Cervical carcinoma is the third most common gynecologic malignancy and is typically seen in younger women, often with serious consequences. The International Federation of Gynecology and Obstetrics (FIGO) staging system provides worldwide epidemiologic and treatment response statistics. However, there are significant inaccuracies in the FIGO staging system, and magnetic resonance (MR) imaging, although not included in that system, is now widely accepted as optimal for evaluation of important prognostic factors such as lesion volume and metastatic lymph node involvement that will help determine the treatment strategy. MR imaging examination obviates the use of invasive procedures such as cystoscopy and proctoscopy, especially when there is no evidence of local extension. Brachytherapy and external beam therapy are optimized with MR imaging evaluation of the shape and direction of lesion growth. In general, T2-weighted MR imaging more clearly delineates cervical carcinoma and is preferred for evaluation of the lymph nodes. Dynamic gadolinium-enhanced T1-weighted imaging may help identify smaller tumors, detect or confirm invasion of adjacent organs, and identify fistulous tracts. MR imaging staging, when available, is invaluable for identifying important prognostic factors and optimizing treatment strategies.
Cervical carcinoma is the third most common gynecologic malignancy, with an average patient age at onset of 45 years (1,2). The International Federation of Gynecology and Obstetrics (FIGO) staging system is widely used for treatment planning but more often for standardization of epidemiologic and treatment results (Table 1) (2,3). This system is based on findings at clinical examination (performed with the patient under anesthesia), chest radiography, intravenous urography, barium enema studies, cystoscopy, and proctoscopy. There are significant inaccuracies in the FIGO staging system, with a 24%–39% error rate in gynecologic examinations (1–4). Without cross-sectional imaging, there is poor evaluation of deep pelvic invasion. Moreover, lesion volume and nodal metastasis, two significant prognostic factors, are not assessed (5). Therefore, magnetic resonance (MR) imaging is now widely accepted as optimal for evaluation of the main prognostic factors and selection of therapeutic strategy.

Table 1
Correlation between FIGO Staging, MR Imaging Staging, and Treatment of Cervical Carcinoma

<table>
<thead>
<tr>
<th>FIGO Staging</th>
<th>MR Imaging Staging</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Carcinoma in situ</td>
<td>Not visible</td>
<td>Surgery</td>
</tr>
<tr>
<td>I Confined to cervix</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IA Mioscopic</td>
<td>No tumor visible</td>
<td>Surgery</td>
</tr>
<tr>
<td>IA-1 Stromal invasion &lt;3 mm</td>
<td>Small enhancing tumor may be seen</td>
<td>Surgery</td>
</tr>
<tr>
<td>IA-2 &gt;3 mm, &lt;5-mm invasion, &lt;7-mm width</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IB Clinically visible (&gt;5 mm)</td>
<td>Tumor visible, intact stromal ring surrounding tumor</td>
<td>Surgery</td>
</tr>
<tr>
<td>IB-1 &lt;4 cm</td>
<td></td>
<td>Surgery</td>
</tr>
<tr>
<td>IB-2 &gt;4 cm</td>
<td></td>
<td>Radiation therapy</td>
</tr>
<tr>
<td>II Extends beyond uterus but not to pelvic wall or lower one-third of vagina</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IIA Vaginal extension, no parametrial invasion</td>
<td>Disruption of low-signal-intensity vaginal wall (upper two-thirds)</td>
<td>Surgery (if &lt;4 cm), radiation therapy (if &gt;4 cm)</td>
</tr>
<tr>
<td>IIB Parametrial invasion</td>
<td>Complete disruption of stromal ring with tumor extending into the parametrium</td>
<td>Radiation therapy</td>
</tr>
<tr>
<td>III Extension to lower one-third of vagina or pelvic wall invasion with hydronephrosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IIIA Extension to lower one-third of vagina</td>
<td>Invasion of lower one-third of vagina</td>
<td>Radiation therapy</td>
</tr>
<tr>
<td>IIIB Pelvic wall invasion with hydronephrosis</td>
<td>Extension to pelvic muscles or dilated ureter</td>
<td>Radiation therapy</td>
</tr>
<tr>
<td>IV Located outside true pelvis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IVA Bladder or rectal mucosa</td>
<td>Loss of low signal intensity in bladder or rectal wall</td>
<td>Radiation therapy</td>
</tr>
<tr>
<td>IVB Distant metastasis</td>
<td></td>
<td>Radiation therapy</td>
</tr>
</tbody>
</table>

In this article, we discuss MR imaging staging of uterine cervical carcinoma and correlate this staging approach with FIGO staging and treatment planning. We also offer suggestions for developing a comprehensive, clinically relevant MR imaging examination for the assessment of uterine cervical carcinoma.

Prognostic Factors

Correct identification of the factors influencing prognosis is crucial for treatment planning. Some of these factors are well depicted at MR imaging, whereas others depend on the histologic evaluation of the lesion (5).

Lesion volume is directly related to the prevalence of spread to lymph nodes. It is not well measured clinically and is highly variable within a FIGO stage. Although not included in the FIGO staging system, nodal disease has a great impact on survival, and the presence of metastatic lymph nodes indicates a poorer prognosis within each stage. A rising prevalence of unsuspected metastatic lymph nodes is found with each successive
Table 2
Reported Accuracies of MR Imaging Staging of Cervical Carcinoma

<table>
<thead>
<tr>
<th>Imaging Finding</th>
<th>Accuracy (%)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parametrial invasion</td>
<td>90–94</td>
<td>71</td>
<td>94</td>
</tr>
<tr>
<td>Vaginal extension</td>
<td>83–94</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Pelvic sidewall extension</td>
<td>86–95</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Bladder extension</td>
<td>96–99</td>
<td>83</td>
<td>100</td>
</tr>
<tr>
<td>Lymph node invasion</td>
<td>88–91</td>
<td>89</td>
<td>70–95</td>
</tr>
<tr>
<td>Overall</td>
<td>76–91</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

Source.—References 1–4,7–9.

Figure 1. MR imaging technique. Sagittal T2-weighted image shows the position of the axial 5-mm sections obtained in two sequences from the lower poles of the kidneys down to the pubis.

Stage, ranging from 5% positive pelvic nodes in stage IA2 to 55% in stage IV (2). Therefore, detection of nodal disease is crucial for treatment planning.

At histologic analysis, depth of invasion, tumor grade, and lymphatic vascular space invasion all have prognostic significance.

Roles of MR Imaging Staging
MR imaging examination obviates the use of invasive procedures such as cystoscopy and proctoscopy, especially when there is no sign of local extension (1-5). The best treatment modality for each patient (i.e., surgery or radiation therapy) can be determined more accurately with MR imaging, which has been shown to influence treatment planning in one-half of patients (2). Brachytherapy and external beam therapy are optimized with MR imaging evaluation of the shape and direction of lesion growth (5,6). MR imaging can also be used to identify important prognostic factors such as lesion volume and metastatic lymph node involvement that will help determine whether treatment will be palliative or curative (5,6).

Staging Criteria and Therapy
Correlation between FIGO staging, MR imaging staging, and treatment is summarized in Table 1. Reported accuracies of MR imaging staging of cervical carcinoma are shown in Table 2.

Surgery is the treatment of choice for stages lower than IIA, except for lesions over 4 cm in diameter (stage IB2 or IIA). Radiation therapy alone or combined with chemotherapy is preferred for stages IIB or higher or for lesions greater than 4 cm.

MR Imaging Technique
To limit bowel motion, it is recommended that patients fast for 4–6 hours prior to imaging. In addition, an antiperistaltic medication is administered intravenously or intramuscularly at the beginning of the examination.

Although a body coil has been shown to provide comparable staging accuracy, use of a phased-array coil increases resolution and decreases the time required for the examination (7). Sagittal and axial non-fat-saturated high-resolution T2-weighted echo-train spin-echo MR images (5-mm section thickness) (512 matrix) are obtained from the lower pole of the kidneys to the pubis (Fig 1). Coverage of the periaortic region is imperative, even if it is at the upper limit
of the phased-array coil. A fat-saturated T2-weighted sequence is not routinely used because it does not provide good contrast between the gynecologic organs and the surrounding tissues. However, it may be useful for evaluation of pelvic soft-tissue edema. Anterior saturation bands are routinely used to minimize respiratory artifacts. However, a posterior saturation band is not necessary. T2-weighted imaging is preferred for evaluation of the lymph nodes, which are more clearly distinguished from the hypointense muscles and blood vessels with this sequence (Fig 2).

Axial fat-suppressed spoiled gradient-echo breath-hold T1-weighted images are obtained once before and twice after dynamic intravenous injection of gadopentetate dimeglumine. Only the pelvic region is examined with T1-weighted imaging. Dynamic gadolinium-enhanced imaging is useful for evaluating small, enhancing cervical lesions, detecting or confirming invasion of adjacent organs, and identifying fistulous tracts (10, 11).

Figure 2. Lymph node evaluation. (a) T1-weighted MR image demonstrates an enlarged left common iliac lymph node (arrow) that is isointense relative to blood vessels and muscles. (b) On a T2-weighted MR image, the enlarged lymph node (arrow) is more clearly differentiated from these structures.

MR Imaging Findings

Tumor

Cervical carcinoma has intermediate signal intensity at T2-weighted imaging and is seen disrupting the low-signal-intensity fibrous stroma (Fig 3). The tumor can demonstrate a wide variety of morphologic features and may be exophytic (Fig 4), infiltrating (Fig 5), or endocervical with a barrel shape (Fig 6). In young women, cervical carcinoma usually originates from the squamocolumnar junction and tends to be more exophytic, whereas in older women it originates more often in the endocervical canal. The bulk of the lesion is centered at the level of the cervix, with either protrusion into the vagina or invasion of the lower myometrium. This permits differentiation from an endometrial mass (polyp or adenocarcinoma), which is centered in the endometrial cavity but protrudes into the endocervical canal. Prolapsed submucous fibroids are distinctly more hypointense at T2-weighted imaging than cervical carcinomas.

In general, cervical carcinoma is better defined at T2-weighted imaging, but small tumors may
Figure 7. Cervical carcinoma. (a) Axial T2-weighted MR image shows a small, slightly hyperintense carcinoma posterior to and to the left of the cervix (arrow). (b, c) On consecutive axial fat-saturated T1-weighted MR images obtained shortly after intravenous injection of gadopentetate dimeglumine, the carcinoma demonstrates rapid enhancement (arrow).

Figure 7. Cervical carcinoma. (a) Axial T2-weighted MR image shows a small, slightly hyperintense carcinoma posterior to and to the left of the cervix (arrow). (b, c) On consecutive axial fat-saturated T1-weighted MR images obtained shortly after intravenous injection of gadopentetate dimeglumine, the carcinoma demonstrates rapid enhancement (arrow).

Vagina
Disruption of the hypointense vaginal wall with hyperintense thickening at T2-weighted imaging and contrast material enhancement at T1-weighted imaging are signs of vaginal invasion (Fig 10). For staging purposes, it is helpful to exclude invasion of the lower one-third of the vagina, which increases the stage and implies modification of the strategy for radiation therapy. However, vaginal extension is well evaluated clinically. If bulky lesions are present, it may be difficult to identify invasion of the fornices at MR imaging.

Parametria
Preservation of a hypointense fibrous stromal ring at T2-weighted MR imaging has a high negative predictive value for parametrial invasion (Fig 11) (1,2). With disruption of the stromal...
Figures 8, 9. Cervical carcinoma. (8a) Axial T2-weighted MR image demonstrates a hyperintense central cervical carcinoma (arrow), in contrast to the hypointense cervical stroma. (8b) On an axial fat-saturated T1-weighted MR image obtained after dynamic intravenous injection of gadopentetate dimeglumine, the carcinoma demonstrates intense enhancement (arrow). (9) Sagittal T2-weighted MR image shows a long, infiltrating central cervical carcinoma. Such a tumor is difficult to evaluate at clinical examination alone.

Figure 10. Cervical carcinoma with vaginal invasion. Sagittal (a) and axial (b) T2-weighted MR images show a posterior cervical carcinoma invading the posterior vaginal fornix (arrow).
Figure 11. Noninvasive cervical carcinoma. Axial T2-weighted MR image shows a cervical carcinoma (arrow) with preservation of the normal hypointense cervical stroma. This finding is a reliable indication that there is no parametrial invasion.

ring but no definite parametrial mass, there may be microscopic invasion (false-negative findings). Complete disruption of the ring with nodular or irregular tumor signal intensity extending into the parametrium are reliable signs of invasion (Fig 12). Linear stranding around the cervical mass is suggestive of parametrial invasion but may be due to peritumoral inflammatory tissue (false-positive findings) (1,2). Unilateral or bilateral parametrial invasion is a definite contraindication to surgery. Contrast material–enhanced T1-weighted imaging has not proved to be more accurate than T2-weighted imaging in this setting (13,14).

Pelvic Wall
Tumor extending to involve the internal obturator, piriform, or levator ani muscles, with or without a dilated ureter, indicates pelvic wall invasion (Fig 13). Ureteral obstruction at the level of the tumor is considered to be an indication of wall invasion.

Bladder and Rectum
Bladder or rectal invasion is present when disruption of their normal hypointense walls is seen at T2-weighted imaging, with or without a mass protruding into the lumen (Fig 14) (8). Dynamic gadolinium-enhanced T1-weighted sequences are helpful for confirming invasion and identifying fistulous tracts (Figs 15, 16) (1,2,8). Hyperintense
Figure 14. Cervical carcinoma with bladder invasion. Sagittal T2-weighted MR images obtained in two different patients demonstrate bladder wall invasion (arrow) with disruption of the normal hypointense bladder wall and a mass protruding into the lumen.

Figure 15. Cervical carcinoma with rectal invasion. Axial (a) and sagittal (b) T2-weighted MR images and corresponding axial contrast-enhanced T1-weighted MR image (c) show a cervical carcinoma with direct extension into the rectal wall. There is irregular thickening of the anterior rectal wall (arrow), which enhances after injection of gadopentetate dimeglumine.
thickening of the bladder mucosa at T2-weighted imaging indicates edema and is not a direct sign of invasion. However, this “bullous edema sign” of the posterior wall mucosa should be analyzed carefully for any associated nodulation suggestive of tumor (Fig 17) (8).

**Lymph Nodes**

Lymph node disease detection is based only on a size criterion, the most widely accepted being a transverse diameter exceeding 10 mm (9,15). Lymph nodes are best detected with T2-weighted imaging (Fig 18), at which they demonstrate intermediate signal intensity and are well differentiated from the hypointense muscles and blood vessels. A slightly hyperintense ring flow artifact is often found in the iliac veins and should not be confused with adenopathy (Fig 19). When treatment planning changes due to a suspicious increase in the volume of a lymph node, biopsy should be performed because the node may be falsely positive due to inflammation.

**Conclusion**

FIGO staging provides worldwide epidemiologic and treatment response statistics. However, MR imaging staging, when available, is invaluable for optimizing treatment strategies and identifying important prognostic factors.

**References**

Figures 18, 19.  

18. Lymph node. Axial T2-weighted MR image shows a slightly hyperintense lymph node (arrow) that is well differentiated from muscles and blood vessels.

19. Ring flow artifact. Axial T2-weighted MR image demonstrates a slightly hyperintense ring flow artifact (arrows), a finding that is often seen in the iliac veins and should not be confused with adenopathy.


