AJR WOMEN'S IMAGING

MRI of Malignant Neoplasms of the Uterine Corpus and Cervix

Evis Sala[1]
Suzanne Wakely
Emma Senior
David Lomas

OBJECTIVE. In this article, we review the role of MRI in the imaging of malignant neoplasms of the uterine corpus and cervix, describing its role in staging, treatment planning, and follow-up.

CONCLUSION. MRI is not officially incorporated in the International Federation of Gynecology and Obstetrics (FIGO) staging system, but is already widely accepted as the most reliable imaging technique for the diagnosis, staging, treatment planning, and follow-up of both endometrial and cervical cancer. MRI protocols need to be optimized to obtain the best results and avoid pitfalls.

The role of MRI in gynecologic oncology has evolved during the past two decades. There is now a substantial body of evidence that MRI is useful in evaluating malignant conditions of the pelvis [1, 2]. MRI has been shown to be superior to CT in staging of endometrial and cervical carcinoma. In addition, there is evidence that MRI may aid in differentiating radiation fibrosis from recurrent tumor [3]. The accuracy of MRI assessment of lymph nodes is similar to that of CT; both rely on size criteria to detect the presence of metastases [4]. However, more recently, lymph node–specific contrast agents have emerged as useful tools for determining the presence of metastases in the lymph nodes [5].

MRI has been shown to minimize costs in some clinical settings by limiting or eliminating the need for further expensive or more invasive diagnostic or surgical procedures [6, 7]. In this article, we review the role of MRI in staging, treatment planning, and follow-up of malignant neoplasms of the uterine corpus and cervix.

Malignant Neoplasms of the Uterine Corpus

Adenocarcinomas arise from the uterine epithelium and constitute 90% of endometrial cancers. The remaining histologic types of endometrial carcinoma include adenocarcinoma with squamous differentiation, adenosquamous carcinoma, clear cell carcinoma, and papillary serous carcinoma. Uterine sarcomas are rare tumors of mesenchymal origin accounting for 2–6% of all uterine malignant tumors [8]. The most common histologic variants are endometrial stromal sarcoma, mixed müllerian tumors, and leiomyosarcoma. Primary uterine lymphoma is very rare, occurring in only 1% of patients with lymphoma. Metastases to the uterus from nongynecologic neoplasms are rare, with breast and the gastrointestinal tract being the two most common primary sites.

Endometrial Carcinoma

Endometrial carcinoma is the fourth most common female cancer and the most common malignancy of the female reproductive tract [9]. In 2007, 39,080 new cases and 7,400 deaths are expected in the United States [9]. The incidence is rising because of increased life expectancy and obesity. Five-year survival rates vary between 96% for stage I disease and 25% for stage IV disease [9]. The prognosis of women with endometrial carcinoma depends on a number of factors, including stage, depth of myometrial invasion, lymphovascular invasion, nodal status, and histologic grade [10]. Preoperative evaluation of these prognostic factors helps in subspecialist treatment planning [11].

MRI Protocol

Imaging technique and patient preparation are important to obtain optimal results. Patients are usually instructed to fast for 4–6 hours before the MRI examination to limit artifact due to small-bowel peristalsis. An antiperistaltic agent (hyoscine butyl bromide or

Keywords: dynamic MRI, genitourinary tract imaging, gynecologic oncology, MRI, oncologic imaging, women's imaging

DOI:10.2214/AJR.06.1196

Received September 7, 2006; accepted after revision January 26, 2007.

[1]All authors: Department of Radiology, Addenbrooke's Hospital, University of Cambridge, Hills Rd., Cambridge CB2 2QQ, United Kingdom. Address correspondence to E. Sala (es220@radiol.cam.ac.uk).

CME
This article is available for CME credit. See www.arrs.org for more information.

AJR 2007; 188:1577–1587

0361–803X/07/1886–1577

TABLE 1: Pearls and Pitfalls of MRI for Staging of Carcinoma of the Endometrium and Cervix

Carcinoma	Pearls	Pitfalls
Endometrium	Dynamic multiphase contrast-enhanced 3D T1-weighted imaging is more accurate than T2-weighted imaging for the assessment of the depth of myometrial invasion	Loss of junctional zone definition; band of subendometrial enhancement seen in only 50–60% of cases
	Early phases better to visualize subendometrial enhancement band (stage IA vs IB)	Distension of endometrial cavity by polypoid tumor compressing myometrium
	Maximum inner–outer myometrium contrast at 1 min (stage IB vs IC)	Poor tumor–myometrium contrast
	Maximum tumor–myometrium contrast at 2–3 min (stage IB vs IC)	Tumor extending to the uterine cornu
	Enhancement of cervical mucosa on delayed images (4–5 min) excludes cervical stroma invasion	Presence of microscopic disease
	Second imaging plane necessary for accurate evaluation of depth of myometrial invasion	Coexisting benign abnormality (e.g., leiomyoma, adenomyosis)
		Congenital uterine anomalies
Cervix	Accurate estimation of tumor size by MRI (within 0.5 cm of measurement at pathology)	Parametria are located lateral and only lateral to the cervix
	Intact low-signal-intensity stromal ring excludes parametrial invasion	Loss of low-signal-intensity stromal ring indicates full stromal but not parametrial invasion
	Recurrent vaginal vault tumor has the same signal intensity as the primary tumor	Overestimation of parametrial invasion on T2-weighted images due to postbiopsy hemorrhage or with large tumors due to stromal edema
	Reconstitution of normal cervical anatomy and low-signal-intensity cervical stroma indicate complete response to radio- or chemotherapy	Early radiation change (within 6 months) and presence of infection may show enhancement
	Dynamic contrast-enhanced MRI improves detection of small tumors and helps in differentiating tumor recurrence from radiation fibrosis	

glucagons) may be administered to the patient before imaging as an alternative to fasting. Ideally, the patient is asked to empty the bladder before going on the MR scanner. A full bladder may degrade T2-weighted images because of ghosting and motion artifacts. Patients are imaged in the supine position using a pelvic surface array multichannel coil.

The basic MRI protocol (Table 1) includes axial T1-weighted spin-echo images with a large field of view to evaluate the entire pelvis and upper abdomen for lymphadenopathy and bone marrow changes; high-resolution T2-weighted fast spin-echo (FSE) images in the axial and sagittal planes for the evaluation of the primary tumor; and dynamic contrast-enhanced T1-weighted images (small field of view) in the sagittal and axial oblique planes to evaluate the extent of myometrial and cervical involvement.

High-resolution T2-weighted FSE sequences perpendicular to the long axis of the uterine corpus are favored for the evaluation of primary tumor and myometrial invasion [12]. Sagittal and oblique axial multiphase IV contrast–enhanced 3D T1-weighted fat-saturated sequences through the uterine corpus are routinely used to improve staging accuracy. The early enhancement phases (0 and 1 minute) allow identification of the subendometrial zone, which enhances earlier than the bulk of the myometrium and corresponds to the inner junctional zone. Identification of this zone is especially important in detecting early myometrial invasion because the junctional zone often becomes indistinct in postmenopausal women [13]. The equilibrium phase (2–3 minutes after injection) allows better evaluation of deep myometrial invasion [14], whereas the delayed phase (4–5 minutes) enables better evaluation of cervical stroma invasion [15]. The tumor–myometrium interface should be assessed in at least two planes.

The Impact of Imaging on Treatment

Endometrial cancer primarily presents at stage I (80% of cases), and the standard treatment is total abdominal hysterectomy and bilateral salpingo-oophorectomy. The clinical challenge is to effectively select patients at risk of relapse for more radical surgery (i.e., radical lymph node resection) and adjuvant treatment and to avoid overtreating low-risk patients. Furthermore, the recent introduction of laparoscopic techniques offers an alternative approach for patients who present with early disease [16, 17].

The major diagnostic factor necessary for the preoperative evaluation of endometrial cancer is to differentiate between stages IA and IB; this is becoming critical with increased use of hormonal treatment for stage IA disease in patients at high-risk for perioperative morbidity.

The risk of lymph node metastasis must be determined to select the appropriate surgical management. Differentiation of stage IB from stage IC has prognostic and morbidity implications. Stage IB patients should undergo lymph node sampling, whereas stage IC patients should undergo radical lymph node resection.

Gross cervical invasion requires preoperative radiation therapy or a different surgical plan—that is, radical hysterectomy instead of total abdominal hysterectomy.

Surgical staging of endometrial carcinoma is intended as the initial treatment and, at the same time, is used to identify patients who may require adjuvant therapy. The depth of myometrial invasion is probably the single most important morphologic prognostic factor because it correlates with tumor grade, tumor extension into the cervix, and the prevalence of lymph node metastases [18, 19]. The incidence of lymph node metastases (pelvic, paraaortic, or both) increases from 3% with superficial myometrial invasion (stage IB) to 46% with deep myometrial invasion (stage IC) [19–21]. Evaluation of the extent of myometrial invasion by gross inspection at surgery or at frozen-section analysis remains inaccurate in a significant proportion of patients [22, 23].

TABLE 2: MRI Protocol for Imaging of Endometrial and Cervical Cancer

Cancer	Sequence	Plane	Reason
Endometrium	T1-weighted (upper abdomen and pelvis)	Axial	Evaluate bone marrow and lymph nodes
	T2-weighted	Axial	Evaluate lymph nodes and provide overview of pelvis
	T2-weighted FSE	Sagittal	Visualize tumor and its relationship with myometrium
	T2-weighted FSE	Axial oblique (short axis)	Evaluate depth of myometrial invasion in a second plane
	T1-weighted (unenhanced and contrast-enhanced) 3D gradient-echo with fat saturation	Sagittal at 0, 1, 3, and 5 min Axial (short axis) at 4 min	Optimize the assessment of superficial (0 and 1 min), deep (3 min) myometrial invasion, cervical extension (5 min) Optimize the assessment of depth of myometrial invasion (4 min) in a second imaging plane
Cervix	T1-weighted (upper abdomen and pelvis)	Axial	Evaluate bone marrow and lymph nodes
	T2-weighted with fat saturation	Axial	Evaluate lymph nodes and provide overview of pelvis (including hydronephrosis)
	T2-weighted FSE	Sagittal	Visualize tumor and its extension to lower uterine segment, vagina, bladder, and rectum
	T2-weighted FSE	Axial oblique (short axis)	Optimize the assessment of parametrial invasion in a second imaging plane

Note—T1-weighted can be conventional spin-echo, but in the interest of time, most centers use gradient-echo sequences, which are faster but at the expense of image quality. FSE = fast spin-echo.

Controversy regarding the role of lymphadenectomy still exists, and practices vary considerably [24, 25]. Indications for lymphadenectomy include grade 1 or 2 tumors with deep myometrial invasion; all grade 3 tumors; cervical stroma invasion; and high-risk histologic subtypes, such as serous papillary and clear cell [25]. Lymphadenectomy carries a high risk of complications and careful selection of high-risk patients is crucial for specialist surgical referral to a gynecologic oncology team [11].

In summary, MRI may assist in the preoperative assessment and surgical planning by accurately predicting the depth of myometrial invasion, cervical stroma invasion, lymph node involvement, and metastatic spread. MRI can also provide additional useful information such as uterine size, tumor volume, and ascites, and can reveal adnexal abnormalities that in turn may determine the surgical approach (i.e., transabdominal vs transvaginal vs laparoscopic). In high-risk patients due to comorbidity, MRI is useful in planning nonsurgical treatment options such as radiation therapy or hormonal therapy (stage IA).

Diagnosis

Endometrial carcinomas are typically diagnosed at endometrial biopsy or dilatation and curettage, with MRI being reserved to evaluate the extent of disease. MRI is the most accurate imaging technique for the preoperative assessment of endometrial cancer because of its superb soft-tissue contrast resolution. The routine use of dynamic IV contrast enhancement is necessary for state-of-the-art MR evaluation of endometrial carcinoma [11, 13, 14, 26–29].

On unenhanced T1-weighted images, endometrial carcinoma is isointense to the normal endometrium. Although endometrial cancer may show high signal intensity on T2-weighted sequences, it is more typically heterogeneous and may even be of low signal intensity. After IV contrast medium administration, the normal inner myometrium shows avid enhancement earlier than the outer myometrium [13, 27, 28]. The maximum contrast between the inner and outer layers of the myometrium occurs at 50 seconds [28]. In general, endometrial cancer enhances earlier than normal endometrium but later than the adjacent myometrium, allowing identification of small tumors, even those contained by the endometrium. The maximum tumor–myometrium contrast occurs during the equilibrium phase [14].

Staging

Imaging criteria for staging of endometrial cancer are based on the TNM or International Federation of Gynecology and Obstetrics (FIGO) classification system (Table 2). However, the FIGO staging system is based on surgical and pathologic findings alone, and imaging, although useful in the preoperative assessment of tumor stage, is not recognized as a method to be used for definitive staging.

MRI is significantly superior to sonography and CT in the evaluation of both tumor extensions into the cervix and myometrial invasion [30, 31]. The overall staging accuracy of MRI has been reported to be between 85% and 93% [13, 14, 26–30, 32, 33]. The routine use of dynamic IV contrast enhancement significantly improves the accuracy of the assessment of depth of myometrial invasion (accuracy of 55–77% for T2-weighted images vs 85–91% for dynamic contrast-enhanced images) [13, 14, 27, 29, 34].

Stage I—Stage I endometrial cancers include tumors confined to the uterine corpus. Stage IA tumors (limited to the endometrium) appear as normal or widened (focal or diffuse) endometrium. An intact junctional zone and a band of early subendometrial enhancement exclude deep myometrial invasion [13, 27] (Fig. 1). Regardless of the MR sequence, the tumor–myometrium interface appears smooth and sharp. In stage IB disease (Fig. 2), tumor extends less than 50% into the myometrium with associated disruption or irregularity of the junctional zone and a band of early subendometrial enhancement. If these landmarks are not present, stage IB tumor is suggested by an irregular tumor–myometrium interface. The presence of low-signal-intensity tumor during the equilibrium phase within the outer myometrium indicates deep myometrial invasion—that is, stage IC disease.

The sensitivity and specificity of MRI in the assessment of the depth of myometrial invasion range from 69% to 94% and from 64% to 100%, respectively [13, 14, 27, 29, 34]. An erroneous MRI assessment of the depth of myometrial invasion may occur when assessing a large polypoid endometrial

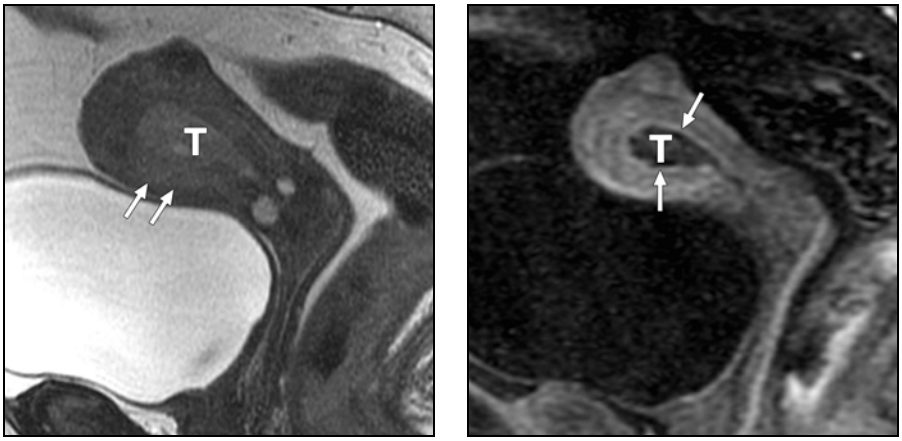

Fig. 1—Stage IA endometrial carcinoma in 64-year-old woman.
A and **B,** Sagittal T2-weighted fast spin-echo (**A**) and early phase (60 seconds) gadolinium-enhanced fat-suppressed T1-weighted (**B**) MR images show endometrial carcinoma (T) confined to endometrium. Zonal anatomy (*arrows* in **A**) is indistinct on T2-weighted image. However, intact band of early subendometrial enhancement seen on T1-weighted image (*arrows* in **B**) excludes myometrial invasion.

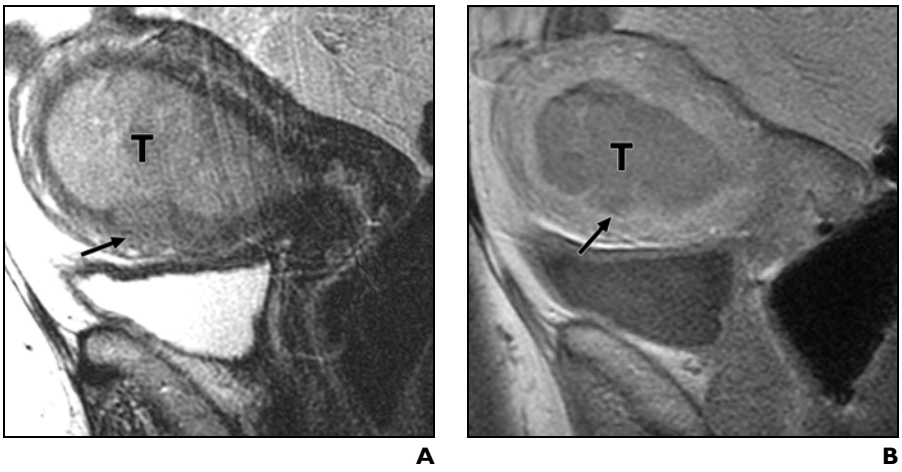

Fig. 2—Stage IB endometrial carcinoma in 65-year-old woman.
A and **B,** Sagittal T2-weighted fast spin-echo (**A**) and gadolinium-enhanced fat-suppressed T1-weighted (**B**) MR images show endometrial carcinoma (T) with superficial myometrial invasion. Note disruption of junctional zone (*arrow* in **A**). Tumor involves less than 50% of myometrium (*arrow* in **B**), which is better shown on T1-weighted image.

carcinoma that distends the uterus so that the thin rim of myometrium is stretched over the carcinoma rather than showing deep infiltration [13, 21, 35]. Other causes include coexistent benign abnormalities (e.g., leiomyomas, adenomyosis) [15, 32, 35], congenital anomalies, indistinct zonal anatomy [15], poor tumor–myometrium contrast [15, 21, 29, 36–38], and tumor extension to the uterine cornu (Table 3).

Stage II—Stage II includes tumor extension beyond the uterine corpus into the cervix. In stage IIA, invasion of the endocervix appears as widening of the internal os and endocervical canal with preservation of the normal low-signal-intensity fibrocervical stroma (Fig. 3).

Disruption of the fibrocervical stroma by high-signal-intensity tumor on T2-weighted images indicates cervical stroma invasion—stage IIB disease. Focal disruption of normal enhancement of the cervical mucosa by low-signal-intensity tumor on late dynamic contrast-enhanced MRI is useful in distinguishing cervical stroma invasion from polypoid tumor protruding from the endometrial cavity into the endocervix.

The accuracy of MRI in detecting cervical invasion reaches 92%, with sensitivities of 75–80% and specificities of 94–96% [14, 39].

Stage III—In stage III disease, tumor extends outside the uterus but not outside the true pelvis. Parametrial involvement—stage IIIA—appears as disruption of the serosa with direct extension into the surrounding parametrial fat. In stage IIIB disease, tumor extends into the upper vagina, and there is segmental loss of the low-signal-intensity vaginal wall. In stage IIIC disease, lymphadenopathy is present.

Stage IV—Stage IV disease is tumor that extends beyond the true pelvis or invades the bladder or rectum. The loss of low signal intensity of the bladder or rectal wall indicates stage IVA disease [15]. In stage IVB disease, there is distant metastasis, malignant ascites, or peritoneal deposits. Peritoneal deposits are better seen on delayed dynamic contrast-enhanced MRI [40].

Uterine Sarcomas (Leiomyosarcomas, Endometrial Sarcomas, Malignant Mixed Müllerian Tumors)

Sarcomas of the uterus are often highly malignant. They are rare, with an incidence of approximately 2 per 100,000 women over the age of 20 years, and account for 3–5% of all uterine cancers. The tumors are frequently large at the time of the examination, and it is difficult to determine the primary origin of the mass. MRI can provide an accurate preoperative assessment of uterine size and degree of involvement. The MRI features are nonspecific and may be indistinguishable from those of endometrial carcinoma [8, 41, 42]. However, uterine sarcomas tend to be large and heterogeneous with areas of hemorrhage and cystic necrosis. Deep myometrial invasion and peritoneal seeding are usually seen at presentation (Fig. 4).

Leiomyosarcomas account for only 1.3% of uterine malignancies. Most leiomyosarcomas arise de novo from the myometrium, although malignant transformation of leiomyomas can occur. It has been suggested that an irregular margin of uterine leiomyoma may indicate malignant transformation [8, 43], but MRI cannot reliably differentiate between a leiomyoma undergoing benign degeneration and a leiomyosarcoma.

MRI of Malignant Neoplasms of the Uterine Cervix

The most common histologic type of cervical carcinoma is squamous cell carcinoma

TABLE 3: Classification of Endometrial Carcinoma Using TNM and International Federation of Gynecology and Obstetrics (FIGO) Staging Systems

TNM	FIGO[a]	Description
T1	I	Carcinoma confined to the uterus
T1a	IA	Carcinoma limited to endometrium
T1b	IB	Invasion less than or equal to half of the myometrium
T1c	IC	Invasion of more than half of the myometrium
T2	II	Invasion of cervix
T2a	IIA	Invasion of endocervical glands
T2b	IIB	Invasion of cervical stroma
T3 and/or N1	III	Local regional or local and regional spread
T3a	IIIA	Involvement of serosa, adnexa, or both serosa and adnexa with or without positive peritoneal cytology
T3b	IIIB	Vaginal involvement
T3c	IIIC	Metastatic to pelvic, paraaortic, or both pelvic and paraaortic nodes
T4	IV	Tumor extends outside pelvis or invades bladder or rectal mucosa
T4a	IVA	Invasion of bladder, bowel mucosa, or both
M1	IVB	Distant metastasis

[a]FIGO staging system is based on surgical and pathologic findings alone; imaging, although useful in preoperative assessment of tumor stage, is not recognized as a method for definitive staging.

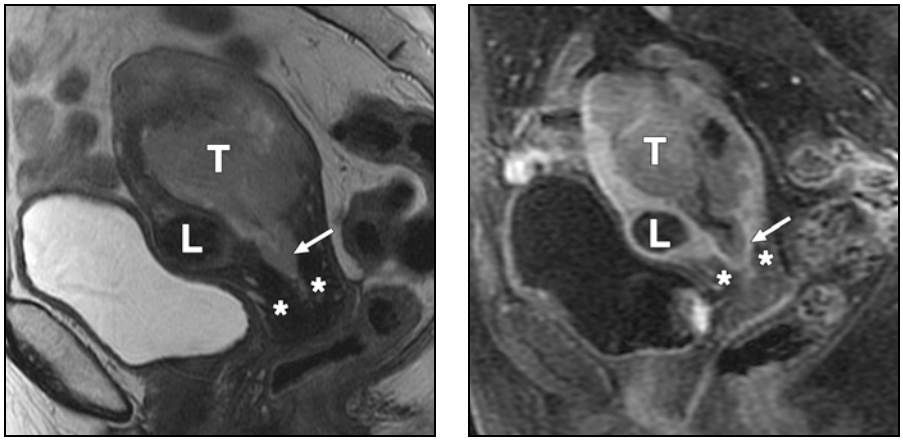

Fig. 3—Stage IIA endometrial carcinoma in 78-year-old woman.
A and **B,** Sagittal T2-weighted fast spin-echo (**A**) and gadolinium-enhanced fat-suppressed T1-weighted (**B**) MR images show endometrial carcinoma (T) with deep myometrial invasion and tumor extension into cervical canal (*arrow* in **A**). Note preservation of low-signal-intensity cervical stroma (*asterisks*). Normal enhancement of cervical mucosa (*arrow* in **B**) on enhanced images excludes cervical stroma invasion. Incidental presence of uterine leiomyoma (L) is noted.

(90%) followed by adenocarcinoma (5–10%). Other rare histologic types include small-cell carcinoma, adenosquamous carcinoma, and lymphoma. MRI features of these rare tumors are the same as those of squamous cell carcinoma [44]. However, small-cell carcinoma usually shows highly aggressive features, such as parametrial involvement, pelvic lymphadenopathy, and distant metastasis [44].

Carcinoma of the Cervix

Cervical carcinoma is the third most common gynecologic malignancy [9]. In 2007, 11,150 new cases and 3,670 deaths are expected in the United States [9]. Five-year survival rates vary between 92% for stage I disease and 17% for stage IV disease [9]. During the past 50 years, there has been a steep decline in the number of deaths from cervical cancer. This improvement in mortality has been attributed to the development of the Papanicolaou test; only minor improvement has been achieved in the survival of invasive cervical cancer.

MRI Protocol

Patient preparation and coil choice for cervical cancer evaluation are similar to that for endometrial carcinoma. Although a body coil has been shown to provide similar staging accuracy, the use of a phased-array coil increases resolution and decreases imaging time [45, 46]. A basic imaging protocol should include axial T1-weighted spin-echo images with a large field of view and T2-weighted FSE images in the axial and sagittal planes with a small field of view (Table 1).

Cervical tumors are best seen on T2-weighted images. The sagittal plane allows evaluation of tumor extension into the body of the uterus and vagina. The axial oblique T2-weighted FSE sequence perpendicular to the long axis of the cervix is important in assessing parametrial invasion [47]. Axial T2-weighted FSE imaging with fat saturation can be helpful in the evaluation of parametrial invasion, especially in younger women who have a prominent pericervical or vaginal plexus. Axial TI-weighted images of the abdomen are also included to identify enlarged abdominal lymph nodes.

The use of contrast medium is not necessary for cervical cancer examinations because it does not improve staging accuracy compared with unenhanced T2-weighted images [48, 49]. However, dynamic contrast-enhanced MRI may help distinguish recurrent tumor from postsurgical changes [3].

Impact of Imaging on Treatment

Staging of cervical cancer is still based on clinical FIGO criteria that—compared with surgical staging—can be erroneous in up to 32% of patients with stage IB disease and up to 65% of patients with stage III disease [50, 51]. The greatest difficulties in the clinical evaluation of patients with cervical cancer are the assessment of parametrial and pelvic sidewall invasion; accurate estimation of tumor size, especially if the tumor is primarily endocervical in location; and evaluation of lymph node metastases [52, 53]. Accurate pretreatment evaluation of these prognostic factors is crucial in determining appropriate therapy in patients with cervical cancer.

The most important issue in staging of cervical cancer is to distinguish early disease

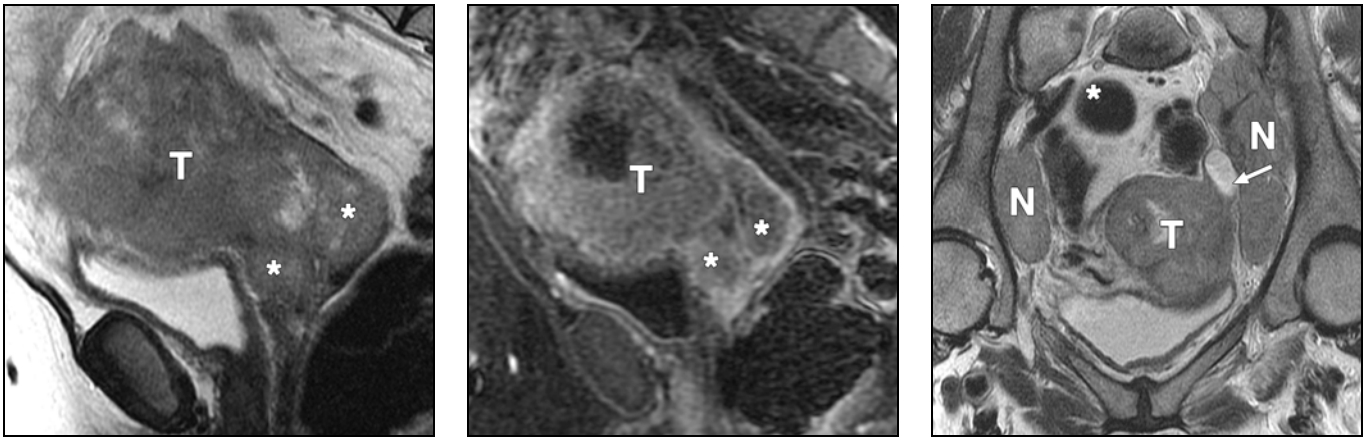

Fig. 4—Malignant mixed müllerian tumor in 55-year-old woman.
A–C, Sagittal T2-weighted fast spin-echo (FSE) (**A**), sagittal gadolinium-enhanced fat-suppressed T1-weighted (**B**), and axial oblique T2-weighted FSE (**C**) images show large heterogeneous mass (T) that contains areas of cystic necrosis. Tumor involves entire depth of myometrium and invades cervical stroma (*asterisks* in **A** and **B**). Note presence of enlarged bilateral obturator lymph nodes (N in **C**) and associated left-side hydronephrosis (*arrow* in **C**).

TABLE 4: Classification of Cervical Carcinoma Using TNM and International Federation of Gynecology and Obstetrics (FIGO) Staging Systems

TNM	FIGO[a]	Description
T1	I	Carcinoma confined to the cervix
T1a	IA	Invasive carcinoma identified only microscopically
T1a1	IA1	Stromal invasion no greater than 3 mm in depth and no wider than 7 mm
T1a2	IA2	Stromal invasion greater than 3 mm but less than 5 mm in depth and no wider than 7 mm
T1b1	IB1	Clinical lesions no larger than 4 cm
T1b2	IB2	Clinical lesions larger than 4 cm
T2	II	Extension beyond cervix and involvement of the upper vagina (but not the lower vagina)
T2a	IIA	No parametrial invasion
T2b	IIB	Parametrial invasion
T3	III	Invasion of the lower third of the vagina, invasion extending to the pelvic sidewall, or both
T3a	IIIA	Invasion of the lower third of the vagina
T3b	IIIB	Extension to the pelvic wall or hydronephrosis (or both)
T4	IVA	Invasion of the mucosa of bladder, rectum, or bladder and rectum; invasion extending beyond the true pelvis; or both
M1	IVB	Spread to distant organs

[a]FIGO staging system is based on surgical and pathologic findings alone; imaging, although useful in preoperative assessment of tumor stage, is not recognized as a method for definitive staging.

(stages I and IIA) that can be treated with surgery from advanced disease (stage IIB or greater) that must be treated with radiation alone or combined with chemotherapy. MRI is the best single imaging investigation that can accurately determine tumor location (exophytic or endocervical), tumor size, depth of stromal invasion, and extension into the lower uterine segment [44, 54–56]. MRI is accurate for evaluation of tumor size, usually within 0.5 cm of the surgical size, in 70–90% of cases [57–59]. Finally, MRI is useful in the evaluation of lymph node metastases [5].

Diagnosis

MRI is recommended for evaluating patients with clinical stage IB disease or greater when the primary lesion is larger than 2 cm [44, 54, 55] because of a relatively high likelihood of parametrial invasion and lymph node metastases. Other MRI indications include evaluation of pregnant patients and patients with endocervical lesions [56].

On T1-weighted images, tumors are usually isointense to the normal cervix and may not be visible. On T2-weighted images, cervical cancer appears as a relatively hyperintense mass and is easily distinguishable from low-signal-intensity cervical stroma. On dynamic contrast-enhanced MRI, small tumors enhance homogeneously and earlier than the normal cervical stroma. Large tumors are frequently necrotic and may or may not enhance, but are often surrounded by an enhancing rim that facilitates tumor definition [60, 61].

Staging

The recommendations for diagnostic evaluation of tumor staging derive from the TNM and FIGO clinical staging systems (Table 4). In single-institution studies, MRI has been shown to be better than either CT or physical examination in depicting parametrial invasion [7, 62, 63]. The staging accuracy of MRI ranges from 75% to 96% [57–59, 62–65]. A recent prospective multicenter study conducted jointly by the American College of Radiology Imaging Network (ACRIN) and the Gynecologic Oncology Group (GOG) compared MRI, CT, and FIGO clinical staging in the pretreatment assessment of early invasive cervical cancer [66]. The study showed that MRI was equivalent to CT for overall preoperative staging.

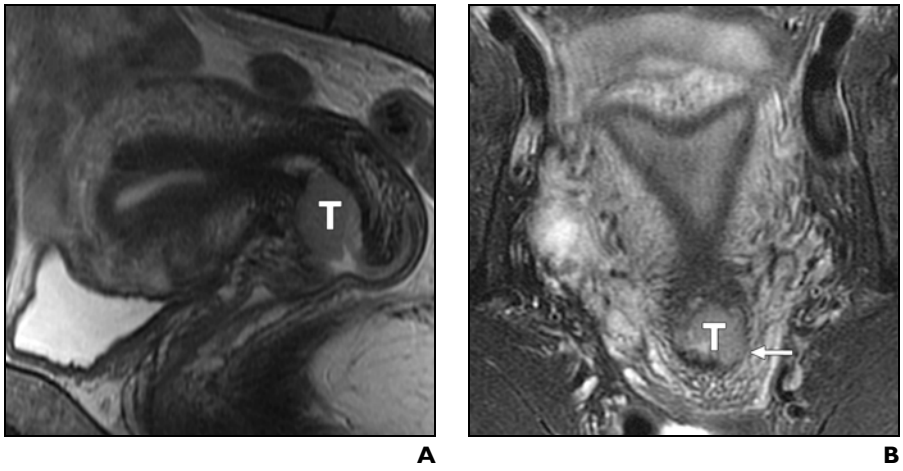

Fig. 5—Stage IIB cervical cancer in 47-year-old woman.
A and **B,** Sagittal fast spin-echo (**A**) and axial fat-suppressed (**B**) T2-weighted images show small cervical cancer (T) involving anterior lip of cervix. Tumor invades fibrocervical stroma on left as shown by focal disruption of low-signal-intensity ring (*arrow* in **B**). Pathology showed full-depth stromal invasion with tumor extending 2 mm into left parametrium.

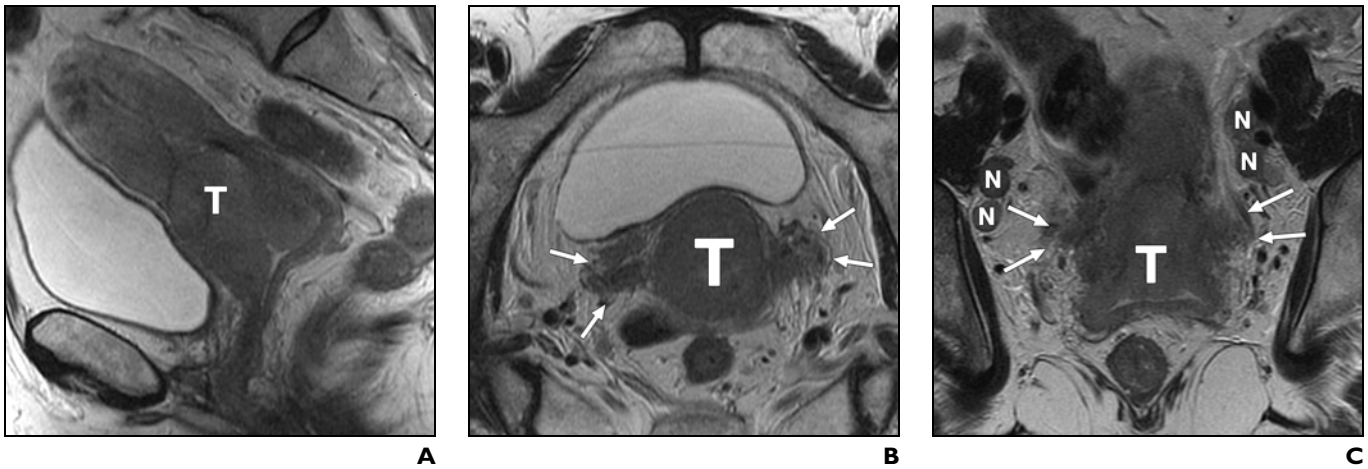

Fig. 6—Stage IIB cervical cancer in 42-year-old woman.
A–C, Sagittal fast spin-echo (**A**), axial oblique (**B**), and coronal oblique (**C**) T2-weighted images show cervical cancer (T) involving both anterior and posterior lips of cervix. Tumor invades fibrocervical stroma bilaterally, as shown by loss of low-signal-intensity ring, and extends to both parametria (*arrows* in **B**). Coronal oblique image shows bilateral parametrial invasion (*arrows* in **C**) and enlarged lymph nodes (N in **C**).

However, MRI performed significantly better than CT for preoperative tumor visualization and determination of parametrial invasion. Reviewer agreement was higher for MRI reviewers than for CT reviewers [66].

Stage I—Stage I tumors are confined to the uterus. Stage IA is defined as a microinvasive tumor that cannot be reliably shown on T2-weighted images. However, microinvasive disease may be detected on dynamic MRI as a strongly enhancing area on early arterial phase images [60]. The accuracy in differentiating deep (> 3 mm) from superficial invasion has been reported to be 76%, 98%, and 63% on T2-weighted images, dynamic contrast-enhanced images, and contrast-enhanced T1-weighted images, respectively [60]. Stage IB carcinoma appears as a high-signal-intensity mass in contrast to the low-signal-intensity fibrocervical stroma seen on T2-weighted images.

Young women with stage IA or small stage IB tumors who wish to retain their fertility are considered for trachelectomy, an operation that excises the cervix but preserves the uterine body and maintains fertility. MRI is accurate for predicting myometrial invasion by tumor and in showing the relationship of cervical carcinoma to the internal os with a sensitivity of 100% and specificity of 96% [67].

Stage II—In stage IIA tumors, segmental disruption of the upper two thirds of the vaginal wall without parametrial invasion is shown on T2-weighted images. Cervical stroma invasion (Fig. 5) and tumor extension into the parametria are defined as stage IIB disease. The reported sensitivity of MRI in the evaluation of parametrial invasion is 69%, and the specificity is 93% [57–59, 62–65]. An intact low-signal-intensity cervical stroma virtually excludes parametrial invasion with a negative predictive value of 94–100% [56]. Segmental disruption of the hypointense cervical stroma usually indicates full-thickness stromal invasion. However, additional features, such as a spiculated tumor–parametrium interface, soft-tissue extension into the parametria (Fig. 6), or encasement of the periuterine vessels, are required to make a confident diagnosis of established parametrial invasion [56].

An important pitfall of MRI staging is overestimation of parametrial invasion on T2-weighted images in large tumors (accuracy of

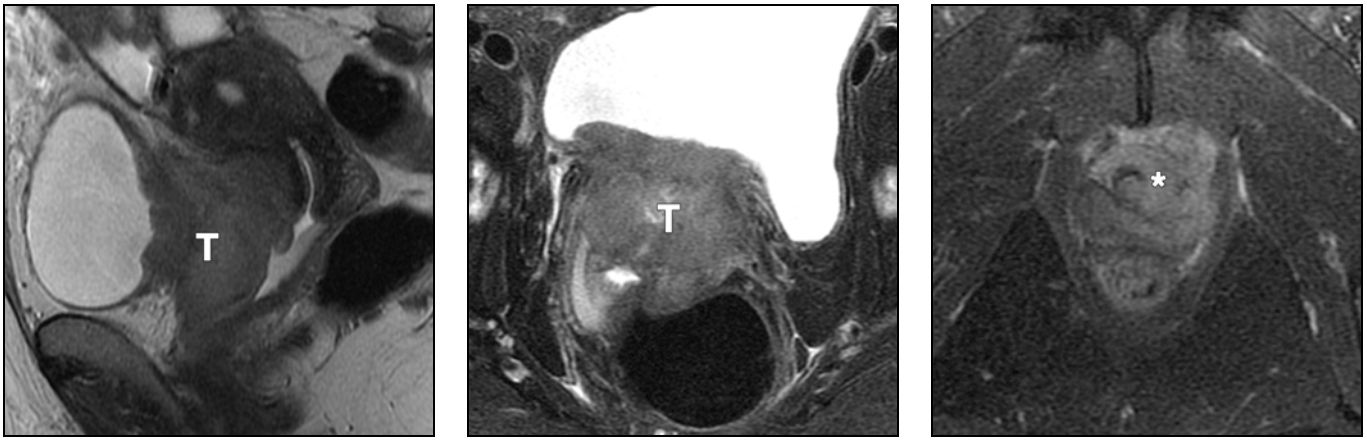

Fig. 7—Stage IVB cervical cancer in 39-year-old woman.
A–C, Sagittal fast spin-echo (**A**) and axial fat-suppressed (**B** and **C**) T2-weighted images show large cervical cancer (T in **A** and **B**) involving anterior lip of cervix. Tumor also invades posterior wall of bladder, entire vagina, and urethra (*asterisk* in **C**).

70%) compared with small ones (accuracy of 96%) due to stromal edema caused by tumor compression or inflammation [56] (Table 3). This pitfall may lead to a higher rate of false-positive assessment of parametrial invasion in patients with large tumors, which must be considered when making the treatment decisions in these patients.

Stage III—In stage IIIA, vaginal involvement reaches the lower one third of the vaginal canal without extending to the pelvic sidewall. When the tumor extends to the pelvic sidewall (i.e., the pelvic musculature or iliac vessels) or causes hydronephrosis, it is defined as stage IIIB.

Stage IV—Once tumor invades the adjacent organs, such as the bladder and rectal mucosa, or distant metastasis occurs, the stage is defined as IV (Fig. 7). MRI findings suggesting bladder invasion include focal or diffuse disruption of the normal low-signal-intensity posterior bladder wall, nodular or irregular bladder wall, mass protruding into the lumen of the bladder, or presence of bullous edema. Rectal invasion is rare and appears as segmental thickening and loss of the anterior rectal wall. Prominent strands between the tumor and the rectal wall may also indicate rectal invasion.

The reported sensitivity of MRI in the evaluation of bladder or rectal invasion is 71–100%, and the specificity is 88–91% [59, 64, 68]. The absence of bladder or rectal invasion can be diagnosed with sufficient confidence using MRI (negative predictive value = 100%) to safely obviate invasive cystoscopic or endoscopic staging in most patients with cervical cancer. This could potentially lead to a reduction in staging costs and morbidity [68]. Although pelvic node metastases do not change the FIGO stage, paraaortic or inguinal node metastases are classified as stage IVB.

The Role of MRI in the Evaluation of Lymph Nodes in Uterine Malignancies

In patients with endometrial and cervical cancer, the presence of lymph node metastases suggests a poor prognosis, with a marked decrease in survival rates [69]. For example, in surgically treated stages IB and IIA cervical cancer, survival rates decline from 85–90% to 50–55%, respectively, in the presence of metastatic lymph nodes [56]. Lymph node involvement, which is not included in the FIGO staging system for carcinoma of the cervix, is also an important factor in the choice of adjuvant radiation therapy in both endometrial and cervical cancer. Surgical lymph node assessment is the gold standard for the diagnosis of lymph node metastases; however, lymphadenectomy carries a high risk of complications, and careful selection of high-risk patients is crucial for specialist surgical referral to a gynecologic oncology team [11]. Therefore, from a clinical point of view, accurate preoperative assessment of lymph node metastases is very important in patients with endometrial and cervical cancer.

MRI and CT have comparable accuracies in detecting nodal metastases: 83–90% for CT and 86–90% for MRI [7, 62, 63, 70, 71]. They both rely on size criteria, which results in a low sensitivity (43–73% for MRI) due to the inability to identify metastasis in normal-size lymph nodes [5, 14, 64]. Recently, the use of lymph node–specific MRI contrast agents, such as ultrasmall superparamagnetic iron oxide (USPIO) particles, has been shown to improve the sensitivity and retain the high specificity of detection of lymph node metastases in patients with endometrial and cervical cancer [5]. In their study, Rockall et al. [5] showed an increase in sensitivity from 29% using the standard size criterion (> 1 cm) to 93% using USPIO criteria on a node-by-node basis and from 27% to 100% on a patient-by-patient basis.

In cervical cancer, PET/CT has proved very valuable for lymph node staging with a sensitivity and specificity of 100% and 99.7%, respectively, for lymph nodes larger than 5 mm in diameter [72]. Furthermore, ^{18}F-FDG uptake within primary cervical cancer and lymph node metastases on FDG PET are reported as independent predictors of disease-free survival, which suggests that PET/CT may be the preferred imaging technique in patients with advanced carcinoma of the cervix for making treatment decisions, assessing nodal involvement, and determining prognosis [73].

Recurrent Disease

The vagina is the sole site of recurrence in 30–50% of patients with endometrial carcinoma recurrence; the remaining patients develop pelvic or paraaortic lymph node involvement or systemic spread manifesting as hepatic, pulmonary, or osseous metastasis or

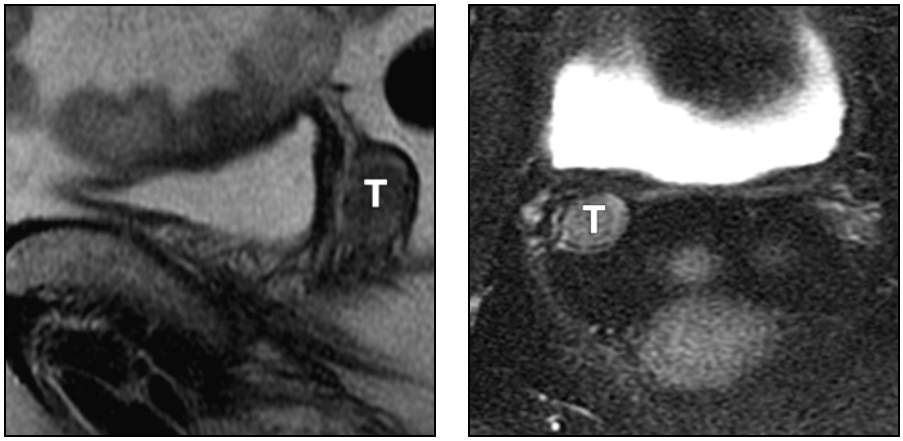

Fig. 8—Tumor recurrence in 45-year-old woman who had undergone hysterectomy for cervical carcinoma. **A** and **B,** Sagittal fast spin-echo (**A**) and axial fat-suppressed (**B**) T2-weighted images show intermediate-signal-intensity mass at vaginal vault (T), which is consistent with tumor recurrence.

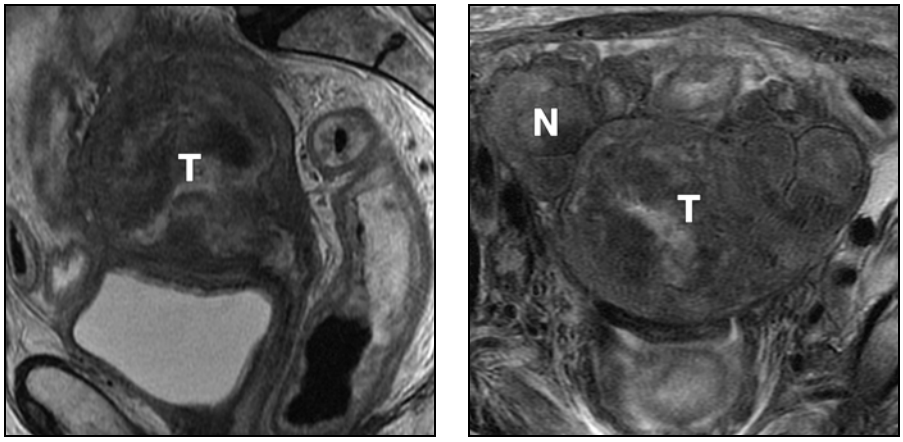

Fig. 9—Tumor recurrence in 67-year-old woman who had undergone radiochemotherapy for cervical carcinoma. **A** and **B,** Sagittal fast spin-echo (**A**) and axial fat-suppressed (**B**) T2-weighted images show heterogeneous mass involving uterine corpus (T), which is consistent with tumor recurrence. Note presence of enlarged right external iliac lymph node (N in **B**).

peritoneal carcinomatosis. Manifestations of recurrent disease in cervical carcinoma can be characterized as typical and atypical. Typical manifestations involve the vaginal vault and lymph nodes. However, with the increasing use of pelvic irradiation in the treatment of this disease, less typical patterns of recurrence are becoming more frequent. These include peritoneal carcinomatosis and solid organ metastasis to the liver, adrenal gland, lung, or bone [74]. Pelvic recurrence may involve other pelvic organs [75]. Tumor extension into the bladder or rectal wall is suggested by abnormally high signal intensity on T2-weighted imaging.

Vaginal vault recurrence after radical surgery for endometrial or cervical cancer has similar appearances. This is indicated by loss of the low-signal-intensity linear configuration of the vaginal vault and visualization of an associated soft-tissue mass of high signal intensity on T2-weighted images, similar to that of the primary tumor (Fig. 8).

In patients who have undergone radiation therapy, the critical issue is distinguishing recurrent disease from postirradiation changes. On MRI studies, recurrent disease appears as a heterogeneous mass on T2-weighted imaging, often similar to the appearance of the primary tumor [75] (Fig. 9). However, T2-weighted images have low specificity for the detection of benign conditions, such as inflammation and edema, that cause increased T2-weighted signal. Dynamic contrast-enhanced MRI has been shown to be helpful in improving specificity and accuracy of tumor recurrence, with maximum tumor enhancement occurring between 45 and 90 seconds after contrast administration [3]. However, early irradiation changes and the presence of infection continue to pose a problem because either may show enhancement. Serial imaging, imaging-guided biopsy, or PET may be required to further clarify the situation.

Conclusion

MRI, although not officially incorporated in the FIGO staging system, is already widely accepted as the most reliable imaging technique for the diagnosis, staging, treatment planning, and follow-up of both endometrial and cervical cancer. MRI protocols need to be optimized to obtain the best results and avoid pitfalls.

In endometrial cancer, MRI is reliable in predicting the depth of myometrial invasion and cervical extension, which correlate with the risk of lymph node metastases. Therefore, MRI is also valuable in selecting patients for lymph node sampling or lymphadenectomy who require specialist gynecology referral. MRI plays a central role in the evaluation of cervical cancer, primarily in identifying tumors without parametrial extension, thereby stratifying patients for surgery and radiation therapy. MRI also aids in the selection of patients for fertility-preserving surgery in early-stage disease and in the detection of recurrent disease after treatment. In summary, MRI plays a key role in staging, patient selection for treatment, and detection of disease recurrence.

References

1. Hricak H, Mendelson E, Bohm-Velez M, et al. Role of imaging in cancer of the cervix. American College of Radiology. ACR appropriateness criteria. *Radiology* 2000; 215[suppl]:925–930
2. Hricak H, Mendelson E, Bohm-Velez M, et al. Endometrial cancer of the uterus. American College of Radiology. ACR appropriateness criteria. *Radiology* 2000; 215[suppl]:947–953
3. Kinkel K, Ariche M, Tardivon AA, et al. Differentiation between recurrent tumor and benign conditions after treatment of gynecologic pelvic carcinoma: value of dynamic contrast-enhanced subtraction MR imaging. *Radiology* 1997; 204:55–63
4. Scheidler J, Hricak H, Yu KK, Subak L, Segal MR. Radiological evaluation of lymph node

metastases in patients with cervical cancer: a meta-analysis. *JAMA* 1997; 278:1096–1101

5. Rockall AG, Sohaib SA, Harisinghani MG, et al. Diagnostic performance of nanoparticle-enhanced magnetic resonance imaging in the diagnosis of lymph node metastases in patients with endometrial and cervical cancer. *J Clin Oncol* 2005; 23:2813–2821
6. Heller D, Hricak H. Cost-effectiveness of new technologies for staging endometrial cancer. *Eur Radiol* 2000; 10[suppl 3]:S381–S385
7. Hricak H, Powell CB, Yu KK, et al. Invasive cervical carcinoma: role of MR imaging in pretreatment work-up—cost minimization and diagnostic efficacy analysis. *Radiology* 1996; 198:403–409
8. Rha SE, Byun JY, Jung SE, et al. CT and MRI of uterine sarcomas and their mimickers. *AJR* 2003; 181:1369–1374
9. Jemal A, Siegel R, Ward E, et al. Cancer statistics, 2007. *CA Cancer J Clin* 2007; 57:43–66
10. Larson DM, Connor GP, Broste SK, Krawisz BR, Johnson KK. Prognostic significance of gross myometrial invasion with endometrial cancer. *Obstet Gynecol* 1996; 88:394–398
11. Frei KA, Kinkel K, Bonel HM, Lu Y, Zaloudek C, Hricak H. 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; 216:444–449
12. Shibutani O, Joja I, Shiraiwa M, et al. Endometrial carcinoma: efficacy of thin-section oblique axial MR images for evaluating cervical invasion. *Abdom Imaging* 1999; 24:520–526
13. Yamashita Y, Harada M, Sawada T, Takahashi M, Miyazaki K, Okamura H. Normal uterus and FIGO stage I endometrial carcinoma: dynamic gadolinium-enhanced MR imaging. *Radiology* 1993; 186:495–501
14. Manfredi R, Mirk P, Maresca G, et al. Local-regional staging of endometrial carcinoma: role of MR imaging in surgical planning. *Radiology* 2004; 231:372–378
15. Ascher SM, Reinhold C. Imaging of cancer of the endometrium. *Radiol Clin North Am* 2002; 40:563–576
16. Eltabbakh GH, Shamonki MI, Moody JM, Garafano LL. Laparoscopy as the primary modality for the treatment of women with endometrial carcinoma. *Cancer* 2001; 91:378–387
17. Wong CK, Wong YH, Lo LS, Tai CM, Ng TK. Laparoscopy compared with laparotomy for the surgical staging of endometrial carcinoma. *J Obstet Gynaecol Res* 2005; 31:286–290
18. Berman ML, Ballon SC, Lagasse LD, Watring WG. Prognosis and treatment of endometrial cancer. *Am J Obstet Gynecol* 1980; 136:679–688
19. Boronow RC, Morrow CP, Creasman WT, et al. Surgical staging in endometrial cancer: clinical–pathologic findings of a prospective study. *Obstet Gynecol* 1984; 63:825–832
20. Piver MS, Lele SB, Barlow JJ, Blumenson L. Paraaortic lymph node evaluation in stage I endometrial carcinoma. *Obstet Gynecol* 1982; 59:97–100
21. 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; 188:797–801
22. Goff BA, Rice LW. Assessment of depth of myometrial invasion in endometrial adenocarcinoma. *Gynecol Oncol* 1990; 38:46–48
23. Quinlivan JA, Petersen RW, Nicklin JL. Accuracy of frozen section for the operative management of endometrial cancer. *BJOG* 2001; 108:798–803
24. Creutzberg CL. Lymphadenectomy in apparent early-stage endometrial carcinoma: do numbers count? *J Clin Oncol* 2005; 23:3653–3655
25. Maggino T, Romagnolo C, Landoni F, Sartori E, Zola P, Gadducci A. An analysis of approaches to the management of endometrial cancer in North America: a CTF study. *Gynecol Oncol* 1998; 68:274–279
26. Barwick TD, Rockall AG, Barton DP, Sohaib SA. Imaging of endometrial adenocarcinoma. *Clin Radiol* 2006; 61:545–555
27. Ito K, Matsumoto T, Nakada T, Nakanishi T, Fujita N, Yamashita H. Assessing myometrial invasion by endometrial carcinoma with dynamic MRI. *J Comput Assist Tomogr* 1994; 18:77–86
28. Joja I, Asakawa M, Asakawa T, et al. Endometrial carcinoma: dynamic MRI with turbo-FLASH technique. *J Comput Assist Tomogr* 1996; 20:878–887
29. Seki H, Kimura M, Sakai K. Myometrial invasion of endometrial carcinoma: assessment with dynamic MR and contrast-enhanced T1-weighted images. *Clin Radiol* 1997; 52:18–23
30. Kim SH, Kim HD, Song YS, Kang SB, Lee HP. Detection of deep myometrial invasion in endometrial carcinoma: comparison of transvaginal ultrasound, CT, and MRI. *J Comput Assist Tomogr* 1995; 19:766–772
31. Kinkel K, Kaji Y, Yu KK, et al. Radiologic staging in patients with endometrial cancer: a meta-analysis. *Radiology* 1999; 212:711–718
32. Hricak H, Stern JL, Fisher MR, Shapeero LG, Winkler ML, Lacey CG. Endometrial carcinoma staging by MR imaging. *Radiology* 1987; 162:297–305
33. Hricak H, Rubinstein LV, Gherman GM, Karstaedt N. MR imaging evaluation of endometrial carcinoma: results of an NCI cooperative study. *Radiology* 1991; 179:829–832
34. Sironi S, Colombo E, Villa G, et al. Myometrial invasion by endometrial carcinoma: assessment with plain and gadolinium-enhanced MR imaging. *Radiology* 1992; 185:207–212
35. Scoutt LM, McCarthy SM, Flynn SD, et al. Clinical stage I endometrial carcinoma: pitfalls in preoperative assessment with MR imaging—work in progress. *Radiology* 1995; 194:567–572
36. Lee EJ, Byun JY, Kim BS, Koong SE, Shinn KS. Staging of early endometrial carcinoma: assessment with T2-weighted and gadolinium-enhanced T1-weighted MR imaging. *RadioGraphics* 1999; 19:937–945
37. Lien HH, Blomlie V, Trope C, Kaern J, Abeler VM. Cancer of the endometrium: value of MR imaging in determining depth of invasion into the myometrium. *AJR* 1991; 157:1221–1223
38. Yamashita Y, Mizutani H, Torashima M, et al. Assessment of myometrial invasion by endometrial carcinoma: transvaginal sonography vs contrast-enhanced MR imaging. *AJR* 1993; 161:595–599
39. Seki H, Takano T, Sakai K. Value of dynamic MR imaging in assessing endometrial carcinoma involvement of the cervix. *AJR* 2000; 175:171–176
40. Low RN, Duggan B, Barone RM, Saleh F, Song SY. Treated ovarian cancer: MR imaging, laparotomy reassessment, and serum CA-125 values compared with clinical outcome at 1 year. *Radiology* 2005; 235:918–926
41. Sahdev A, Sohaib SA, Jacobs I, Shepherd JH, Oram DH, Reznek RH. MR imaging of uterine sarcomas. *AJR* 2001; 177:1307–1311
42. Shapeero LG, Hricak H. Mixed müllerian sarcoma of the uterus: MR imaging findings. *AJR* 1989; 153:317–319
43. Pattani SJ, Kier R, Deal R, Luchansky E. MRI of uterine leiomyosarcoma. *Magn Reson Imaging* 1995; 13:331–333
44. Okamoto Y, Tanaka YO, Nishida M, Tsunoda H, Yoshikawa H, Itai Y. MR imaging of the uterine cervix: imaging–pathologic correlation. *RadioGraphics* 2003; 23:425-445
45. Hawighorst H, Schoenberg SO, Knapstein PG, et al. Staging of invasive cervical carcinoma and of pelvic lymph nodes by high resolution MRI with a phased-array coil in comparison with pathological findings. *J Comput Assist Tomogr* 1998; 22:75–81
46. Yu KK, Hricak H, Subak LL, Zaloudek CJ, Powell CB. Preoperative staging of cervical carcinoma: phased array coil fast spin-echo versus body coil spin-echo T2-weighted MR imaging. *AJR* 1998; 171:707–711
47. Shiraiwa M, Joja I, Asakawa T, et al. Cervical carcinoma: efficacy of thin-section oblique axial T2-weighted images for evaluating parametrial invasion. *Abdom Imaging* 1999; 24:514–519
48. Van Vierzen PB, Massuger LF, Ruys SH, Barentsz JO. Fast dynamic contrast enhanced MR imaging of cervical carcinoma. *Clin Radiol* 1998; 53:183–192
49. Scheidler J, Heuck AF, Steinborn M, Kimmig R, Reiser MF. Parametrial invasion in cervical carcinoma: evaluation of detection at MR imaging with

fat suppression. *Radiology* 1998; 206:125–129

50. Lagasse LD, Creasman WT, Shingleton HM, Ford JH, Blessing JA. Results and complications of operative staging in cervical cancer: experience of the Gynecologic Oncology Group. *Gynecol Oncol* 1980; 9:90–98
51. Van Nagell JR Jr, Roddick JW Jr, Lowin DM. The staging of cervical cancer: inevitable discrepancies between clinical staging and pathologic findings. *Am J Obstet Gynecol* 1971; 110:973–978
52. Creasman WT. New gynecologic cancer staging. *Gynecol Oncol* 1995; 58:157–158
53. Piver MS, Chung WS. Prognostic significance of cervical lesion size and pelvic node metastases in cervical carcinoma. *Obstet Gynecol* 1975; 46:507–510
54. Scheidler J, Heuck AF. Imaging of cancer of the cervix. *Radiol Clin North Am* 2002; 40:577–590
55. Nicolet V, Carignan L, Bourdon F, Prosmanne O. MR imaging of cervical carcinoma: a practical staging approach. *RadioGraphics* 2000; 20:1539–1549
56. Kaur H, Silverman PM, Iyer RB, Verschraegen CF, Eifel PJ, Charnsangavej C. Diagnosis, staging, and surveillance of cervical carcinoma. *AJR* 2003; 180:1621–1631
57. Subak LL, Hricak H, Powell CB, Azizi L, Stern JL. Cervical carcinoma: computed tomography and magnetic resonance imaging for preoperative staging. *Obstet Gynecol* 1995; 86:43–50
58. Togashi K, Nishimura K, Itoh K, et al. Uterine cervical cancer: assessment with high-field MR imaging. *Radiology* 1986; 160:431–435
59. Hricak H, Lacey CG, Sandles LG, Chang YC, Winkler ML, Stern JL. Invasive cervical carcinoma: comparison of MR imaging and surgical findings. *Radiology* 1988; 166:623–631
60. Seki H, Azumi R, Kimura M, Sakai K. Stromal invasion by carcinoma of the cervix: assessment with dynamic MR imaging. *AJR* 1997; 168:1579–1585
61. Yamashita Y, Takahashi M, Sawada T, Miyazaki K, Okamura H. Carcinoma of the cervix: dynamic MR imaging. *Radiology* 1992; 182:643–648
62. Kim SH, Choi BI, Han JK, et al. Preoperative staging of uterine cervical carcinoma: comparison of CT and MRI in 99 patients. *J Comput Assist Tomogr* 1993; 17:633–640
63. Kim SH, Choi BI, Lee HP, et al. Uterine cervical carcinoma: comparison of CT and MR findings. *Radiology* 1990; 175:45–51
64. Bipat S, Glas AS, van der Velden J, Zwinderman AH, Bossuyt PM, Stoker J. Computed tomography and magnetic resonance imaging in staging of uterine cervical carcinoma: a systematic review. *Gynecol Oncol* 2003; 91:59–66
65. Sheu M, Chang C, Wang J, Yen M. MR staging of clinical stage I and IIa cervical carcinoma: a reappraisal of efficacy and pitfalls. *Eur J Radiol* 2001; 38:225–231
66. Hricak H, Gatsonis C, Chi DS, et al. Role of imaging in pretreatment evaluation of early invasive cervical cancer: results of the intergroup study American College of Radiology Imaging Network 6651–Gynecologic Oncology Group 183. *J Clin Oncol* 2005; 23:9329–9337
67. Peppercorn PD, Jeyarajah AR, Woolas R, et al. Role of MR imaging in the selection of patients with early cervical carcinoma for fertility-preserving surgery: initial experience. *Radiology* 1999; 212:395–399
68. Rockall AG, Ghosh S, Alexander-Sefre F, et al. Can MRI rule out bladder and rectal invasion in cervical cancer to help select patients for limited EUA? *Gynecol Oncol* 2006; 101:244–249
69. Inoue T, Morita K. The prognostic significance of number of positive nodes in cervical carcinoma stages IB, IIA, and IIB. *Cancer* 1990; 65:1923–1927
70. Williams AD, Cousins C, Soutter WP, et al. Detection of pelvic lymph node metastases in gynecologic malignancy: a comparison of CT, MR imaging, and positron emission tomography. *AJR* 2001; 177:343–348
71. Yang WT, Lam WW, Yu MY, Cheung TH, Metreweli C. Comparison of dynamic helical CT and dynamic MR imaging in the evaluation of pelvic lymph nodes in cervical carcinoma. *AJR* 2000; 175:759–766
72. Sironi S, Buda A, Picchio M, et al. Lymph node metastasis in patients with clinical early-stage cervical cancer: detection with integrated FDG PET/CT. *Radiology* 2006; 238:272–279
73. Xue F, Lin LL, Dehdashti F, Miller TR, Siegel BA, Grigsby PW. F-18 fluorodeoxyglucose uptake in primary cervical cancer as an indicator of prognosis after radiation therapy. *Gynecol Oncol* 2006; 101:147–151
74. Fulcher AS, O'Sullivan SG, Segreti EM, Kavanagh BD. Recurrent cervical carcinoma: typical and atypical manifestations. *RadioGraphics* 1999; 19(Spec No):S103–S116
75. Jeong YY, Kang HK, Chung TW, Seo JJ, Park JG. Uterine cervical carcinoma after therapy: CT and MR imaging findings. *RadioGraphics* 2003; 23:969–981

FOR YOUR INFORMATION

This article is available for CME credit. See www.arrs.org for more information.