RadioGraphics

The Revised FIGO Staging System for Uterine Malignancies: Implications for MR Imaging[1]

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LEARNING OBJECTIVES

After completing this journal-based CME activity, participants will be able to:

- List the revised FIGO stages for both cervical and endometrial carcinoma and their respective management implications.
- Discuss the optimal MR imaging sequences and protocols for staging uterine malignancies.
- Describe the appearances of the different stages of uterine malignancy at MR imaging.

TEACHING POINTS

See last page

Cancers of the uterine corpus and cervix are the most common gynecologic malignancies worldwide. The International Federation of Gynecology and Obstetrics (FIGO) staging system was first established in 1958, when it was recognized that the recurrence rate and patient outcomes were directly related to the degree of tumor spread at the patient's initial presentation. Changes in understanding of tumor biology led to a recent update in the FIGO staging system that reflects the variation in treatment strategies between endometrial and cervical cancer. Patients with endometrial cancer are primarily treated with hysterectomy; thus, staging is done at surgery and histologic analysis. Magnetic resonance (MR) imaging may accurately depict the extent of endometrial cancer at diagnosis and, in conjunction with the tumor grade and histologic subtype, help stratify risk, which determines the therapeutic course. Cervical carcinoma is staged at clinical examination because many tumors are inoperable at the time of patient presentation. Preoperative MR imaging criteria are not formally included in the revised FIGO staging system because cervical carcinoma is most prevalent in developing countries, where imaging resources are limited. However, MR imaging is highly sensitive and specific for depicting important prognostic factors and, when available, is recommended as an adjunct to clinical examination. The MR imaging findings of uterine carcinoma should be discussed in a multidisciplinary setting in conjunction with clinical and histologic findings, an approach that provides accurate staging and risk stratification and allows for individualized treatment.

Abbreviations: ADC = apparent diffusion coefficient, DWI = diffusion-weighted imaging, ESUR = European Society of Urogenital Radiology, FIGO = International Federation of Gynecology and Obstetrics, NCCN = National Comprehensive Cancer Network

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Introduction

Endometrial and cervical carcinomas are the most common gynecologic malignancies worldwide: Endometrial cancer is the most common gynecologic cancer in industrialized countries, whereas cervical cancer is most common in developing countries. The International Federation of Gynecology and Obstetrics (FIGO) staging system is the most widely accepted method for staging endometrial and cervical cancers (1). The first FIGO staging system was created in 1958. It was updated in 1988 and was most recently revised in 2009. Cancer staging is fundamentally important in treating patients with cancer and must be reliable, reproducible, and practical. Unified criteria must be established to enable treatment planning, assess tumor response, predict prognosis, and allow information to be exchanged between different treatment centers (2). This process ensures that identical cases are accurately assigned a tumor stage, which leads to consistent management decisions and is reflected in similar clinical outcomes, and it provides a major prognostic factor in predicting the rate of recurrence and patient outcomes. Changes in our understanding of tumor biology led to a recent update in the FIGO staging system in June 2009. Cancer classification systems must continue to respond to changes in our knowledge of tumor etiology, pathogenesis, and predisposing genetic factors because they affect prognosis.

The FIGO staging system for endometrial and cervical cancers reflects their different clinical management strategies. Management of endometrial carcinoma is primarily surgical, whereas that for cervical carcinoma depends on the FIGO stage at the time of its manifestation. MR imaging has an integral role in evaluating the extent of disease and managing its pathway.

The primary treatment for patients with endometrial cancer is hysterectomy; for this reason, staging is done on the basis of surgical and histologic findings. However, MR imaging has been shown to accurately delineate the local extent of disease and depict extrauterine tumor spread. MR imaging accurately depicts the depth of myometrial invasion and cervical stromal invasion and may depict metastatic spread, including peritoneal deposits (1,3–5). Lymph node metastasis is the most common form of extrauterine disease spread and is the strongest predictor for recurrence. Enlarged or abnormal lymph nodes may be depicted at MR imaging and used as a road map for sampling at surgery. MR imaging features of abnormal lymph nodes include clusters of multiple small lymph nodes, necrosis, and signal intensity similar to that of the primary tumor. MR imaging findings are reviewed in conjunction with the tumor grade determined on the basis of endometrial biopsy and histologic findings at the multidisciplinary team meeting or tumor board conference. This meeting provides an accurate risk stratification, which determines the prognosis and management strategy, including whether lymph node dissection is necessary (6). In the United Kingdom and other countries, risk stratification determines whether patients are treated at a local center (those with low and intermediate risk) or a specialist gynecologic oncology center (those with high risk).

MR imaging may also provide additional useful information, including the size of the uterus, tumor volume, presence of ascites, and adnexal pathologic characteristics, that may guide the surgical approach (eg, transabdominal, transvaginal, or laparoscopic). Pelvic and paraaortic lymph node dissection is not routinely performed in low- and intermediate-risk patients because its clinical benefit remains uncertain (7–10). However, if suspicious lymph nodes are seen preoperatively or in the presence of a high-grade, high-stage tumor at MR imaging, lymph node dissection may be considered (10). In medically high-risk patients, MR imaging may be useful in planning nonsurgical treatment options.

In contrast, although cervical cancer is the third most common gynecologic malignancy in the United States, it remains the most common gynecologic malignancy worldwide (11,12). Cervical cancer screening programs and improvements in chemoradiotherapy have helped reduce mortality in industrialized nations. Nevertheless, cervical carcinoma remains a common cause of cancer-related death among women in developing countries. Given its epidemiologic characteristics, the FIGO staging system must reflect the available resources: Any system must allow for uniform staging between different centers and countries and remain practical, accessible, and reliable (2). Because access to imaging may be limited in developing countries, cervical carcinoma continues to be staged at clinical examination under anesthesia and combined with cystoscopy and sigmoidoscopy. However, the revised FIGO staging system acknowledges the benefits of staging on the basis of MR imaging findings and encourages its use when available.

Table 1
MR Imaging Techniques for Staging Cervical Carcinoma

	T1-weighted		T2-weighted			Diffusion-weighted	
Weighting and Plane	Axial	Axial Upper Abdomen	Axial	Sagittal	Axial Oblique	Sagittal	Axial Oblique
Pulse sequence	SE	SE	FRFSE	FRFSE	FRFSE	EP	EP
Repetition time (msec)	700	700	4500	4500	4500	5000	5000
Echo time (msec)	Min full	14	85	85	85	Minimum	Minimum
No. of signals acquired	2	2	4	4	4	6	6
No. of dimensions	2	2	2	2	2	2	2
Section thickness (mm)	5	10	5	5	4	4.5	4.5
Section gap (mm)	2.5	5	2.5	2.5	1	0	0
Matrix	320 × 256	256 × 192	384 × 256	384 × 256	384 × 256	128 × 128	128 × 128
Field of view (mm)	240	280	240	240	240	240	280
Bandwidth (kHz)	15.63	15.63	41.67	41.67	41.67	...	...
No. of sections	20	20	20	24	26	21	26
b value (sec/mm^2)	...	...	...	...	...	500	800
Acquisition time*	6 min, 10 sec	5 min	4 min, 50 sec	4 min, 50 sec	4 min, 50 sec	2 min, 10 sec	4 min, 10 sec

Note.—EP = echoplanar, FRFSE = fast recovery fast spin-echo, Min full = minimum full echo train (equates to about 14–16 msec), SE = spin echo.
*Varies depending on required coverage.

In particular, imaging provides accurate information about important prognostic factors, such as tumor size, parametrial and pelvic sidewall invasion, and lymphadenopathy (13,14). When possible, MR imaging should be used as an adjunct to clinical assessment, which currently remains the reference standard. The role of imaging is to distinguish early stage disease, which is treated with surgery, from early stage bulky disease and locally advanced disease, which are not treated with surgery and require chemoradiotherapy. In this article, we discuss the added value of MR imaging in staging endometrial and cervical carcinoma and the effect of MR imaging findings on determining prognosis, treatment strategies, and treatment planning with respect to the revised FIGO staging system.

MR Imaging Technique

Optimal acquisition of MR images depends on good patient preparation. Motion artifacts caused by bowel peristalsis may be reduced by instructing patients to fast 4 hours before the examination and by intravenously administering an antiperistaltic agent (eg, hyoscine butyl bromide or glucagon) (15). Immediately before imaging, patients must also void their bladder to reduce movement and ghosting artifacts on T2-weighted images (16–18). MR images are acquired with patients lying supine and a surface array multichannel coil to optimize image quality and reduce acquisition time (1,17,19). Endoluminal coils are not routinely used because of the reduced field of view, which limits depiction of extrauterine extension to adjacent organs.

MR Imaging Sequences and Planes

The basic gynecologic pelvic MR imaging protocol includes acquiring axial, sagittal, and coronal T2-weighted images. Axial spin-echo T1- or T2-weighted images of the abdomen and pelvis are used to depict enlarged lymph nodes, hydronephrosis, and bone marrow abnormalities (20,21). The protocol is then tailored for either cervical or endometrial cancer staging (Tables 1, 2). In patients with endometrial cancer, high-resolution T2-weighted fast spin-echo images are acquired in the axial oblique plane,

Table 2
MR Imaging Techniques for Endometrial Carcinoma Staging

	T1-weighted		T2-weighted			Diffusion-weighted		Multiphase Dynamic Contrast-enhanced	
Weighting and Plane	Axial	Axial Upper Abdomen	Axial	Sagittal	Axial Oblique	Sagittal	Axial Oblique	Sagittal	Axial Oblique
Sequence	FSE	SE	FRFSE	FRFSE	FRFSE	EP	EP	GRE	GRE
Repetition time (msec)	470	700	4500	4500	4500	5000	5000	6.4	6.4
Echo time (msec)	Min full	14	85	85	85	Minimum	Minimum	2.1	2.1
No. of signals acquired	2	2	3	4	4	6	6	1	1
No. of dimensions	2	2	2	2	2	2	2	3	3
Section thickness (mm)	5	10	5	5	3	4.5	4.5	4	4.2
Section gap (mm)	2.5	5	2.5	2.5	0.5	0	0	...	...
Matrix	448 × 288	256 × 192	384 × 256	384 × 256	384 × 256	128 × 128	128 × 128	288 × 192	288 × 192
Field of view (mm)	240	280	240	240	220	280	280	240	320
Bandwidth (kHz)	31.25	15.63	31.25	41.67	41.67	...	...	83.33	83.33
No. of sections	20	20	20	21	26	21	26	32 per slab	24 per slab
b value (sec/mm^2)	...	...	...	...	...	500	800	...	...
Timing*	...	...	...	...	...	...	...	Preinjection; 1 and 2 min after injection	Preinjection; 3 min after injection
Acquisition time†	4 min, 50 sec	5 min	3 min, 10 sec	3 min, 58 sec	4 min, 34 sec	2 min, 10 sec	4 min, 10 sec	18 sec	22 sec

Note.—EP = echoplanar, FRFSE = fast recovery fast spin-echo, FSE = fast spin-echo, GRE = gradient-recalled echo, Min full = minimum full echo train (equates to about 14–16 msec), SE = spin echo.
*Relative to administration of contrast medium.
†Varies depending on required coverage.

perpendicular to the endometrium, allowing accurate assessment of myometrial invasion (22). High-resolution axial oblique T2-weighted fast spin-echo images are also obtained in patients with cervical cancer; however, they are obtained perpendicular to the cervical canal to accurately depict parametrial invasion (23).

Dynamic multiphase contrast material–enhanced imaging may be used to assess the local extent of endometrial carcinoma. Before administration of contrast material, T1-weighted gradient-echo MR images are acquired in the axial and sagittal planes. One and 2 minutes after administration of contrast material, they are acquired in the sagittal plane, and 3 minutes after contrast material administration, they are acquired in the axial oblique plane. Many studies have reported the additional benefit of dynamic contrast enhancement in evaluating myometrial invasion in patients with endometrial carcinoma (5,24–31). However, tumor extension into the cornua and loss of the junctional zone remain confounding factors in assessing the depth of myometrial invasion at dynamic contrast-enhanced MR imaging.

Use of intravenous contrast medium does not improve depiction of disease extent in patients with cervical carcinoma because of the variable enhancement of cervical tumors; therefore, contrast medium is not routinely used in cervical cancer staging protocols. The European Society of Urogenital Radiology (ESUR) guidelines for staging cervical carcinomas recommend considering the use of intravenous contrast medium or diffusion-weighted imaging in patients with small lesions, which are not well depicted on T2-weighted images, and those who underwent treatment (20). Dynamic multiphase contrast-enhanced T1-weighted gradient-echo imaging may improve depiction and delineation of small cervical lesions that are 3 mm or larger with 98% sensitivity, providing important information for surgical planning in patients being considered for trachelectomy (32,33). It is also useful in distinguishing between tumors with a cervical or endometrial uterine cancer origin in patients with biopsy-proved adenocarcinoma, especially when both the cervix and lower uterine segment are involved (34).

Diffusion-weighted imaging (DWI) has an increasingly accepted role in routine cervical and endometrial carcinoma staging because it increases tumor conspicuity and aids in image interpretation (35–40). DWI is a physiologic imaging technique that provides information about water mobility, tissue cellularity, and the integrity of cellular membranes (39,41,42). Diffusion-weighted images are acquired in the sagittal and axial oblique planes, perpendicular to the endometrial cavity or cervical canal in patients with endometrial and cervical carcinoma, respectively. To distinguish between perfusion and diffusion, diffusion-weighted images are acquired with a low *b* value (eg, 0 or 50 sec/mm^2) followed by a high *b* value (eg, 800 or 1000 sec/mm^2). Compared with adjacent tissues, tumor typically demonstrates restricted diffusion, which is seen as an area of high signal intensity on diffusion-weighted images and an area of hypointensity on apparent diffusion coefficient (ADC) maps. In particular, DWI may accurately depict the depth of myometrial invasion in patients with endometrial cancer. It may be of particular use in patients with tumor extension to the cornua, myometrial compression from a polypoid tumor, poor tumor-to-myometrium contrast, leiomyomas, or adenomyosis, as well as when intravenous contrast medium is contraindicated (43,44).

ADC may be calculated with images with different *b* values, providing a measurement in square millimeters per second. Coregistration of diffusion-weighted images with corresponding T2-weighted images improves anatomic correlation. ADC maps should always be reviewed with diffusion-weighted images to avoid pitfalls from T2 shine-through and water restriction in normal tissues or highly cellular benign tumors (41).

Endometrial Carcinoma

Endometrial carcinoma is the most common gynecologic malignancy in industrialized nations. The mean age at presentation is 63 years, and more than 90% of patients are women over the age of 50 years (45). Postmenopausal women who present with vaginal bleeding should undergo transvaginal ultrasonography as the initial imaging evaluation. If endometrial thickness of more than 4 mm is identified, endometrial biopsy should be performed (46).

Teaching Point

Endometrial carcinomas are divided into two histologic subtypes. Endometrioid adenocarcinoma (type 1), the most common histologic subtype, accounts for almost 90% of cases of endometrial cancer, which are further subdivided according to the histologic grade of tumor differentiation, from grade 1 (well differentiated) to grade 3 (poorly differentiated). Type 2 endometrial carcinomas include serous papillary and clear cell adenocarcinomas. Serous papillary, clear cell, and grade 3 endometrioid adenocarcinomas demonstrate more aggressive tumor biologic characteristics and have a 50% pretest probability of locally advanced or distant disease at manifestation.

Staging on the basis of the revised FIGO system for endometrial carcinoma remains surgical because the condition is predominantly treated with surgery. Currently, the National Comprehensive Cancer Network (NCCN) guidelines only recommend that chest radiography be performed preoperatively; MR imaging is only recommended when gross cervical invasion is suspected (47). However, the information provided by MR imaging has become invaluable in managing endometrial carcinoma. In response to growing evidence, the National Cancer Institute in France incorporated preoperative MR imaging into its guidelines for managing endometrial carcinoma. MR imaging is also recommended by the ESUR for staging high-risk endometrial carcinoma, including all histologic subtype 2 and high-grade subtype 1 tumors (21,48).

MR imaging plays an important role in the treatment stratification of patients with endometrial carcinoma. Accurate preoperative delineation of local disease extent and involved lymph nodes is essential. When combined with tumor histologic findings, this information may be used to guide the surgical approach.

Effect of Imaging on Risk Stratification and Disease Management

The approach to preoperative staging on the basis of MR imaging findings varies among different countries and centers but may become more established as the use of laparoscopic and robotic surgery increases. The information obtained at preoperative MR imaging provides crucial information regarding local extent and distant spread of endometrial tumors before surgery. The depth of myometrial and cervical stromal invasion may be used as surrogate markers to determine possible lymphovascular space invasion and the risk for lymph node metastases (28,49).

The tumor grade and histologic subtype, determined on the basis of preoperative hysteroscopy and biopsy or pipelle sampling findings, are invaluable prognostic indicators. Grade 3 endometrioid adenocarcinoma and all type 2 tumors correlate with a poor prognosis because more than 50% of patients present with stage IB or higher. However, the histologic subtype and grade determined on the basis of biopsy findings often differ from the definitive histologic subtype and grade determined after hysterectomy, a result of the small biopsy sample, which often does not represent the whole tumor (4).

When the extent of disease at MR imaging is combined with the histologic subtype and grade determined at endometrial biopsy, an accurate assessment of risk stratification and prognosis may be made. Stage I may be divided into the following three risk categories: *(a)* low risk, which includes stage IA, histologic subtype 1 (endometrioid), grades 1 and 2; *(b)* intermediate risk, which includes stage IA, histologic subtype 1, grade 3 and stage IB, histologic subtype 1, grades 1 and 2; and *(c)* high risk, which includes stage IB, histologic subtype 1, grade 3 and all stages with histologic subtype 2 (nonendometrioid) (45).

Patients with a low- or intermediate-risk early stage tumor have a good prognosis and, thus, may be treated with simple hysterectomy and bilateral salpingo-oopherectomy. In the United Kingdom, these patients may be treated in local centers. Pelvic lymph node dissection may be considered only if suspicious lymph nodes are identified at MR imaging. Furthermore, in patients with low or intermediate risk and no myometrial invasion who are ineligible for surgery, hormonal treatment or brachytherapy may be considered.

In contrast, high-risk patients require hysterectomy; bilateral salpingo-oopherectomy; and paraaortic, common iliac, and, possibly, pelvic lymph node dissection. These procedures are performed in a specialist gynecologic cancer center. There is no consensus regarding routine systematic lymph node dissection because its clinical benefit remains uncertain (7–10). It may be associated with substantial morbidity and have little effect on the patient's final outcome if performed routinely, without preoperative imaging. MR imaging enables assessment of the pelvic and paraaortic lymph nodes, and if a lymph node is suspicious for tumor involvement, individual treatment decisions may be established regarding the need for lymph node dissection.

Endometrial carcinoma of stage II or higher, with any tumor grade or histologic subtype, necessitates radical hysterectomy, bilateral salpingo-oophorectomy, and pelvic lymph node dissection. Paraaortic lymphadenectomy may be considered. In all patients with histologic subtype 2 disease, omentectomy, pelvic and paraaortic lymphadenectomy, peritoneal washing, and biopsy are recommended (48). In addition, in patients with stage III and IV disease, M fast track R imaging is able to depict the extent of local tumor invasion and the organs involved, providing a preoperative road map regarding resectability and the

Table 3
Pearls and Pitfalls of MR Imaging of Endometrial Carcinoma

Pearls
Assessment of the depth of myometrial invasion is optimized by using both the sagittal and oblique (perpendicular to endometrial lining) planes.
Dynamic multiphase contrast-enhanced imaging and DWI increase the accuracy of T2-weighted imaging for depicting the depth of myometrial invasion.
Enhancement of cervical mucosa on delayed images (3 min) excludes cervical stromal invasion.
Type 2 endometrial carcinoma may demonstrate a pattern of spread similar to that of ovarian carcinoma (with peritoneal metastases and serosal deposits).
Pitfalls
Poor tumor-to-myometrium interface; polypoid tumor compresses the adjacent myometrium; adenomyosis and leiomyomas may cause the depth of myometrial invasion to be miscalculated at T2-weighted imaging. Avoid by correlating the depth of invasion with corresponding DWI findings.
Underestimation of the depth of myometrial invasion in the presence of cornual tumors because the myometrium thins in the region of the cornua.
Overestimation of the depth of myometrial invasion on dynamic multiphase contrast-enhanced images because of peritumoral inflammation.

need for colorectal or urologic surgical intervention or adjuvant chemoradiotherapy (50).

Appearances at MR Imaging

Normal uterine zonal anatomy is exquisitely demonstrated on T2-weighted images, which typically depict the high-signal-intensity endometrium surrounded by the low-signal-intensity junctional zone and the intermediate-signal-intensity myometrium (Table 3). Thus, pathologic processes of the uterus are best identified on T2-weighted images.

Endometrial carcinoma is usually isointense relative to the normal endometrium on T1-weighted images and hypointense relative to the endometrium on T2-weighted images. On dynamic multiphase contrast-enhanced T1-weighted images, endometrial tumors demonstrate mild homogeneous enhancement that is slower and less avid than that in the adjacent myometrium. At 50–120 seconds after intravenous administration of gadolinium contrast material, the myometrium demonstrates maximal enhancement compared with the relatively low signal intensity of endometrial tumors.

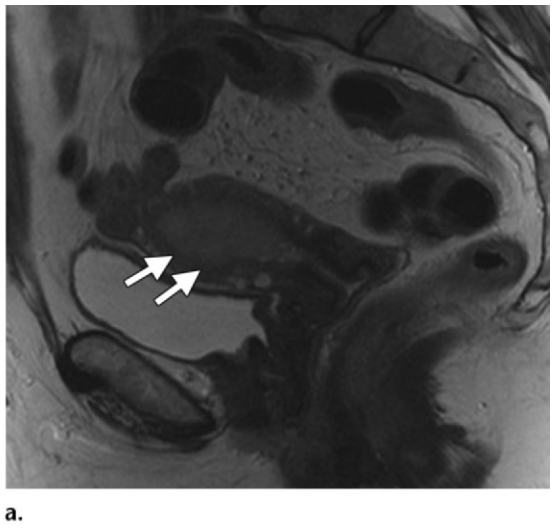
Table 4
FIGO Staging of Endometrial Carcinoma

Stage	Description
I	Tumor confined to the uterus
IA	<50% invasion of the myometrium
IB	≥50% invasion of the myometrium
II	Tumor invades the cervical stroma but does not extend beyond the uterus
III	Local or regional spread of tumor
IIIA	Serosal or adnexal invasion
IIIB	Vaginal or parametrial involvement
IIIC	Metastasis to pelvic or paraaortic lymph nodes
IIIC1	Pelvic lymph node involvement
IIIC2	Paraaortic lymph node involvement (with or without pelvic nodes)
IV	Extension to the pelvic wall, lower one-third of the vagina, or hydronephrosis or nonfunctioning kidney
IVA	Invasion of bladder or bowel mucosa
IVB	Distant metastases, including abdominal, or involvement of inguinal lymph nodes

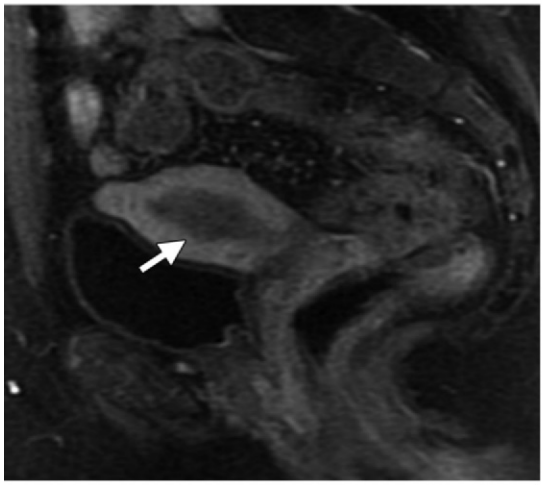
Endometrial tumors demonstrate high signal intensity on diffusion-weighted images and low signal intensity (restricted diffusion) on ADC maps. The main role of DWI in patients with endometrial cancer is to improve tumor depiction. In particular, DWI may be used to depict drop metastases in the cervix and vagina and unexpected extrauterine spread of disease within the adnexa and peritoneum (38,43,44). It may play a role in preoperative lymph node mapping (35). DWI may also depict endometrial cancer when endometrial biopsy is technically impossible because of cervical stenosis or when histopathologic results are inconclusive. Studies have shown that the ADC value of endometrial cancer is significantly lower than those of endometrial polyps and normal endometrium (35,39). A trend toward lower ADC values in high-grade endometrial cancers has also been reported (39).

Revised FIGO Staging System

There are three major changes in the revised FIGO staging system that affect MR imaging interpretation (Table 4). First, the previous FIGO stages IA and IB were combined to form the



a.



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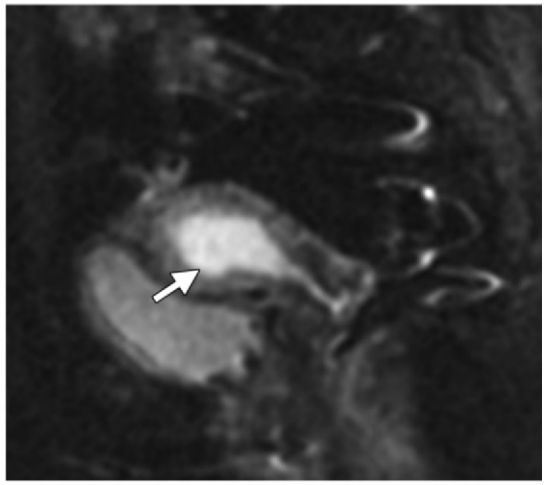


c.

Figure 1. Stage IA endometrial carcinoma (grade 3 endometrioid adenocarcinoma) in a 51-year-old woman. **(a)** Sagittal T2-weighted MR image shows an intermediate- to high-signal-intensity endometrial tumor (arrows). It is difficult to distinguish the extent of myometrial invasion on T2-weighted images alone. **(b)** Sagittal T1-weighted MR image obtained after administration of intravenous gadolinium-based contrast material shows the endometrial tumor (arrow), which demonstrates relatively poor enhancement compared with that of the myometrium, which avidly enhances. **(c)** Corresponding diffusion-weighted MR image shows an area of high signal intensity within the endometrial tumor (arrow), a finding indicative of restricted diffusion. The tumor is seen to invade only the inner myometrium.

revised FIGO stage IA, eliminating the imaging limitations of the previous FIGO stages by no longer requiring radiologists to differentiate between tumors that are confined to the endometrium and those that invade the inner one-half of the myometrium. This change reflects the similar prognosis associated with these two clinical scenarios. In the revised FIGO staging system, stage IB now represents invasion of the outer one-half of the myometrium. (Before 2009, outer myometrial invasion was classified as stage IC.) Second, stage II no longer has subsets A and B. In the revised FIGO staging system, stage II represents invasion of the cervical stroma. Involvement of only the endocervical glands and mucosa, with sparing of the cervical stroma (previously IIA disease in the 1988 FIGO staging system), was reclassified as stage I. It is important to distinguish cervical stromal invasion because it is associated with a higher risk for lymphovascular space invasion and confers a poorer prognosis. Third, stage IIIC was subdivided into pelvic and paraaortic lymph node involvement, becoming stages IIIC1 and IIIC2, respectively.

Teaching Point

Stage I.—Because the previous stages IA and IB were combined to form stage IA in the revised FIGO staging system, there is no need to differentiate between tumors that are confined to the endometrium and those that invade the inner myometrium. Stage IA reflects tumors that involve less than 50% of the myometrial thickness (Fig 1). Consequently, in the new FIGO staging system, stage IB represents tumor invasion into more than 50% of the myometrial thickness (Fig 2). It is important to distinguish between stages IA and IB because they have different risk stratifications when combined with the tumor grade and histologic subtype. The presence of lymphovascular space invasion correlates strongly with the

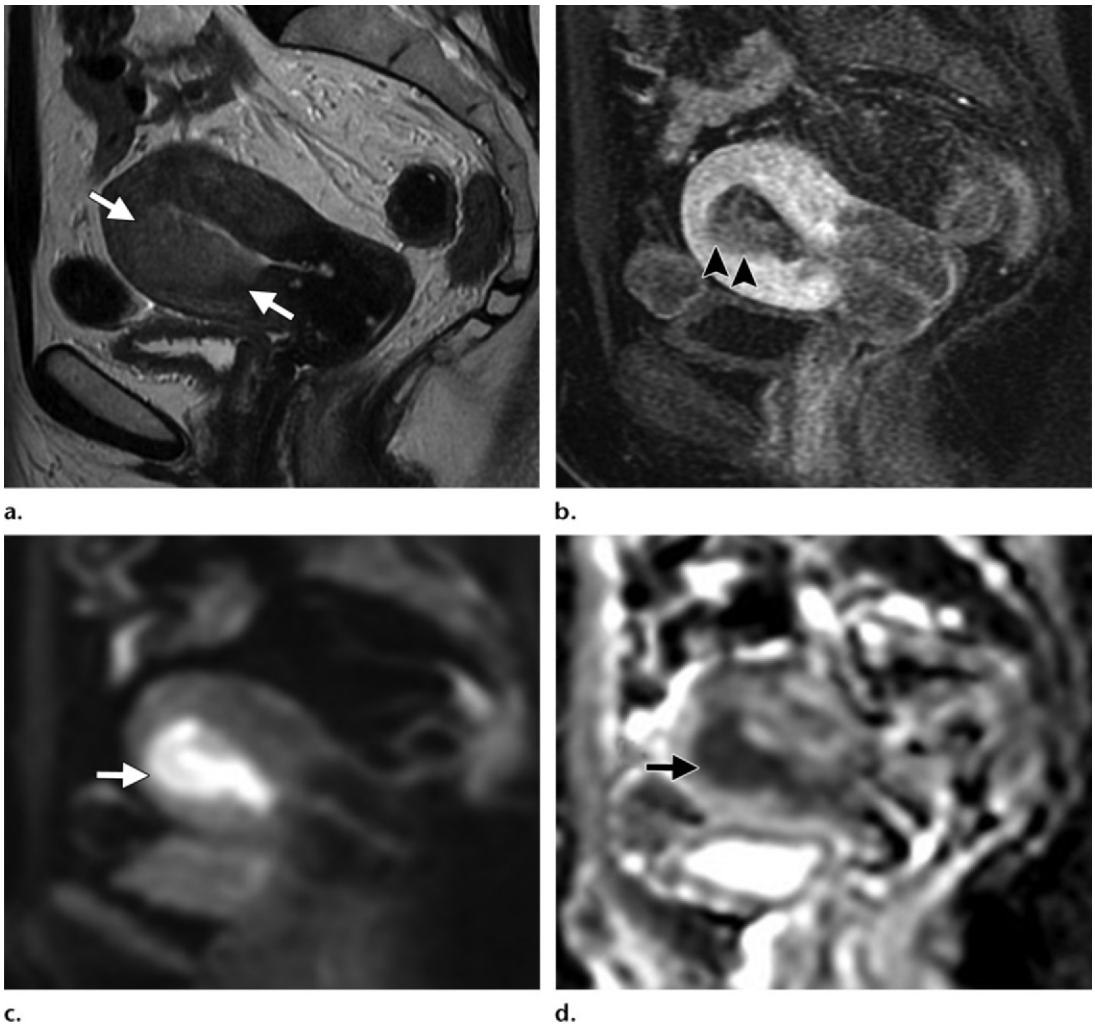


Figure 2. Stage IB endometrial carcinoma (grade 3 endometrioid adenocarcinoma) in a 67-year-old woman. **(a)** Sagittal T2-weighted MR image shows an intermediate- to high-signal-intensity endometrial tumor (arrows). **(b)** Dynamic contrast-enhanced MR image shows the endometrial tumor (arrowheads), which demonstrates poor enhancement compared with that of the myometrium. **(c, d)** Corresponding diffusion-weighted image **(c)** and ADC map **(d)** show restricted diffusion within the endometrial tumor (arrow), which extends into the outer one-half of the myometrium. The extent of myometrial invasion is clearly delineated on the dynamic contrast-enhanced image, diffusion-weighted image, and ADC map.

presence of lymph node metastases and a higher relapse rate. However, invasion of the lymphovascular space may only be identified at pathologic analysis of the hysterectomy specimen; it cannot be identified at preoperative imaging. The extent of myometrial invasion may be used as a surrogate imaging marker for potential lymphovascular space invasion and, therefore, the likelihood of nodal metastases (28,49). The incidence of involved lymph nodes among patients with endometrial carcinoma increases from 2.4% in those with low risk to 9% in those with intermediate risk and 24% in those with high risk (7,9).

The sensitivity and specificity of MR imaging for depicting the depth of myometrial invasion vary between 69%–94% and 64%–100%, respectively (5). The presence of fibroids and adenomyosis reduce its accuracy, but their effect may potentially be reduced by performing dynamic multiphase contrast-enhanced imaging and DWI (43).

Debate remains regarding the value of dynamic contrast-enhanced multiphase imaging in evaluating patients with endometrial carcinoma. The presence of tumoral enhancement within the endometrial cavity enables differentiation from blood products and debris, which demonstrate similar signal intensity on T2-weighted

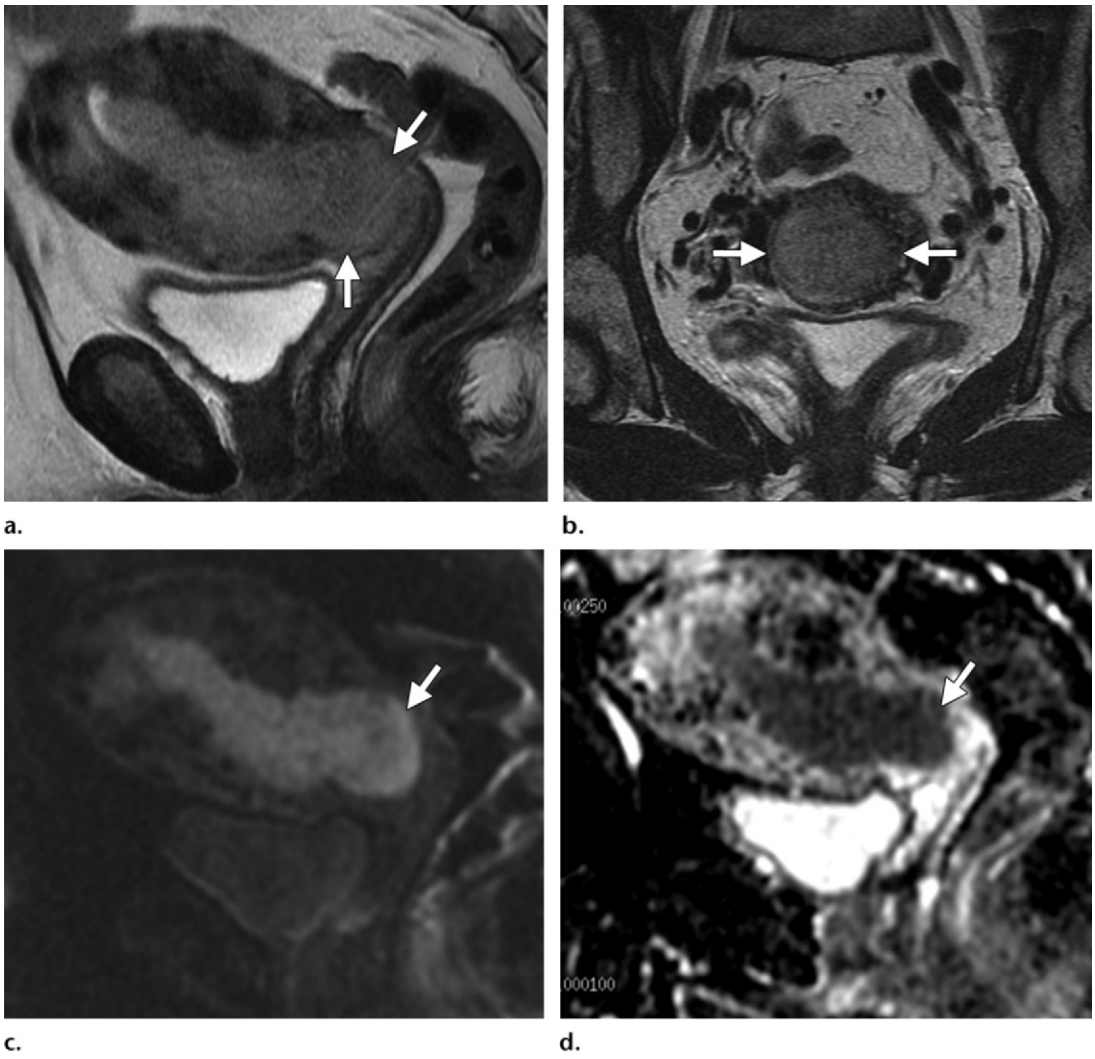


Figure 3. Stage II endometrial carcinoma (grade 3 endometrioid adenocarcinoma) in a 55-year-old woman. **(a)** Sagittal T2-weighted MR image shows an intermediate- to high-signal-intensity endometrial tumor (arrows) invading the normal, low-signal-intensity cervical stroma. **(b)** Axial oblique T2-weighted MR image, obtained perpendicular to the endocervical canal, shows the tumor (arrows) invading the cervical stroma but not the parametrium. **(c, d)** Sagittal diffusion-weighted image **(c)** and ADC map **(d)** show restricted diffusion within the endometrial tumor (arrow), with invasion of the cervical stroma and the outer one-half of the myometrium but not the serosa.

images. Peritumoral inflammation may cause overestimation of myometrial invasion, a potential pitfall. Some studies have reported that the pretest probability of myometrial invasion and overall staging accuracy of T2-weighted imaging increase from 55%–77% to 85%–91% with the use of dynamic contrast-enhanced imaging (5,25–27,29–31,51). However, other studies reported no additional benefit with the use of dynamic contrast-enhanced imaging (5,24–31). The use of DWI may also improve accuracy of tumor depiction, particularly when intravenous contrast material is contraindicated. Accuracy of DWI for depicting myometrial invasion is reported to be 62%–90% (38,52). In addition, the use of DWI may improve staging accuracy when tumor delineation is difficult because tumors appear iso- or hyperintense relative to the myometrium on T2-weighted images or demonstrate marked peritumoral enhancement after administration of contrast material, (43,44).

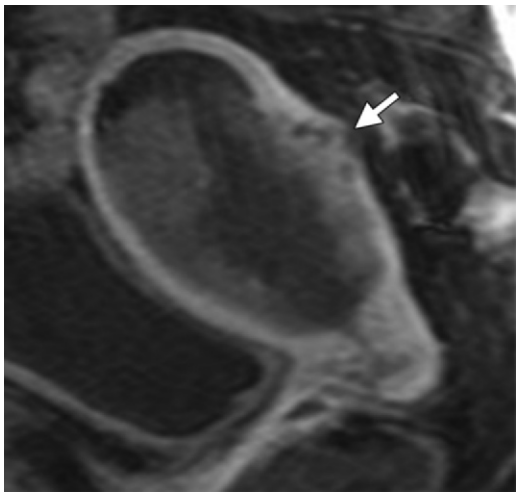


Figure 4. Stage IIIA endometrial carcinoma (grade 3 endometrioid adenocarcinoma) in a 60-year-old woman. Sagittal T1-weighted MR image obtained after intravenous administration of gadolinium-based contrast material shows a bulky endometrial tumor with relatively low signal intensity distending the endometrial cavity and extending through the avidly enhancing myometrium to the serosal surface (arrow).

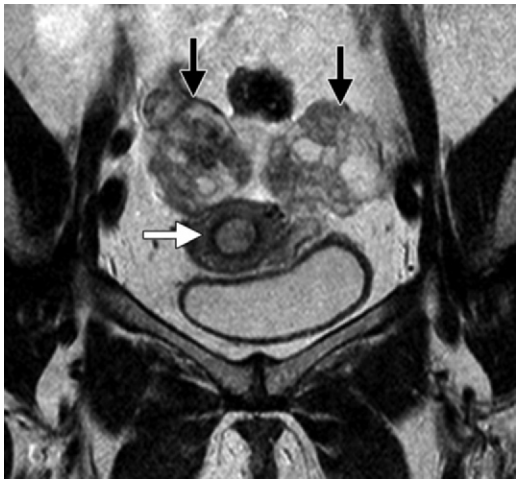


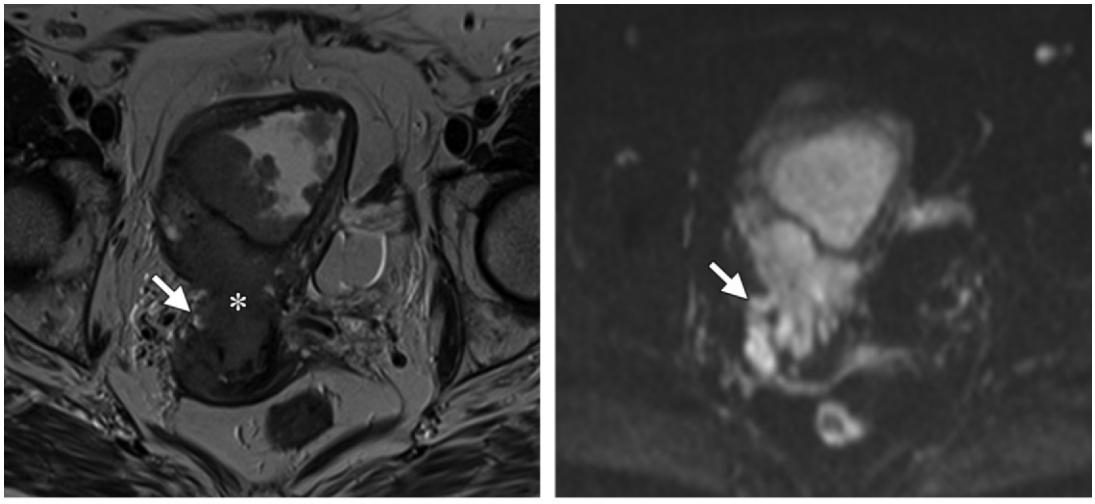
Figure 5. Stage IIIA endometrial carcinoma (mixed high-grade serous papillary and grade 3 endometrioid adenocarcinoma) in a 71-year-old woman. Coronal T2-weighted MR image shows an endometrial tumor with intermediate signal intensity within the endometrial cavity (white arrow) and enlarged ovaries (black arrows), which demonstrate abnormal heterogeneous signal intensity, a finding consistent with ovarian metastases.

Stage II.—In the revised FIGO staging system, stage II represents stromal invasion of the cervix, a finding that is best depicted on sagittal and axial oblique T2-weighted images as an area of low signal intensity (the cervical stroma) disrupted by the intermediate- or high-signal-intensity tumor (Fig 3). Stage II endometrial tumors must be differentiated from stage I tumors, which enter the endocervical canal and widen the internal os, with preservation of the normal low-signal-intensity cervical stroma (1).

The use of dynamic imaging after administration of intravenous contrast material helps distinguish between stromal invasion and polypoid tumor protruding from the endometrial cavity and into the endocervix (1). On delayed phase images (obtained 2–3 min after administration of contrast material), normal enhancement of the cervical mucosa excludes stromal invasion (53).

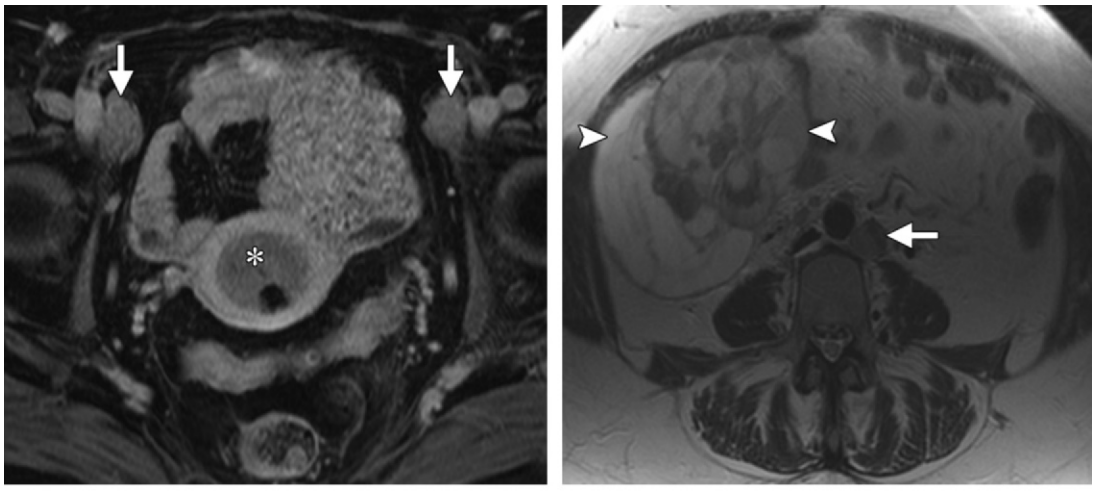
It is important to distinguish between stage I and stage II disease because of their different prognoses. Invasion of the cervical stroma is associated with a high risk for lymphovascular space invasion, which directly correlates with the risk for lymph node metastases.

Stage III.—Stage III reflects local or regional tumor spread: that is, beyond the uterus but not outside the true pelvis. Stage IIIA tumors (those that invade the serosa) appear as an area of intermediate to high signal intensity that disrupts the contour of the outer myometrium (Fig 4). In stage IIIA disease, the adnexa is also involved, particularly in high-grade or type 2 tumors (Fig 5). The use of DWI improves depiction of extrauterine metastatic deposits. In stage IIIB disease, tumor extends into the parametrium, with vaginal involvement by direct invasion or metastatic spread, a finding indicated by segmental loss of low signal intensity in the vaginal wall on T2-weighted images (Fig 6). Stage IIIC disease is characterized by lymph node involvement, which



a. b.

Figure 6. Stage IIIB endometrial carcinoma (high-grade serous papillary adenocarcinoma) in a 67-year-old woman. **(a)** Axial T2-weighted MR image shows a tumor (*) with intermediate signal intensity invading the cervical stroma and extending into the right parametrium (arrow). **(b)** Corresponding axial diffusion-weighted image shows an area of restricted diffusion within the tumor extending into the right parametrium (arrow).

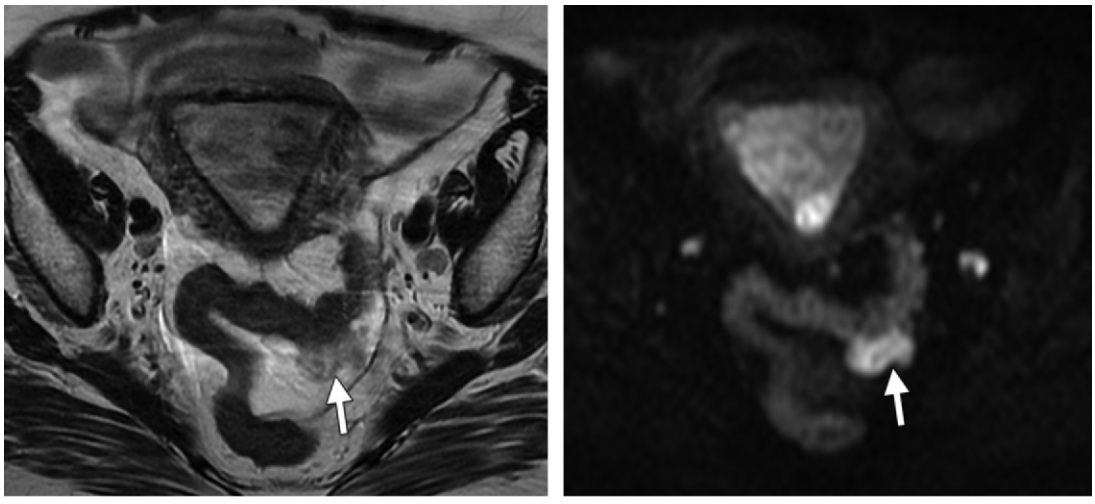


7. 8.

Figures 7, 8. **(7)** Stage IIIC1 endometrial carcinoma (high-grade serous carcinoma) in a 75-year-old woman. Axial T1-weighted fat-saturated MR image obtained after administration of intravenous gadolinium-based contrast material shows the tumor (*), which demonstrates relatively poor enhancement compared with the avidly enhancing myometrium. Bilateral enlarged external iliac lymph nodes (arrows) are also seen. **(8)** Stage IIIC2 endometrial carcinoma (grade 3 endometrioid adenocarcinoma) in a 59-year-old woman. Axial T2-weighted MR image shows an enlarged left paraaortic lymph node (arrow) and an endometrial tumor that has spread to the right ovary (arrowheads), which is grossly enlarged and heterogeneous, a finding consistent with ovarian metastasis.

is further subdivided into pelvic (stage IIIC1) and paraaortic (stage IIIC2) node involvement in the revised FIGO staging system (Figs 7, 8). MR imaging features that are considered suspicious for lymph node involvement include a size larger than 1 cm, multiplicity, an irregular contour, necrosis, and abnormal signal intensity similar to that of the primary tumor. The revised FIGO staging system reflects the different prognoses associated with lymph node metastases in the pelvic and paraaortic regions (3).

Teaching Point



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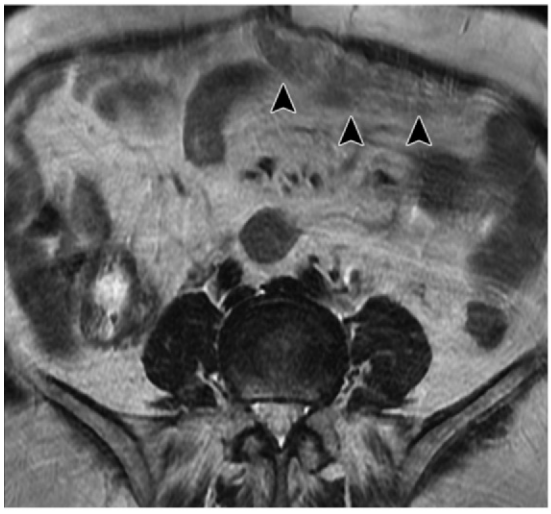


c.

Figure 9. Stage IVB endometrial carcinoma (high-grade serous papillary adenocarcinoma) in a 61-year-old woman. **(a, b)** Axial T2-weighted **(a)** and diffusion-weighted **(b)** MR images show peritoneal deposits (arrow), a finding typical for serous papillary endometrial carcinoma. **(c)** Axial T2-weighted MR image shows omental cake (arrowheads), a pattern of metastatic spread similar to that of ovarian carcinoma.

Stage IV.—Stage IV disease represents direct invasion of the bladder or rectal mucosa (stage IVA) or the presence of distant metastases (stage IVB). On T2-weighted images, extension of tumor directly into the normally hyperintense vesical or rectal mucosa is indicative of endometrial tumor invasion into the bladder or rectum. Bullous edema, which appears as thickening of the high-signal-intensity mucosal layer, is not indicative of mucosal invasion. Disruption of the hypointense muscularis layer does not indicate stage IV disease because it cannot be visualized at subsequent cystoscopy or sigmoidoscopy. In stage IVB disease, distant metastases, including paraaortic lymphadenopathy, occur above the renal vessels, and inguinal lymph node metastases are seen (54). Malignant ascites and peritoneal deposits are more common in type 2 endometrial tumors and high-grade type 1 tumors. Type 2 (serous papillary and clear cell adenocarcinoma) tumors demonstrate a pattern of metastatic spread similar to that of ovarian carcinoma, with omental cake and serosal deposits (Fig 9). Liver, lung, and bone metastases are rare at the time of manifestation.

Cervical Carcinoma

Although cervical carcinoma is the third most common gynecologic malignancy in the United States, it remains the most common gynecologic malignancy worldwide; an estimated 540,000 women were diagnosed with cervical carcinoma in 2010 (11). The highest prevalence of cervical carcinoma is in Central and South America, South Central Asia, and parts of Africa, with Asia accounting for approximately 80% of cervical carcinoma diagnoses (12). Whereas the introduction of cervical cancer screening programs and improved treatment strategies have caused a reduction in mortality rates in industrialized nations, there has been little change in developing countries, where tumors are usually detected at an advanced stage. Because of its epidemiologic characteristics, cervical carcinoma continues to be staged at clinical examination, with anesthesia and often with cystoscopy and sigmoidoscopy, according to the FIGO classification system (55). However, there are discrepancies between tumors

that are staged at clinical examination according to the FIGO staging system and those that are staged at surgery, with an error rate as high as 32% in patients with stage IB disease and 65% in patients with stage III disease (13). In addition, clinical staging has been shown to be limited in evaluating important prognostic factors such as parametrial and pelvic sidewall invasion, tumor size, and lymph node metastases (54,56). Studies have reported discordance between findings seen at clinical evaluation and MR imaging. In particular, endocervical lesions are often discrepant, with underestimation of tumor size at clinical examination compared with that at MR imaging. Overall, the accuracy of MR imaging for depicting tumor size is 93%, whereas that of clinical staging is less than 60% (57). Tumor size is clinically important for risk stratification because of its direct correlation with lymph node involvement, prognosis, and patient outcome (58,59). This relationship is reflected in the FIGO classification system, in which tumor stages IB and IIA are subdivided according to size (smaller or larger than 4 cm in the maximal dimension).

Effect of Imaging on Risk Stratification and Disease Management

The revised FIGO staging system now recommends performing computed tomography (CT) or MR imaging when available. CT is of limited use in local staging, but it is able to depict extrauterine spread of disease, including enlarged lymph nodes, fistulation into the bladder or rectum, and distant metastases. In contrast, MR imaging has exquisite soft-tissue contrast resolution and is able to clearly define the local extent of primary tumor and depict metastatic spread (59,60). It accurately depicts findings that are important for prognosis, including tumor size, parametrial and pelvic sidewall invasion, bladder or rectal invasion, and lymph node metastases. Accurate risk stratification of patients with cervical carcinoma is used to determine the most appropriate management pathway, which ensures the best clinical outcome.

There is no role for MR imaging in patients with stage IA disease because it is, by definition, microscopic and, therefore, not visible at MR imaging. NCCN guidelines state that imaging is optional in patients with tumors that are stage IB1 or lower. Chest radiography, CT, or positron emission tomography (PET)/CT may be considered in patients with distant disease spread. The NCCN guidelines also state that MR imaging be used to exclude disease high in the endocervix (61). However, treatment of patients with early stage disease (stages IIA1 and IB1) comprises surgery, including trachelectomy and radical hysterectomy. Therefore, it is crucial that tumor extension beyond the cervix be identified preoperatively. If parametrial invasion or lymph node metastases are detected at surgery, adjuvant chemoradiotherapy is necessary. In this context, patients will have undergone unnecessary surgery and have higher postoperative morbidity associated with chemoradiotherapy. Evaluation of parametrial invasion is difficult at clinical examination, depending on the extent of tumor invasion, with studies reporting variable accuracy of 29%–53% (62). In comparison, MR imaging is able to depict parametrial invasion with 88%–97% accuracy and 93% specificity (1,63). Most important, MR imaging helps exclude parametrial invasion with a negative predictive value of 94%–100%, enabling identification of patients who are suitable for radical surgery, which is contraindicated in patients with parametrial invasion (57,64,65). In addition, MR imaging assessment of patients' suitability to undergo trachelectomy is essential; ideally, trachelectomy requires that tumors be smaller than 2 cm, the cervix be longer than 2 cm, and the distance from the internal cervical os be more than 1 cm (64,66).

Teaching Point

Bulky early stage disease includes stages IB2 and IIA2, with tumors measuring more than 4 cm. The size of the primary tumor may be precisely determined at MR imaging with an accuracy of 93%, stratifying patients into an appropriate prognostic group and treatment regimen (57). Given the poorer prognosis of bulky tumors, patients undergo the same treatment pathway as those with locally advanced tumors (stage IIB and above), including chemo- and radiation therapy. MR imaging also provides information for brachytherapy planning.

MR imaging may exclude local invasion into the bladder and rectum with a negative predictive value of 100% (65–69). In comparison, when FIGO staging is performed on the basis of cystoscopy or sigmoidoscopy findings, bladder

Table 5
Pearls and Pitfalls of MR Imaging of Cervical Carcinoma

Pearls
Preservation of an intact low-signal-intensity cervical stromal ring excludes parametrial invasion.
Multiphase contrast-enhanced imaging or DWI may improve delineation of small tumors (important in patients being considered for trachelectomy).
Use of dynamic intravenous contrast medium may help distinguish between cervical and endometrial tumors in patients with biopsy-proved adenocarcinoma, especially when both the cervix and lower uterine segment are involved.
Pitfalls
Cervical stroma can be indistinct due to the presence of stromal edema in patients with large tumors.
High-signal-intensity thickening of the bladder mucosa on T2-weighted images indicates bullous edema and is not a sign of direct invasion.*
After hysterectomy, nodularity or fullness at the vaginal vault may be seen on T1-weighted images and should not be mistaken for a lesion.

*One study has shown that the addition of dynamic contrast-enhanced T1-weighted images may improve the accuracy of distinguishing edema from bladder and rectal invasion (70).

or rectal invasion is identified in less than 5% of patients. In view of this, the revised FIGO staging system states that cystoscopy and sigmoidoscopy are no longer mandatory. However, when MR imaging findings are equivocal or assessment is difficult due to the presence of bullous edema, endoscopy may be used to depict or exclude mucosal invasion. Furthermore, distant metastases, including liver and bone metastases, which are not apparent at clinical assessment, may be depicted at MR imaging.

The presence of involved pelvic lymph nodes does not alter the FIGO stage, but it is associated with a poorer prognosis and alters the treatment in patients with cervical carcinoma. MR imaging is sensitive and specific for depicting lymph node metastases (see section on "Lymph Node Evaluation") (71,72). In early stage disease, the presence of pelvic lymph node metastases significantly causes survival rates to decrease, from 85%–90% to 50%–55% (58). Therefore, lymph nodes that are enlarged or have other suspicious features at preoperative MR imaging indicate the need for a two-stage surgical procedure. Initially, laparoscopic lymph node sampling is performed before definitive surgery. If laparoscopy findings are negative for tumor involvement, hysterectomy or trachelectomy may be performed. Surgical lymph node assessment remains the reference standard for detecting lymph node metastases, although it is associated with complications (73,74).

Appearances at MR Imaging

The normal cervix demonstrates a trilaminar pattern of signal intensity, with high-signal-intensity endocervical mucosal glands surrounded by low-signal-intensity stroma and a rim of intermediate-signal-intensity smooth muscle. On T2-weighted images, cervical carcinoma appears as an intermediate- to high-signal-intensity mass that replaces the low-signal-intensity cervical stroma.

Enhancement of cervical cancer varies on dynamic multiphase contrast-enhanced T1-weighted images, with small tumors enhancing earlier than adjacent cervical stroma and larger tumors demonstrating a variable degree of enhancement. Depiction of poorly circumscribed lesions may be aided by the use of DWI and ADC mapping; tumors demonstrate high signal intensity on diffusion-weighted images and low signal intensity on corresponding ADC maps, and the ADC value of cervical cancer is significantly lower than that of normal cervical tissue (Table 5) (37,75,76).

Revised FIGO Staging

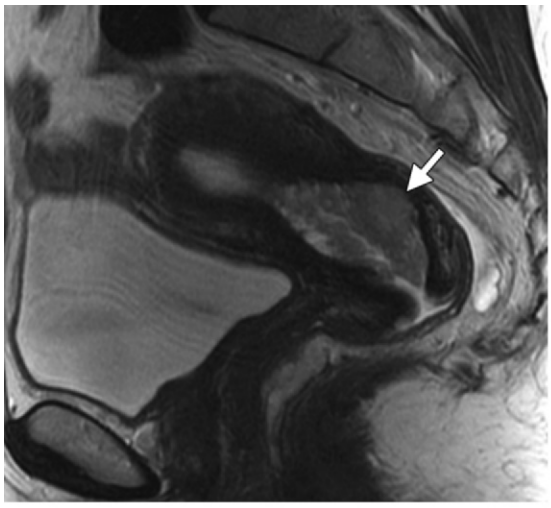
The revised FIGO staging system for cervical carcinoma was implemented on June 1, 2009 (Table 6). In the new FIGO staging system, the following three changes, which affect imaging and interpretation, were made: First, the use of diagnostic imaging, including CT and MR imaging, to stage cervical tumors is recommended but remains nonmandatory (55). CT is able to depict lymph nodes, hydronephrosis, and distant metastases. MR imaging has superb soft-tissue resolution and is able to delineate both the local extent of tumor and distant tumor spread.

Table 6
FIGO Staging of Cervical Carcinoma

Stage	Description
0	Tumor confined to the surface layer (the cell lining) of the cervix; also called carcinoma in situ
I	Extension deeper into the cervix with no spread beyond (extension to the corpus is disregarded)
IA	Invasive carcinoma; may only be diagnosed at microscopy
IA1	Stromal invasion 3.0 mm deep and extension 7.0 mm
IA2	Stromal invasion >3.0 mm and 5.0 mm with extension ≤7.0 mm
IB	Clinically visible lesions limited to the cervix uteri or preclinical cancers higher than stage IA
IB1	Clinically visible lesion 4.0 cm in greatest dimension
IB2	Clinically visible lesion >4.0 cm in greatest dimension
II	Cervical carcinoma extends beyond the uterus but not to the pelvic wall or the lower one-third of the vagina
IIA	No parametrial invasion
IIA1	Clinically visible lesion 4.0 cm in greatest dimension
IIA2	Clinically visible lesion >4.0 cm in greatest dimension
IIB	With obvious parametrial invasion
III	Extension to the pelvic wall, involvement of lower one-third of the vagina, or hydronephrosis or nonfunctioning kidney
IIIA	Involvement of lower one-third of the vagina with no extension to the pelvic wall
IIIB	Extension to the pelvic wall, hydronephrosis, or nonfunctioning kidney
IV	Extension beyond the true pelvis or involvement of the bladder or rectal mucosa (biopsy proved); bullous edema does not convey stage IV disease
IVA	Spread to adjacent organs
IVB	Spread to distant organs

Second, stage II tumors extend beyond the uterus but not to the pelvic sidewall or the lower one-third of the vagina. Stage IIA tumors involve the upper two-thirds of the vagina, and stage IIB tumors demonstrate parametrial invasion. In the revised FIGO staging system, stage IIA was also subdivided according to size into stages IIA1 (tumors 4 cm or smaller) and IIA2 (tumors larger than 4 cm), a reflection of recent prognostic data regarding the size of IIA tumors and patient outcomes. In contrast, no such data support a subdivision of stage IIB (77). The presence of parametrial invasion alone is a poor prognostic indicator, with a high risk for recurrence.

Third, examinations performed with anesthesia, including cystoscopy and proctoscopy, are optional and no longer mandatory, a change from the 1988 FIGO staging system (78). Before 2009, such examinations were the primary method for staging cervical cancer by assessing the fixation of the tumor to the parametrium and pelvic sidewall. Proctoscopy and cystoscopy are still used to depict stage IVA disease, in which tumor invades rectal and bladder mucosa. However, T2-weighted MR imaging accurately depicts bladder (sensitivity, 75%) and rectal (sensitivity, 71%) involvement (79). Moreover, T2-weighted MR imaging findings may be used to confidently exclude bladder or rectal involvement with a negative predictive value of 100%, obviating the need for invasive procedures (67). It should be noted that T2-weighted imaging also has a high false-positive rate due to the presence of bullous edema, which appears as thickened, high-signal-intensity mucosa.



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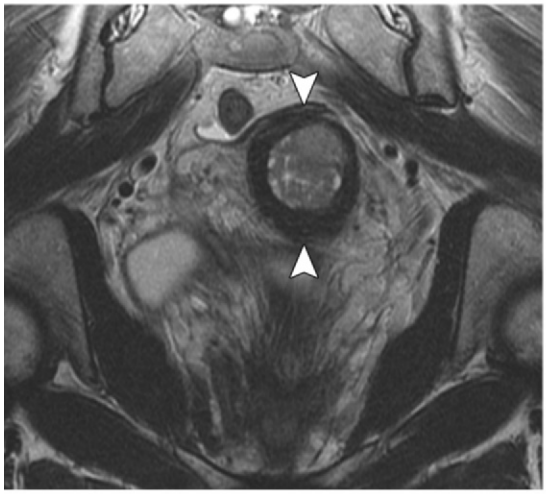

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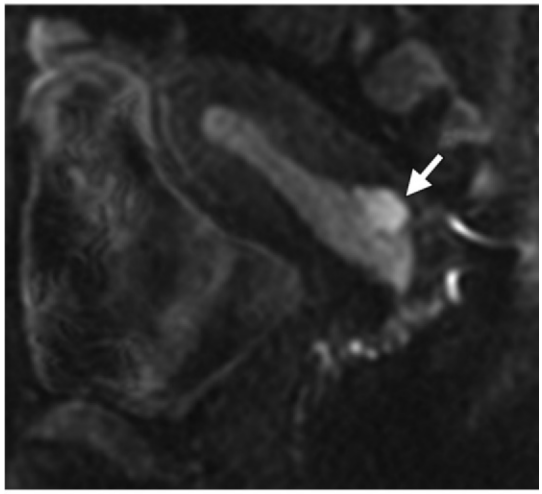


c.

Figure 10. Stage IB1 cervical carcinoma (squamous cell carcinoma) in a 36-year-old woman. **(a, b)** Sagittal **(a)** and axial oblique **(b)** T2-weighted MR images show a mass (arrow in **a**) with intermediate signal intensity within the endocervical canal. The surrounding low-signal-intensity cervical stroma is intact (arrowheads in **b**), excluding parametrial invasion. It is difficult to determine the exact size of the tumor on T2-weighted images. **(c)** Sagittal diffusion-weighted MR image shows an area of high signal intensity within the small endocervical tumor (arrow), a finding indicative of restricted diffusion. Tumors that arise entirely within the endocervical canal are difficult to accurately stage at clinical examination.

Stage I.—In stage I, tumors are confined to the cervix. Stage IA is defined as a microinvasive tumor that cannot be reliably depicted on T2-weighted images; thus, there is no established role for MR imaging in evaluating patients with a stage IA tumor. Stage IB tumors are further subdivided by size: Stage IB1 tumors are smaller than 4 cm, and stage IB2 tumors are 4 cm or larger (Fig 10). On T2-weighted images, stage IB tumors typically demonstrate intermediate to high signal intensity compared with the cervical stroma, which demonstrates low signal intensity.

MR imaging is recommended in patients with clinical stage IB disease or higher because of the importance of accurate measurement of tumor size and identification of parametrial invasion, lower vaginal involvement, and lymph node metastases (63). Identification of these prognostic factors is crucial because their presence precludes surgery (72,80).

Stage II.—In stage II, tumors extend beyond the uterus and involve the upper two-thirds of the vagina but do not extend to the pelvic sidewall or the lower one-third of the vagina. Stage II is further subdivided according to the absence (stage IIA) or presence (stage IIB) of parametrial invasion. Involvement of the upper two-thirds of the vagina is seen on T2-weighted images as a high-signal-intensity lesion disrupting the low-signal-intensity vaginal wall. A large exophytic polypoid cervical tumor may widen the vaginal

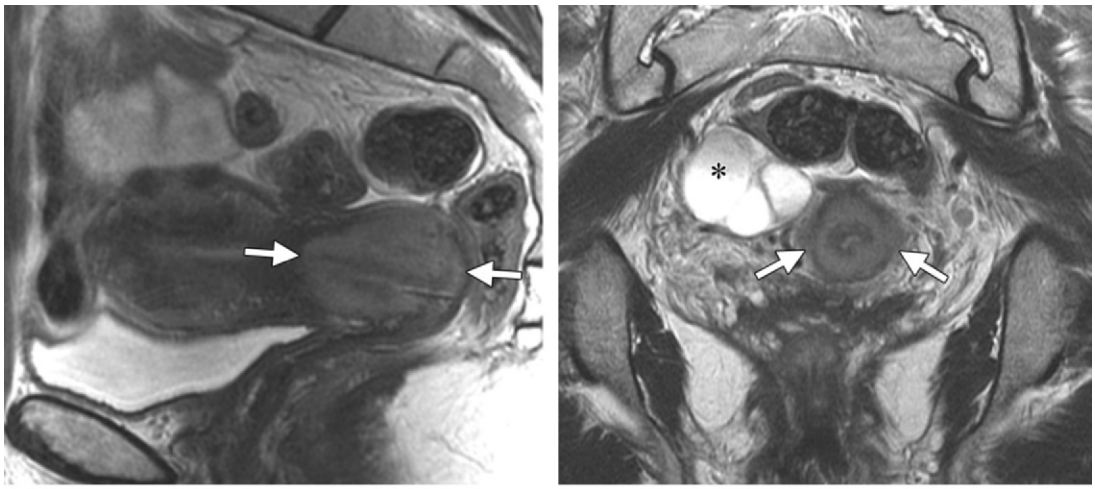


Figure 11. Stage IIB cervical carcinoma (adenocarcinoma) in a 48-year-old woman. **(a)** Sagittal T2-weighted MR image shows a tumor (arrows) with intermediate signal intensity replacing the normal low-signal-intensity cervical stroma. **(b)** Axial oblique T2-weighted MR image obtained perpendicular to the endocervical canal shows interruption of the low-signal-intensity cervical stromal ring. Nodular soft tissue extends bilaterally into the parametrium (arrows), a finding indicative of parametrial invasion. Right hydrosalpinx (*) is also incidentally noted.

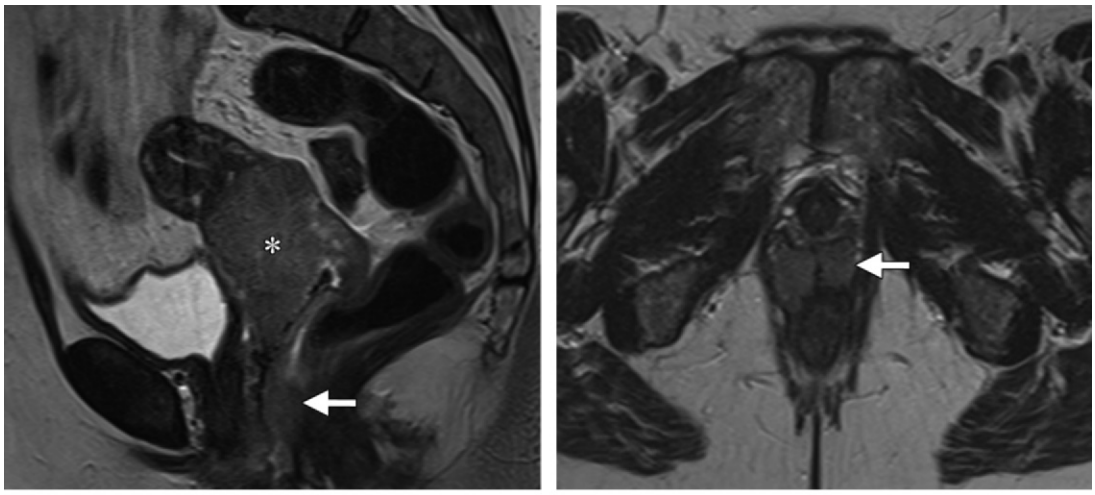
fornix, mimicking vaginal infiltration; however, in these cases, the low-signal-intensity vaginal wall remains intact. According to the FIGO annual report database, the maximum tumor diameter affects the prognosis of patients with a stage IIA tumor. Hence, stage IIA is subdivided into stages IIA1 (those that are 4 cm or smaller) and IIA2 (those that are larger than 4 cm) (77).

In stage IIB, parametrial invasion is present but does not extend to the pelvic sidewall (Fig 11). Stage IIB is not subdivided by size because the presence of parametrial invasion alone indicates a poor prognosis, which is reflected in the FIGO staging system. Parametrial invasion is indicated by disruption of the low-signal-intensity cervical stromal ring, with nodular or irregular tumor extending into the parametrium (59). Segmental disruption of the cervical stroma is highly indicative of parametrial invasion; however, additional features, such as a spiculated tumor-parametrium interface, soft-tissue extension into the parametrium, and encasement of the periuterine vessels, improve confidence in diagnosing parametrial invasion (58). Conversely, parametrial invasion may be confidently excluded, with specificity as high as 99%, if the low-signal-intensity cervical stromal rim is thicker than 3 mm, a finding known as the "hypointense rim" sign (62). MR imaging has 97% specificity and 100% negative predictive value for depicting parametrial invasion (67).

In large tumors, parametrial invasion may be overestimated on T2-weighted images due to the presence of stromal edema, which is caused by compression of the tumor or inflammation (58). Studies have reported that MR imaging has 69% sensitivity and 93% specificity for depicting parametrial invasion (57,65). Its accuracy varies according to the size of the tumor, with 96% accuracy in small tumors and 70% accuracy in large tumors (71). Postbiopsy hemorrhage may cause peristromal stranding, another pitfall of assessing parametrial invasion (58,62). In these cases, DWI and ADC mapping may help determine the true extent of tumor (43).

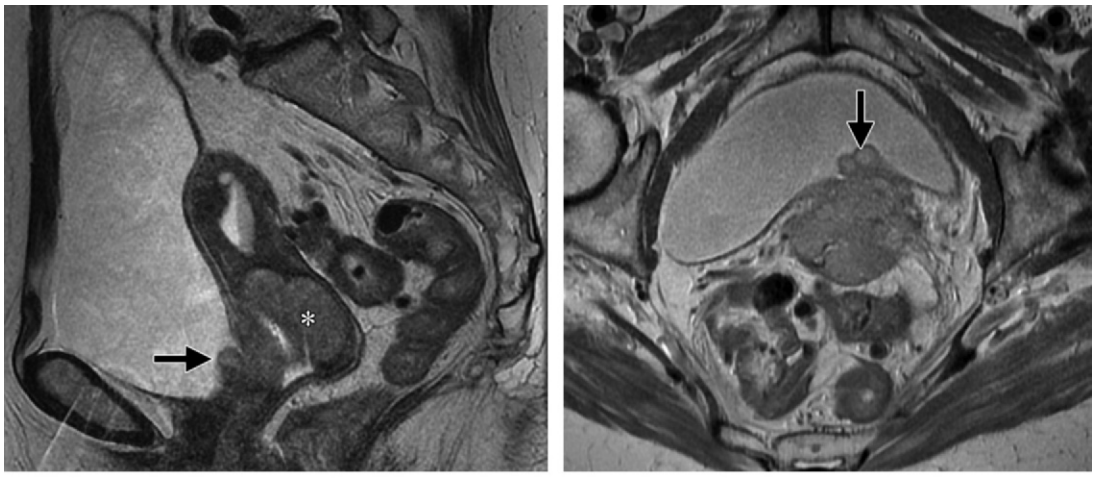
Stage III.—In stage IIIA, tumors extend to the lower one-third of the vagina but not the pelvic sidewall (Fig 12). Extension to the pelvic sidewall or involvement of the ureters, which causes hydronephrosis, is classified as stage IIIB. Visualization of tumor within 3 mm of the obturator internus, levator ani, and piriform muscles or the iliac vessels is considered highly suggestive of stage IIIB disease (62).

Teaching Point



a. b.

Figure 12. Stage IIIA cervical carcinoma (squamous cell carcinoma) in a 61-year-old woman. Sagittal **(a)** and axial **(b)** T2-weighted MR images show a bulky cervical tumor (∗ in **a**) with intermediate signal intensity extending into the lower one-third of the vagina (arrow).



a. b.

Figure 13. Stage IVA cervical carcinoma (adenocarcinoma) in a 76-year-old woman. Sagittal **(a)** and axial **(b)** T2-weighted MR images show a cervical tumor (∗ in **a**) with intermediate signal intensity and nodular local invasion into the bladder (arrow).

Stage IV.—Stage IVA reflects local pelvic organ invasion, which is characterized by infiltration of the rectal mucosa or urinary bladder (Fig 13). Rectal invasion usually follows the path of the uterosacral ligaments because the peritoneal reflection of the pouch of Douglas acts as a barrier for direct invasion from the posterior fornix and into the rectum (62). On T2-weighted images, rectal invasion is indicated by segmental disruption of the low-signal-intensity muscularis layer by the hyperintense tumor. The reported sensitivity and specificity of MR imaging for depicting bladder or rectal invasion are 71%–100% and 88%–91%, respectively (67,68). Bullous edema within the bladder causes high-signal-intensity thickening along the superficial internal surface of the bladder, a finding that may mimic tumor involvement (63). Conversely, bladder or rectal

involvement may be confidently excluded at MR imaging with a negative predictive value of 100%, making cystoscopy and sigmoidoscopy redundant (67). In stage IVB, tumors spread beyond the pelvis, including the paraaortic and inguinal lymph nodes, lung, liver, and bone. Although the presence of pelvic lymph node metastases does not change the FIGO stage, it guides the surgical approach in patients with early stage tumors.

Lymph Node Evaluation

In patients with endometrial and cervical cancer, the presence of lymph node metastases confers a poor prognosis and adversely affects survival (80,81). Therefore, identification of involved pelvic and paraaortic lymph nodes alters the therapeutic approach. With accuracies of 83%–90% and 86%–90%, respectively, MR imaging and CT have comparable accuracies for depicting nodal involvement (82–85). Both modalities rely on size criteria, such as a short-axis diameter of up to 10 mm in normal nodes, a characteristic that inevitably leads to low sensitivity due to the inability of CT and MR imaging to depict metastases in normal-sized lymph nodes (26,83,86,87).

Detection of lymph nodes increases with the use of DWI because of the conspicuous high signal intensity of nodes, although correlation with T2-weighted imaging is advised. However, differentiating an involved lymph node from a benign one is difficult because both may demonstrate high signal intensity at DWI (88). Lin et al (89) reported that with MR images obtained at 3 T, it was possible to successfully differentiate between metastatic and benign lymph nodes by combining ADC, relative ADC, and size criteria. Further studies of 1.5-T MR images reported conflicting results (90,91). Other promising studies have shown that combining DWI with ultrasmall super paramagnetic iron oxide (USPIO)-enhanced MR imaging has a role in preoperative planning (92). It has been demonstrated that the use of lymph node–specific MR imaging contrast agents, such as USPIO, improves sensitivity for depicting lymph node metastases, with sensitivity of 93% with the use of USPIO criteria compared with 29% with the standard size criterion (>1 cm) (86).

Conclusions

The revised FIGO staging system has served to improve risk stratification in patients with endometrial or cervical carcinoma. As our knowledge and understanding of tumor biology improve, staging systems must also improve in order to identify significant prognostic factors, which will inform treatment decisions. The FIGO staging system provides a robust, uniform method of describing tumor extent, enabling accurate exchange of information between clinical centers and consistent treatment strategies. Ultimately, it provides high-quality data, including response to treatment, survival, and mortality.

In the revised FIGO staging system, endometrial carcinoma continues to be surgically staged. However, studies have shown that MR imaging is accurate in delineating local disease extent, and MR imaging findings in conjunction with tumor grade and histologic subtype enable preoperative risk stratification, which guides surgery and chemoradiotherapy. Studies have also shown that MR imaging has higher accuracy than clinical examination and surgical staging in delineating local extent of cervical carcinoma. Consequently, the revised FIGO staging system recommends that, when available, imaging be used as an adjunct to clinical assessment in staging cervical carcinoma. Thus, it is important that radiologists familiarize themselves with the revised staging classification of endometrial and cervical carcinoma and understand their relevance to disease management.

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The Revised FIGO Staging System for Uterine Malignancies: Implications for MR Imaging

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Endometrial carcinomas are divided into two histologic subtypes. Endometrioid adenocarcinoma (type 1), the most common histologic subtype, accounts for almost 90% of cases of endometrial cancer, which are further subdivided according to the histologic grade of tumor differentiation, from grade 1 (well differentiated) to grade 3 (poorly differentiated). Type 2 endometrial carcinomas include serous papillary and clear cell adenocarcinomas. Serous papillary, clear cell, and grade 3 endometrioid adenocarcinomas demonstrate more aggressive tumor biologic characteristics and have a 50% pretest probability of locally advanced or distant disease at manifestation.

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In the revised FIGO staging system, stage II represents invasion of the cervical stroma. Involvement of only the endocervical glands and mucosa, with sparing of the cervical stroma (previously IIA disease in the 1988 FIGO staging system), was reclassified as stage I. It is important to distinguish cervical stromal invasion because it is associated with a higher risk for lymphovascular space invasion and confers a poorer prognosis.

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MR imaging features that are considered suspicious for lymph node involvement include a size larger than 1 cm, multiplicity, an irregular contour, necrosis, and abnormal signal intensity similar to that of the primary tumor. The revised FIGO staging system reflects the different prognoses associated with lymph node metastases in the pelvic and paraaortic regions (3).

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In addition, MR imaging assessment of patients' suitability to undergo trachelectomy is essential; ideally, trachelectomy requires that tumors be smaller than 2 cm, the cervix be longer than 2 cm, and the distance from the internal cervical os be more than 1 cm (64,66).

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Extension to the pelvic sidewall or involvement of the ureters, which causes hydronephrosis, is classified as stage IIIB. Visualization of tumor within 3 mm of the obturator internus, levator ani, and piriform muscles or the iliac vessels is considered highly suggestive of stage IIIB disease (62).