Chapter 1
Pelvis MRI: introduction and technique

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Imaging evaluation of the female pelvis

- Imaging plays an important role in the management of gynecological disease
- Ultrasound is often the initial imaging test
- Poor tissue contrast of CT limits gynecologic applications
- MRI benefits from excellent tissue contrast and lack of ionizing radiation
- Increased experience and availability have led to increased role of MRI
- MRI deemed appropriate by American College of Radiology for gynecological conditions, especially pre-treatment assessment of endometrial and cervical cancer, work-up of suspected adnexal mass, and evaluation of acute pelvic pain in reproductive-aged women in the setting of indeterminate ultrasound [1–4]
- Numerous gynecological and obstetric conditions are depicted by MRI, which may provide initial imaging (e.g., suspected urethral diverticulum) or problem-solving after ultrasound

Indications for MRI

(Table 1.1)

- **Benign uterine conditions**
  - Anomalies
    - MRI considered imaging modality of choice
    - Informs management decisions (e.g., septate versus bicornuate uterus)
  - Acquired disease
    - Problem solving for indeterminate ultrasound
    - MRI allows definitive diagnosis for conditions such as urethral diverticulum, leiomyoma, adenomyosis, endometriosis, and dermoid
- **Uterine malignancy**
  - Endometrial cancer
    - Preoperative staging: deep myometrial invasion correlated with lymph node invasion [5, 6]
    - MRI shown to aid management for advanced and high grade cancer [7]
  - Cervical carcinoma
    - Depth of stromal and parametrial invasion [8, 9]
    - MRI particularly aids management for
      - Tumors larger than 2 cm
      - Endocervical tumors [10]
      - Biopsy-proved adenocarcinoma (cervical versus endometrial origin)
      - Coexistent pelvic mass(es)
      - New diagnosis of cervical cancer during pregnancy
      - Prior radiation therapy [11–15]
- **Adnexal mass**
  - Determine origin of mass
  - Tissue characterization aids specific diagnosis (e.g., endometrioma, dermoid)
  - MRI helps predict likelihood of malignancy to direct proper management and limit surgical intervention for benign disease [16, 17]
  - For known ovarian cancer, CT typically used for staging; MRI if CT contraindicated
  - MRI may yield definitive diagnosis for adnexal disease that is indeterminate on ultrasound, obviating need for follow-up imaging
- **Abdominal pain in pregnancy**
  - Accurate evaluation for appendicitis (and other acute diseases) without ionizing radiation [18, 19]
  - Increasing availability of MRI in acute setting
- **Fetal anomalies**
  - Problem solving for indeterminate ultrasound
  - Usefulness of MRI has increased with ultrafast sequences

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Table 1.1. Indications for MRI of the female pelvis

Indication	Protocol	Notes
Pelvic pain	General	FS T1WI for endometriosis
Urethral diverticulm	Urethra	Contrast if known/visualized mass
Vaginal mass	Urethra	Contrast if known/visualized mass
Pelvic floor symptoms	Pelvic floor	Sagittal images with Valsalva
Uterine anomaly	Uterine anomaly	True coronal to uterine fundus
Adenomyosis	General	Bright myometrial foci on T2WI
Fibroids	General	Add contrast if pre-embolization
Fibroid versus adnexal mass	General	Vessels extending from uterus to mass suggest uterine origin
Endometrial cancer	Uterine malignancy	High resolution T2WI and T1WI + contrast oblique to endometrium for tumor invasion
Cervical cancer	Uterine malignancy	High resolution T2WI oblique to cervix for parametrial invasion
Adnexal mass characterization	General	FS T1WI for dermoid, endometrioma
Abdominal pain in pregnancy	Maternal abdominal pain	SS-ETSE (+ FS), and steady-state GE for appendix, monitor if possible
Fetal anomaly	Fetal	SS-ETSE oriented to region of interest, monitor if possible

FS = fat saturated; T1WI = T1-weighted images; T2WI = T2-weighted images; SS = single shot; ETSE = echo-train spin-echo; GE = gradient echo

Patient preparation for MRI

- Empty bladder
- Fasting 4 hours
- Optional
  - Antispasmotic (e.g., glucagon 1 mg)
  - Intra-vaginal gel [20]
- Supine position, or decubitus in late pregnancy
- Phased-array coil positioned over pelvis
- To reduce artifact, may utilize
  - Saturation band over anterior abdominal wall for non-fat-saturated sagittal
  - Supplemental anteroposterior frequency-encoding direction for axial images
- Intrauterine contraceptive devices are safely imaged [21]

Sequence protocols

- Many protocol options
- Appropriate choice depends on
  - Specific clinical question
  - Available equipment and expertise
- For known or suspected uterine disease/anomalies, T2-weighted sequences are obtained in an oblique plane oriented to uterus (Figure 1.1)
- Individual sequence parameters may vary based on manufacturer, etc.
- Sequences may include
  - Single-shot (SS) echo-train spin echo (ETSE)
    - For example, HASTE or SSFSE
    - Sensitive to fluid, resistant to motion and susceptibility
    - Large field of view
      - Localization, evaluation of coil position
      - Coronal: evaluation of renal anomalies/obstruction
      - Axial: prescribe true sagittal view of uterus
  - T2-weighted
    - Breathhold may be sufficient for benign disease
    - Non-breathhold (high-resolution) for uterine malignancy
    - With or without fat saturation
    - May be done as 3D ETSE
    - Best sequence for uterine zonal anatomy
  - T1-weighted

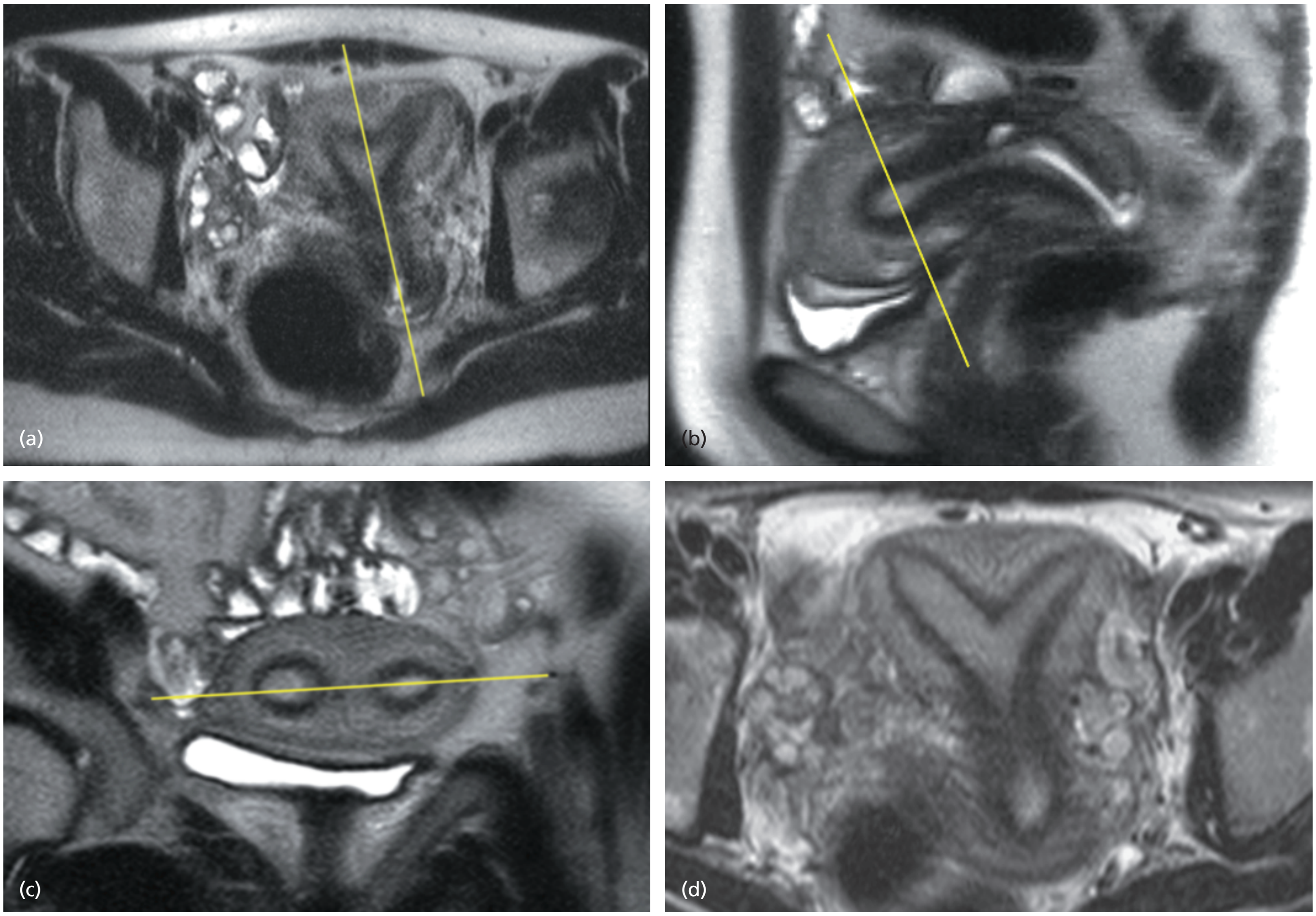

Figure 1.1. Imaging planes oriented to the uterus. Multiple T2-weighted images in a patient with septate uterus. Large field-of-view single-shot sequence **(a)** is obtained first and is used to plan an oblique sagittal T2-weighted sequence **(b)** obtained parallel to the endometrium (line, **a**). The oblique sagittal is used to plan an oblique axial **(c)** obtained perpendicular to the endometrium (line, **b**). The oblique axial may then be used to plan a true coronal of the uterus **(d)** obtained parallel to the endometrium (line, **c**). In the absence of 3D T2-weighted imaging, this process assures appropriate imaging planes regardless of angle/tilt of the uterus.

        - Breathhold in- and out-of-phase dual echo
            - Differentiates fat- and blood-containing lesions
            - Sensitive to small foci of fat within adnexal mass
        - Non-breathhold (high-resolution) for uterine cancer
        - Chemically selective fat saturation for endometriosis
    - T2/T1-weighted steady-state free precession gradient echo (GE)
        - For example, TruFISP or FIESTA
        - Rapid, resistant to motion
        - Differentiates vessels from bowel (e.g., appendix)
        - Useful for fetal and maternal imaging
    - T1-weighted 3D GE pre- and post-contrast
        - Fat-suppressed GE, repeated for dynamic imaging
        - Provides enhancement information
        - May use MRA parameters (e.g., vascular malformation)
    - Diffusion-weighted imaging (DWI) (optional)
        - B values of 0 and at least one other value up to 1000
        - Apparent diffusion coefficient (ADC) map created
        - DWI sequence and ADC map interpreted together
        - Aids detection of tumor, inflammation

    - Additional functional techniques may have increasing role [7]
- Oblique planes oriented to the endometrium or cervix important for cancer [22]
- Protocol tailored to clinical question (Table 1.2, Table 1.3, Table 1.4, Table 1.5, Table 1.6, Table 1.7, Table 1.8)

Table 1.2. General female pelvis

Sequence	Plane	FOV (cm)	Slice thickness (mm)
SS-ETSE	Coronal	32	8
SS-ETSE	Axial	32	8
T2 ETSE	Sagittal	24	5
T2 ETSE	Axial	24	5
T1 GE in/out- of-phase	Axial	24	5
T1 GE FS	Axial	24	5
DWI (optional)	Axial	28	6
T1 3D GE FS (pre)	Axial or sagittal	24	3
Contrast			
T1 3D GE FS (post × 3)	Axial or sagittal	24	3
T1 GE FS (delayed)	Axial	24	5

SS = single shot; ETSE = echo-train spin-echo; GE = gradient echo; FS = fat saturated; DWI = diffusion-weighted imaging

Table 1.3. Urethra

Sequence	Plane	FOV (cm)	Slice thickness (mm)
SS-ETSE	Coronal	32	8
T2 ETSE	Coronal	16	4
T2 ETSE	Axial	16	4
T1 GE	Axial	16	4
T1 3D GE FS (pre)	Axial	24	3
Contrast (if known or visualized lesion)			
T1 GE FS (delayed)	Axial	24	3

SS = single shot; ETSE = echo-train spin-echo; GE = gradient echo; FS = fat saturated

Table 1.4. Pelvic floor

Sequence	Plane	FOV (cm)	Slice thickness (mm)
SS-ETSE	Coronal	32	8
SS-ETSE	Axial	32	8
SS-ETSE	Sagittal	32	5
SS-ETSE (Valsalva, repeat × 3)	Sagittal	32	5 (midline slice)

SS = single shot; ETSE = echo-train spin-echo

Table 1.5. Uterine anomaly

Sequence	Plane	FOV (cm)	Slice thickness (mm)
SS-ETSE	Coronal	32	8
SS-ETSE	Axial	32	8
T2 ETSE	Sagittal (to uterus)	24	5
T2 ETSE	Axial (to uterus)	24	5
T2 ETSE	Coronal (to uterus)	24	5
T1 GE in/ out-of-phase	Coronal (to uterus)	24	5
T1 GE FS	Axial	24	5

SS = single shot; ETSE = echo-train spin-echo; GE = gradient echo; FS = fat saturated

Table 1.6. Uterine malignancy

Sequence	Plane	FOV (cm)	Slice thickness (mm)
SS-ETSE	Coronal	32	8
SS-ETSE	Axial	32	8
T2 ETSE	Sagittal	24	5
T2 ETSE	Axial	24	5
T1 GE in/out-of-phase	Axial	24	5
T1 GE FS	Axial	24	5
DWI (optional)	Axial	28	6
T1 3D GE FS (pre)	Axial or sagittal	24	3
Contrast			
T1 3D GE FS (post × 3)	Axial or sagittal	24	3
T1 GE FS (delayed)	Axial	24	5

SS = single shot; ETSE = echo-train spin-echo; GE = gradient echo; FS = fat saturated

Table 1.7. Maternal abdominal pain

Sequence	Plane	FOV (cm)	Slice thickness (mm)
SS-ETSE	Coronal	32–40	8
SS-ETSE	Axial	32	5
SS-ETSE FS	Axial	32	5
Steady-state GE	Coronal	32	5
Steady-state GE	Axial	32	5
T1 GE in/out-of-phase	Axial	32	5

SS = single shot; ETSE = echo-train spin-echo; GE = gradient echo; FS = fat saturated

Table 1.8. Fetal

Sequence	Plane	FOV (cm)	Slice thickness (mm)
SS-ETSE	Coronal	40	8
SS-ETSE	Axial	40	8
SS-ETSE	Sagittal	40	8
SS-ETSE (repeat as needed)	Directed	24–32	4–6
Steady-state GE (optional)	Directed	24–32	4–6
T1 GE in/out-of-phase (optional)	Directed	24–32	4–6

SS = single shot; ETSE = echo-train spin-echo; GE = gradient echo; FS = fat saturated

Image optimization at 3T

- Potential advantages
  - Increase in signal-to-noise ratio (SNR), or
  - Similar SNR at a faster speed
- Challenges
  - Signal shading magnified by dielectric effects
  - Increased specific absorption rates (SARs)
  - Changes in optimal TR and TE
  - Increased signal inhomogeneities
    - Greater shimming challenge for extrinsic magnetic field
    - Intrinsic field distortion due to increased susceptibility/chemical shift
- Solutions [23–28]
  - Dialectric effect: dialectric pad (= radiofrequency cushion) placed between patient and surface coil
  - Susceptibility: use shorter TE/higher receiver bandwidth, higher spatial resolution
  - 3D GE and ETSE sequences may benefit from higher field strength
  - Consider individual patient
    - Pregnant patients less suitable for 3T due to standing wave effects from amniotic fluid and safety concerns [26]
    - Non-pregnant patients may be imaged safely and effectively at 3T using optimized parameters [28]

Image interpretation

- Large volume data acquisition
- May be useful to employ a systematic checklist (Table 1.9)
- Several gynecological conditions have MRI features that allow definitive diagnosis

Table 1.9. Diagnostic checklist for female pelvis MRI

Structure	MRI features evaluated
Gynecological	
Uterine corpus	Size and position
	Presence of myometrial mass
	Endometrium thickness
	Junctional zone thickness
Cervix	Presence of cystic mass
	Presence of solid tumor
	Size of lesion
	Parametrial involvement
Vagina	Presence of cystic mass
	Presence of wall thickening/solid tumor
Adnexa	Ovarian size
	Presence of ovarian mass
	Cystic or solid
	Fat containing
	Blood containing
	Enhancement features
	Unilateral or bilateral
	Paraovarian cystic or solid mass
Non-gynecological	
Bladder	Presence of solid mass
	Presence of cystocele
Urethra	Presence of diverticulum
	Size and configuration
	Solid/enhancing components
	Presence of hypermobility
Bowel	Caliber
	Presence of rectocele
Musculoskeletal	Bone marrow signal
	Degenerative changes
	Traumatic injury
Lymphatic	Enlarged lymph nodes

References

1. Lee, J.H., Dubinsky, T., Andreotti, R.F., et al. ACR Appropriateness Criteria(R) pretreatment evaluation and follow-up of endometrial cancer of the uterus. *Ultrasound Quarterly* 2011; 27(2):139–45.
2. Siegel, C.L., Andreotti, R.F., Cardenes, H.R., et al. ACR Appropriateness Criteria(R) pretreatment planning of invasive cancer of the cervix. *Journal of the American College of Radiology* 2012; 9(6):395–402.
3. Harris, R.D., Javitt, M.C., Glanc, P., et al. ACR Appropriateness Criteria(R) clinically suspected adnexal mass. *Ultrasound Quarterly* 2013; 29(1):79–86.
4. Andreotti, R.F., Lee, S.I., Dejesus Allison, S.O., et al. ACR Appropriateness Criteria(R) acute pelvic pain in the reproductive age group. *Ultrasound Quarterly* 2011; 27(3): 205–10.
5. Kinkel, K., Kaji, Y., Yu, K.K., et al. Radiologic staging in patients with endometrial cancer: a meta-analysis. *Radiology* 1999; 212(3):711–18.
6. Wakefield, J.C., Downey, K., Kyriazi, S., deSouza, N.M. New MR techniques in gynecologic cancer. *AJR. American Journal of Roentgenology* 2013; 200(2):249–60
7. Frei, K.A., Kinkel, K., Bonél, H.M., et al. Prediction of deep myometrial invasion in patients with endometrial cancer: clinical utility of contrast-enhanced MR imaging – a meta-analysis and Bayesian analysis. *Radiology* 2000; 216(2): 444–9.
8. Sironi, S., De Cobelli, F., Scarfone, G., et al. Carcinoma of the cervix: value of plain and gadolinium-enhanced MR imaging in assessing degree of invasiveness. *Radiology* 1993; 188(3):780–97.
9. Subak, L.L., Hricak, H., Powell, C.B., Azizi, L., Stern, J.L. Cervical carcinoma: computed tomography and magnetic resonance imaging for preoperative staging. *Obstetrics and Gynecology* 1995; 86(1):43–50.
10. Hricak, H., Powell, C.B., Yu, K.K., et al. Invasive cervical carcinoma: role of MR imaging in pretreatment work-up – cost minimization and diagnostic efficacy analysis. *Radiology* 1996; 198(2):403–9.
11. Flueckiger, F., Ebner, F., Poschauko, H., et al. Cervical cancer: serial MR imaging before and after primary radiation therapy – a 2-year follow-up study. *Radiology* 1992; 184(1):89–93.
12. Hricak, H., Swift, P.S., Campos, Z., et al. Irradiation of the cervix uteri: value of unenhanced and contrast-enhanced MR imaging. *Radiology* 1993; 189(2):381–8.
13. Weber, T.M., Sostman, H.D., Spritzer, C.E., et al. Cervical carcinoma: determination of recurrent tumor extent versus radiation changes with MR imaging. *Radiology* 1995; 194(1):135–9.
14. Yamashita, Y., Harada, M., Torashima, M., et al. Dynamic MR imaging of recurrent postoperative cervical cancer. *Journal of Magnetic Resonance Imaging* 1996; 6(1): 167–71.
15. Hertel, H., Köhler, C., Grund, D., et al. Radical vaginal trachelectomy (RVT) combined with laparoscopic pelvic lymphadenectomy: prospective multicenter study of 100 patients with early cervical cancer. *Gynecologic Oncology* 2006; 103(2): 506–11.

16. Hricak, H., Chen, M., Coakley, F.V., et al. Complex adnexal masses: detection and characterization with MR imaging – multivariate analysis. *Radiology* 2000; 214(1):39–46.
17. Sohaib, S.A., Sahdev, A., Van Trappen, P., Jacobs, I.J., Reznek, R.H. Characterization of adnexal mass lesions on MR imaging. *AJR. American Journal of Roentgenology* 2003; 180(5):1297–304.
18. Birchard, K.R., Brown, M.A., Hyslop, W.B., Firat, Z., Semelka, R.C. MRI of acute abdominal and pelvic pain in pregnant patients. *AJR. American Journal of Roentgenology* 2005; 184(2):452–8.
19. Oto, A., Ernst, R.D., Shah, R., et al. Right-lower-quadrant pain and suspected appendicitis in pregnant women: evaluation with MR imaging – initial experience. *Radiology* 2005; 234(2):445–51.
20. Brown, M.A., Mattrey, R.F., Stamato, S., Sirlin, C.B. MRI of the female pelvis using vaginal gel. *AJR. American Journal of Roentgenology* 2005; 185(5):1221–7.
21. Pasquale, S.A., Russer, T.J., Foldesy, R., Mezrich, R.S. Lack of interaction between magnetic resonance imaging and the copper-T380A IUD. *Contraception* 1997; 55(3): 169–73.
22. Shiraiwa, M., Joja, I., Asakawa, T., et al. Cervical carcinoma: efficacy of thin-section oblique axial T2-weighted images for evaluating parametrial invasion. *Abdominal Imaging* 1999; 24(5): 514–19.
23. Kataoka, M., Kido, A., Koyama, T., et al. MRI of the female pelvis at 3T compared to 1.5T: evaluation on high-resolution T2-weighted and HASTE images. *Journal of Magnetic Resonance Imaging* 2007; 25(3): 527–34.
24. Martin, D.R., Friel, H.T., Danrad, R., De Becker, J., Hussain, S.M. Approach to abdominal imaging at 1.5 Tesla and optimization at 3 Tesla. *Magnetic Resonance Imaging Clinics of North America* 2005; 13(2):241–54.
25. Hussain, S.M., van den Bos, I.C., Oliveto, J.M., Martin, D.R. MR imaging of the female pelvis at 3T. *Magnetic Resonance Imaging Clinics of North America* 2006; 14(4):537–44.
26. Merkle, E.M., Dale, B.M. Abdominal MRI at 3.0 T: the basics revisited. *AJR. American Journal of Roentgenology* 2006; 186(6):1524–32.
27. Cornfeld, D., Weinreb, J. Simple changes to 1.5-T MRI abdomen and pelvis protocols to optimize resuts at 3T. *AJR. American Journal of Roentgenology* 2008; 190(2): W140–50.
28. Morakkabati-Spitz, N., Schild, H.H., Kuhl, C.K., et al. Female pelvis: MR imaging at 3.0 T with sensitivity encoding and flip-angle sweep technique. *Radiology* 2006; 241(2): 538–45.