] 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.

MRI is an important noninvasive tool for detection of deep pelvic endometriosis, endometriotic cysts, and decidualization in pregnancy as well as malignant transformation of endometriomas [80,81]. Use of the proposed MRI lexicon and compartmental approach for reporting deep pelvic and extrapelvic endometriosis is important for improving multidisciplinary patient care [80,82]. Polypoid endometriosis, a rare form seen in women over 50 years
old, or those on hormonal replacement therapy, can mimic a neoplasm due to its polypoid growth on bowel, bladder, or within the ovary [83]. Malignancy in association with endometriotic cysts is seen in younger women and includes endometrioid adenocarcinoma, clear cell carcinoma, and benign and borderline seromucinous carcinoma [84]. Enhancing mural nodules, doubling in size, and a lack of T2 shading during follow-up are MRI features suggestive of malignancy [85,86].

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

A. 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 two-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 [68-72].

Before 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 before the examination, and no bowel preparation is required before the examination [72]. Although a study has shown superiority of the physiologic sitting position for the evaluation of defecography [87], 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 [88].

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. Routine use of vaginal gel is not necessary for MR defecography [71]. 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 [89]. 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 2–3 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 [68,90]. 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. Images that demonstrate maximum effort or maximum abnormality must be used for measurement.

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I. SPECIFICATIONS OF THE EXAMINATION

A. 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 [53].

DWI reflects water mobility and tissue cellularity. ADCs can be calculated from images with different b-values [91]. This technique can be useful when attempting to differentiate typical fibroids from uterine sarcomas [92]. ADC values may also show quantitative differences between fibroids and adenomyosis [52].

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 [93].

I. SPECIFICATIONS OF THE EXAMINATION

B. 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, localization, and characterization [94]. It is increasingly performed in symptomatic patients being evaluated for both minimally invasive uterine-sparing therapies, such as uterine fibroid embolization (UFE) [95], MR-guided focused US (MRgFUS) [96] and ablative techniques, and surgical interventions such as myomectomy and hysterectomy [35]. For UFE candidates, MRI provides additional information compared with US and affects clinical management in a significant number of patients [97]. Single-institution and multicenter randomized controlled trials report significant decrease in symptoms and improved health-related quality of life following UFE [97-99]. MRI following UFE and MRgFUS has also been used to monitor outcome and diagnose complications. Preprocedural imaging with MRI for ablative treatment with various energy sources such as radiofrequency ablation and high intensity focused US (HIFU) is important to determine the optimal fibroids to treat and also to exclude confounding entities such as adenomyosis [100,101].

MRI before surgical interventions is also important for surgical planning and risk stratification of fibroids given the 1 in 352 (0.28%) prevalence of all uterine sarcomas and 1 in 498 (0.2%) prevalence of leiomyosarcoma (LMS), the most common uterine sarcoma [102,103]. Minimally invasive surgical techniques are preferred over open techniques as they offer lower morbidity and mortality; however, morcellation required for minimally invasive surgery carries a risk for dissemination of occult neoplasm [104,105].

Imaging is performed with a pelvic phased array coil. Fasting 4–6 hours before imaging decreases artifacts from bowel peristalsis; alternatively, subcutaneous (SQ) or intramuscular (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. Minimum of two orthogonal planes of T2-W FSE without fat suppression (at least one plane should be a high-resolution sequence and/or a 3-D T2-W volumetric acquisition)
ii. Axial in-phase and opposed-phase T1-W

iii. Axial T1-W with fat suppression
iv. Precontrast and dynamic postcontrast fat-suppressed 3-D T1-W gradient-echo images
v. DWI with ADC maps (suggested b-values of 0 or 50 sec/mm2 and 1000 sec/mm2)
vi. 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 or an atypical benign 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 [106-108]. Although these features may be used as secondary features to assess for malignancy, intermediate, or high signal on T2-W images, and DWI and ADC values are the most consistent and specifically described features associated with uterine sarcomas with ADC value of ≤ 0.9 x 10-3 mm2/sec of enhancing soft tissue suggesting increased risk for uterine sarcoma [109-111].

Use of the following algorithm is recommended to determine whether an atypical uterine mass is benign or at risk for uterine sarcoma [35]. First, assessment for extrauterine disease such as peritoneal metastases or malignant lymph nodes should be performed, which indicates high suspicion for malignancy. Second, T2-W SI of the solid enhancing tissue of a fibroid should be evaluated with intermediate/high T2-W SI indicating potential for malignancy. Low T2-W SI indicates a benign fibroid. A fibroid with intermediate/high T2-W SI of the enhancing solid tissue should then be evaluated on DWI. If the T2-W SI is equal or greater than endometrium on high b-value images, then evaluation of the fibroid on ADC map is the next step. Fibroids without high SI on high b-value images of DWI are benign. On an ADC map, enhancing soft tissue of an atypical fibroid with intermediate/high T2- W SI, high SI on high b-value images, and ADC values of ≤ 0.9 x 10-3 mm2/sec is suspicious for uterine sarcoma [35]. If ADC values are above the cutoff value, then the fibroid is likely benign. Of note, there is some overlap in imaging appearance of benign cellular fibroids and smooth-muscle tumors of unknown malignant potential with uterine sarcomas [35].

MRI features pertinent to the outcome of UFE include location, size, viability, ovarian arterial collateral supply to the uterus, and comorbid conditions [95].

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 IV contrast administration [112]. 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 [113].

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I. SPECIFICATIONS OF THE EXAMINATION

A. 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 before imaging or to drink 500–1000 mL of water in the 30 minutes before the examination [114]. Administration of an antiperistaltic agent can reduce bowel peristalsis for assessment for extravesical disease [115].

Suggested sequences include the following:

i. Three-plane orthogonal T2-W FSE or 3-D T2-W volumetric acquisition
ii. Precontrast fat-suppressed 3-D T1-W gradient echo and DCE T1-W
iii. Wholepelvis or small FOV DWI with ADC maps

Non–fat-saturated small FOV high spatial resolution (slice thickness of 3–4 mm, no gap) FSE T2-W imaging is performed in three 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 fat-suppressed 3-D gradient-echo T1-W imaging is obtained before and following contrast material administration. 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 [116,117]. Studies using DCE-MRI for quantitative analysis have shown correlation with T stage and prediction of tumor response to neoadjuvant therapy and have been shown to improve detection of muscle-invasive bladder cancer [118-122].

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 [118,123-128]. 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 because there is more contrast between tumor and surrounding structures, and there is significant signal variation in ADC measurements [129,130]. Reduced FOV DWI has been shown to improve image quality, reduce artifacts, and yield high spatial resolution compared with whole-body DWI [131].

I. SPECIFICATIONS OF THE EXAMINATION

A. Examination Technique

2. Therapy Response and Pelvic Recurrence

MRI technique in the posttreatment setting is similar to that described for preoperative staging regardless of whether the patient has undergone radical cystectomy, transurethral resection, or systemic therapy., MRI can evaluate therapeutic response, detect recurrence, and help optimize patient selection for bladder-sparing therapies [132-134].

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I. SPECIFICATIONS OF THE EXAMINATION

A. 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 [135-138]. MRI is also recommended for local staging of testicular germ cell tumors [136].

Patients are prepared by placing a towel under the scrotum to elevate both testes to a horizontal plane, and the penis is draped along 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 with 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 T1-W gradient-echo
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 sequences are best obtained with echo time (TE) of 100–140 ms to optimize contrast [136]. In-phase and opposed-phase imaging of the scrotum can identify the fat-water interface, help characterize lipomatous lesions, or detect hemosiderin, calcifications, or gas DCE-MRI with 3-D gradient-echo T1-W imaging has been shown to improve characterization of scrotal lesions [139,140]. .

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 [141,142]. 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 [143].

I. SPECIFICATIONS OF THE EXAMINATION

A. Examination Technique:

2. Penis

MRI is a sensitive imaging modality for the assessment of penile pathology, including neoplasms [144,145]. 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, ideally along the midline for imaging slice orientation. 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 [146,147]. Suggested sequences include the following:

i. Three-plane orthogonal high-resolution T2-W FSE (optional fat suppression in one plane)
ii. Axial T1-W
iii. DCE fat-suppressed 3-D T1-W gradient-echo

High spatial resolution T2-W sequence (3–4 mm) provides excellent contrast resolution between the hypointense tunica albuginea and hyperintense corpora and urethra. Artificial erection by intracavernous injection of prostaglandins or combinations, originally implemented to improve the definition of the tunica albuginea and corpora, is now rarely used given the risk of priapism and more recent evidence showing lack of a clear benefit over evaluation without erection [148,149]. Osseous structures can be assessed with a T1-W sequence and inguinal lymph nodes can be evaluated 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

I. SPECIFICATIONS OF THE EXAMINATION

A. Technical Advances:

Fat-suppressed T2-W images are sensitive to edema, inflammation, and abscess formation [150]. The use of negative or biphasic endoluminal bowel-contrast agents reduce the SI in the bowel lumen on T2-W images, thereby increasing the conspicuity of high signal inflammation and abscess [151]. DWI may assist in the differentiation between cystic lesions and abscesses [152,153].

I. SPECIFICATIONS OF THE EXAMINATION

B. 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 [154].

MRI is performed with a pelvic phased array coil. Suggested sequences include the following [155]:
i. Three-plane or fat-suppressed 3-D T2-W FSE to highlight inflammation and/or edema
ii. Axial T1-W
iii. Axial precontrast and dynamic postcontrast fat-suppressed 3-D T1-W gradient echo
iv. 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 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 [156]. Gas may cause blooming artifact on dual-echo gradient-echo in-phase images (longer TE images) [157]. MR shows inflammation as enhancement on T1-W contrast-enhanced scans and edema as fluid signal on fat-suppressed T2-W images [73]. In the acute setting, an abscess may show high signal on high b-value DWI and restricted diffusion on the ADC map[158]. 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 [159,160].

Urinomas can result from obstructive uropathy, trauma, or surgery, or may occur iatrogenically after instrumentation [159]. MRI does not play a role in acute urinary tract injuries [161], 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 are usually a complication of lymphadenectomy after extraperitoneal surgical procedures rather than intraperitoneal procedures because the peritoneum helps to absorb lymph [162], preventing lymphocele formation. These collections may be managed by catheter drainage with or without sclerotherapy [158]. Uncomplicated lymphoceles are unilocular with fluid signal and thin or imperceptible walls [162] on all MR sequences and are located in the distribution of previous lymph node dissection [163].

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 because it is more sensitive to injury. Chronic radiation enteropathy occurring 1–2 years after completion of radiation therapy [164] usually presents with bowel obstruction due to stricture formation with findings of 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). T1-W sequences may depict loss of definition of muscle layers [165]. Fistulas may form secondary to radiation injury with tissue breakdown [166].

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 Fast Imaging Employing Steady-state Acquisition [FIESTA] or true Fast Imaging with Steady-state Precession [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 [167]. For more information, see the ACR–SAR–SPR Practice Parameter for the

Performance of Magnetic Resonance (MR) Enterography [168].

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. Multiplanar T2-W images depict fistulas as high signal due to fluid content, and fat suppression techniques in at least one plane improves detection of edema and inflammation [169]. Air-filled tracts produce low SI on all MR pulse sequences [170]. Postcontrast 3-D T1-W sequences help to depict hypervascular fistula walls and possible associated abscess and/or malignancy.

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 [170].

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I. SPECFICATIONS OF THE EXAMINATION

A. Technical Advances

DWI increases the diagnostic performance of MRI in evaluating pregnant patients with abdominal pain, particularly with regard to appendicitis [171-174]. Furthermore, abbreviated MR protocols solely comprised of DWI and T2-W SSFSE images can decrease MR imaging and interpretation times in emergency department patients suspected of appendicitis [175].

I. SPECFICATIONS OF THE EXAMINATION

B. Examination Technique:

Please also refer to the ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging Acute lower abdominal pain in pregnancy may be caused by gastrointestinal, gynecologic, or genitourinary entities. In pregnancy the most common nonobstetric cause of acute abdominal pain and the most frequent nonobstetric surgical indication is acute appendicitis [176-178]. Other common etiologies of lower abdominal pain include degenerating fibroids and significant hydronephrosis [177].

US remains the initial imaging modality for evaluating pregnant patients with lower abdominal or pelvic pain.[176- 183].[184-186].

While 3T magnets are FDA approved for imaging of pregnant patients, 1.5T magnets are preferred to decrease specific absorption rates [180]. Patients can be imaged in the supine or left lateral decubitus position using a multicoil array and a large FOV. Oral contrast is not needed [187].

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: DWI with ADC maps
v. Optional: Axial 2-D time-of-flight (TOF)
vi. Optional: Orthogonal T2-W fast imaging with steady-state free precession images
vii. Optional: Fat-suppressed 3-D T1-W gradient echo

(See the ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients with Ionizing Radiation [3].)

I. SPECFICATIONS OF THE EXAMINATION

B. Examination Technique:

1. Gastrointestinal Disease

MRI features of acute appendicitis include a fluid-filled, dilated (≥ 7 mm) appendix with a thickened (≥ 2 mm) wall, periappendiceal inflammation and fluid [178,180]. The inflamed appendix shows increased SI on DWI and decreased SI on ADC maps, with low SI in the periappendiceal tissues on ADC maps suggesting complicated

appendicitis [171,173]. As the appendix may be displaced superiorly by the enlarging uterus, sagittal T2-W can assist in localizing the appendiceal location on MRI by noting the cecal tilt angle [188]. 2-D TOF imaging can help distinguish the appendix from adjacent engorged gonadal vessels [178].

Multiplanar T2-W images are helpful in diagnosing other gastrointestinal tract disorders in pregnancy. Small bowel obstruction severity and transition point location can be readily assessed on T2-W imaging without IV or oral contrast material [189].[190].

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 [190]. 2-D TOF imaging can help distinguish the appendix from adjacent engorged gonadal vessels.

I. SPECFICATIONS OF THE EXAMINATION

B. Examination Technique:

2. Gynecologic Disease

Fibroids may be a source of acute pain during pregnancy owing to rapid growth, degeneration, or torsion. High SI on T2-W and DWI in the fibroid suggests interstitial edema, the initial sign of fibroid degeneration. Red or carneous degeneration which can be seen in pregnancy typically appears as diffuse or peripheral high SI on T1-W images with central high SI on T2-W images and restricted diffusion [178,191].

Adnexal and pelvic masses can be challenging to characterize in pregnancy with US alone. MRI can be used as a problem-solving technique to delineate the origin of the mass as uterine or adnexal and can diagnose ovarian mature cystic teratomas and endometriomas with confidence. Ovarian torsion can be readily apparent on fat suppressed T2-W images, appearing as an asymmetrically enlarged and edematous ovary with peripherally displaced follicles [192]. An edematous twisted pedicle, a specific sign of torsion, may be identified on T2-W images. As the torsion progresses, adnexal hemorrhage, which can be seen as high SI on T1-W imaging, can indicate hemorrhagic infarction and necrosis [193,194].

A twisted pedicle, though specific, is not commonly identified.

I. SPECFICATIONS OF THE EXAMINATION

B. Examination Technique:

3. Genitourinary Disease

Physiologic hydronephrosis in pregnancy can be differentiated from obstruction by noting smooth tapering and extrinsic compression of the distal ureter by the gravid uterus upon the iliopsoas muscle. Dilatation of the ureter distal to the sacral promontory is suspicious for pathologic obstruction such as from a ureterovesical calculus. Obstructing ureteral calculi appear as filling defects on T2-W or steady-state free precession imaging and are associated with perinephric and periureteral edema [178,195]. Pyelonephritis may appear as heterogeneous SI in the kidney on T2-W images with perinephric fluid and results in lower ADC values compared with normal renal cortex [195,196]. Cystitis can present as bladder wall thickening and should be strongly suspected when nondependent signal voids suggesting air in the bladder are depicted in the absence of instrumentation [178].

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Section 8. Identification and Classification of Perianal Fistulas

For parameters on performance of MRI for abscess, section 6, Evaluation of Complications Following Pelvic Surgery, Including Abscess, Urinoma, Lymphocele, Radiation Enteritis, and Fistula Formation

I. SPECIFICATIONS OF THE EXAMINATION

A. Technical Advances

Multiplanar assessment is essential for the evaluation of perianal fistulas. Oblique axial and coronal images perpendicular and parallel to the long axis of the anal canal allow correct evaluation of the anal canal anatomy over straight axial and coronal images [197].

I. SPECIFICATIONS OF THE EXAMINATION

B. Examination Technique

MR images offer high soft-tissue resolution to evaluate complex branching tracts and fistula extension. 1.5T and 3T MRI scanners are used to image patients with perianal fistulous disease using a pelvic phased array coil. Imaging with a pelvic phased array coil is standard practice that results in high accuracy for detecting perianal fistulas [198-201]. This is especially true for patients with Crohn disease who are prone to distant fistulous extensions and abscesses. Some centers have used an endoluminal coil alone or in combination with an external coil and reported good imaging results, but endoluminal coils are not routinely used [202]. Endorectal coil insertion is not well tolerated in a number of patients due to pain, and visualization of secondary tracts remote from the anal sphincter is limited.

Suggested sequences include [203,204] 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 and oblique coronal T2-W FSE
iii. Oblique axial fat-suppressed T2-W FSE
iv. Oblique axial fat-suppressed T1-W
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: STIR images
viii. Optional: DWI with ADC maps

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 [205,206].

MRI is superior to digital rectal examination and anal endosonography in classifying fistulous tracts and identifying their internal opening [207,208]. 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 [209,210]. The most accepted MRI fistula classification system is the St. James University Hospital classification [211], which is a modification of the Parks classification [212].

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 short tau inversion recovery (STIR) images, linear fistulas and their complications (secondary tracts and/or abscesses) have high SI compared to surrounding structures. Fat-suppressed T2-W and STIR images are used to assess for inflammation, edema, and fluid-containing tracts and cavities. Using contrast increases the conspicuity of the fistulous tracts and abscess cavity walls. T2-W FSE images with fat saturation may be an alternative to postcontrast T1-W fat-saturated imaging for assessment of the primary fistula and secondary complications [213,214]; IV contrast, however, is helpful in abscess cavity delineation. DWI may improve diagnostic confidence as an adjunct to T2-W images in patients with a contraindication to IV contrast [215].

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I. SPECIFICATIONS OF THE EXAMINATION

A. 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 [53]. When evaluating nonpalpable undescended testes, DWI is complementary to conventional imaging [216]. High-resolution images of the seminal vesicles can be obtained by acquiring images on a 3T system.

I. SPECIFICATIONS OF THE EXAMINATION

B. 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 [217,218], MRI is the most accurate modality to characterize and classify MDAs [219]. Mullerian anomaly assessment before puberty can be difficult due to the lack of defined uterine zonal anatomy. Thus, assessment is usually performed when patients are postmenarchal and hormonal stimulation has induced improved uterine zonal delineation, improving uterine assessment [220]. In young patients who are not sexually active, MRI with its nearly 100% accuracy may be performed rather than the more invasive transvaginal US [221,222]. Hysterosalpingography and hysterosalpingo contrast sonography are best suited to evaluate synechiae and fallopian tube patency. However, these examinations are more invasive than MRI and do not assess for possible urinary tract anomalies.

The American Society of Reproductive Medicine classification system is the most widely used classification system and has been modified and expanded in 2021 from its 1988 version [223]. Accurate classification is critical as treatments vary by subtype, thus underscoring the role of diagnostic imaging. A comprehensive MRI examination performed either on a 1.5T or 3T scanner evaluates the uterine corpus, uterine cervix, vagina, and adnexa [224]. Vaginal gel insertion for adult patients may aid in evaluating cervical and/or vaginal involvement, such as a vaginal septum [225]. 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 before imaging decreases artifacts from bowel peristalsis; alternatively, buscopan or glucagon may be administered if not contraindicated. Patients should void before the examination to reduce motion and ghosting artifacts from a distended bladder [222].

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 for retrospective multiplanar reformation in the desired planes
ii. Sagittal T2-W FSE
iii. Axial T1-W with and without fat suppression
iv. Coronal large FOV T2-W SSFSE that includes the renal fossae
v. 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
vi. Optional: T2-W FSE with vaginal gel to define the vaginal canal and/or cervix
vii. Optional: T2-W FSE that includes the abdomen in patients with DSD for presurgical planning of prophylactic gonadectomy or surveillance in those who choose gonad preservation
viii. Optional: DWI can help identify and characterize the gonads in patients with DSD

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, thereby resulting in the development of the uterus and the proximal two-thirds of the

vagina. 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 allow for uterine zonal anatomy delineation and assessment for anomalous communication between the two cavities [222]. The T2-W sagittal sequence allows for vaginal length assessment. T1-W images allow diagnosis of concomitant hematometra and/or endometriosis that may accompany certain MDAs. Finally, a large FOV coronal image assesses for renal abnormalities that often accompany MDAs.

I. SPECIFICATIONS OF THE EXAMINATION

B. Examination Technique

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 [226]. 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 [227,228] the following with the penis taped to the anterior abdominal wall and a small towel placed between the thighs to stabilize the testes:

i. Three-plane T2-W
ii. Axial T1-W
iii. Orthogonal contrast-enhanced T1-W images may be performed in complicated cases (eg, proteinaceous cyst)
iv. DWI can help in evaluating spermatogenesis
v. Optional: Coronal large FOV T2-W SSFSE that includes renal fossae

I. SPECIFICATIONS OF THE EXAMINATION

B. Examination Technique

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 [229]. US is often the initial modality in the workup of a nonpalpable testis and has moderate success [230]; however, a meta-analysis found that US rarely impacts treatment while at the same time increases health care costs [231]. MRI is usually reserved for patients with nondiagnostic US to help localize abdomino-pelvic or inguinal locations of the testes and possible complications of cryptorchidism, including torsion and malignancy [232].

Sequences include the following:

1. Axial and coronal T1-W images
2. Axial T2-W images
3. Axial and coronal T2-W fat-suppressed images to include the abdomen to assist in locating the testes in cryptorchidism

4. Optional: Orthogonal contrast-enhanced T1-W images may increase conspicuity of the nonpalpable testis
5. Optional: Axial high b-value single-shot spin-echo echoplanar images with chemical shift selective fat suppression to assess for possible malignancy

The nonpalpable testis is typically hypointense to muscle on T1-W images, hyperintense to muscle on T2-W images, 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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