



# MR Imaging for Staging of Cervical Carcinoma: Update

## 자기공명영상을 이용한 자궁경부암의 병기결정: 최신지견

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Uterine cervical cancer is globally the third most common cancer among women, and shows high mortality with invasive cervical carcinoma. Early detection of the disease, its correct staging, and treatment are therefore of great importance. The staging system updated in 2009 by the International Federation of Gynecology and Obstetrics (FIGO), is commonly used for planning the treatment. However, there are significant inaccuracies in the FIGO staging system. Accurate tumor staging is very important to decide the treatment strategy. Although not included in the staging system, magnetic resonance (MR) imaging is a valuable tool for local staging of the disease, and is useful in assessing the spread of the tumor and metastatic lymph nodes, thereby becoming a more accurate substitute for clinical staging of cervical carcinoma. In addition, it is capable of assessing the disease response to surgery or chemoradiation. This review briefly describes the role of MR imaging and the basic MR scanning protocol in evaluating cervical carcinoma. The MR findings with staging, and MR evaluation of treatment response, are further addressed.

### Index terms

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## INTRODUCTION

Cervical cancer is globally the third most common cancer among women, having frequent mortality. About 85% of cervical cancer occurs in the developing countries. The most important risk factors for cervical cancer include human papillomavirus exposure, age of first sexual intercourse, multiple sexual partners, multiparity, low socioeconomic status, and high risk sexual partners (1).

Squamous cell carcinoma accounts for about 80% cases of cervical carcinoma. The 20% of nonsquamous cervical carcinoma are adenocarcinoma, adenosquamous carcinoma, adeno-cystic carcinoma, small cell carcinoma, lymphoma, and undifferentiated carcinoma. Adenocarcinomas show a higher frequency of lymphatic and hematogenous metastasis (2). Most cervical

squamous cell carcinomas originate from the squamocolumnar junction (SCJ). In younger females, the SCJ is located outside the external os, and the tumor tends to show exophytic masses. In older females, the SCJ is located within the cervical canal, and the disease tends to display endocervical masses (3). Gradual changes of the epithelium develop into cervical carcinomas; from progressively severe dysplasia to carcinoma *in situ* (CIS) to invasive carcinoma. The recognition of this progression and its detection with papanicolaou (PAP) smear and biopsy, has led to striking improvements in the mortality rate.

Cervical carcinoma is clinically staged according to the International Federation of Gynecology and Obstetrics (FIGO) staging system. Updated in 2009, FIGO is commonly used for scheduling the treatment of cervical carcinoma. The TNM staging system is based on the same criteria as the FIGO staging system

(1). However, the clinical staging system has significant inaccuracies in the evaluation of prognostic factors, such as tumor size, parametrial or pelvic side wall invasion, and lymph node status. This is because clinical staging based primarily on pelvic examination, cystoscopy, and proctoscopy is imprecise, and the surgical staging for clinical stages II to IV, which have significant morbidity, is not performed routinely (4). It is predicted that up to 12% of patients with clinical stage I disease have a planned hysterectomy aborted by intraoperative findings, which usually includes gross extension of the pelvic disease or paraaortic lymphadenopathy (5). Patients treated with radiation therapy only, e.g., those with stage II and III disease, may be understaged or overstaged, thus adversely affecting the mortality (6). For these reasons, magnetic resonance (MR) imaging may be beneficial as a more accurate substitute for clinical staging of cervical carcinoma.

This review briefly discusses the staging system, and basic MR imaging techniques of the female pelvis, to evaluate uterine cervical carcinoma. The role of MR evaluation for cervical carcinoma and treatment response is further described.

## CLINICAL STAGING

The FIGO staging system provides worldwide epidemiologic

and treatment response statistics, and serves as a standardized tool of communication among institutions. Updated in 2009, this clinical staging system is commonly used for treatment planning, although it is inadequate in the evaluation of prognostic factors like tumor volume and lymph node status. In the revised FIGO staging, stage 0 is deleted from the staging system in cervical carcinoma, since it is a pre-invasive lesion. Stage IIA is subdivided into IIA1 ( $\leq 4$  cm) and IIA2 ( $> 4$  cm), according to the maximum diameter of the tumor size. However, in stage IIB disease, supporting data for a subdivision regarding tumor size is not available (Table 1) (7, 8).

Traditionally, the FIGO staging system relies on physical examination, which may be performed under anesthesia, chest radiography, intravenous urography, barium enema, colposcopy, cystoscopy, and proctoscopy (1, 3). Although diagnostic imaging such as computed tomography (CT) and MR to assess the primary tumor is not mandatory in the revised FIGO staging, its use is encouraged (8). This trend is due to an error rate up to 32% in patients with stage IB disease, and up to 65% in patients with stage III disease, using the clinical FIGO staging system (9, 10). The greatest limitations in the clinical examination of patients with cervical carcinoma are the estimation of important prognostic factors that include tumor size, the assessment of parametrial invasion and pelvic side wall invasion,

**Table 1. Revised FIGO Staging of Cervical Carcinoma**

Stage I	The carcinoma is strictly confined to the cervix (extension to the corpus would be disregarded)
IA	Invasive carcinoma diagnosed only by microscopy
IA1	Measured stromal invasion of $\leq 3$ mm in depth and extension of $\leq 7$ mm
IA2	Measured stromal invasion of $> 3$ mm and not $> 5$ mm with an extension of not $> 7$ mm
IB	Clinically visible lesions limited to the cervix uteri or pre-clinical cancers greater than stage IA
IB1	Clinically visible lesion $\leq 4$ cm in greatest dimension
IB2	Clinically visible lesion $> 4$ cm in greatest dimension
Stage II	Cervical carcinoma invades beyond the uterus, but not to the pelvic wall or to the lower third of the vagina
IIA	Without parametrial invasion
IIA1	Clinically visible lesion $\leq 4$ cm in greatest dimension
IIA2	Clinically visible lesion $> 4$ cm in greatest dimension
IIB	With parametrial invasion
Stage III	The tumor extends to the pelvic wall and/or involves lower third of the vagina and/or causes hydronephrosis or non-functioning kidney
IIIA	Tumor involves lower third of the vagina, with no extension to the pelvic wall
IIIB	Extension to the pelvic wall and/or hydronephrosis or non-functioning kidney
Stage IV	The carcinoma has extended beyond the true pelvis or has involved (biopsy proven) the mucosa of the bladder or rectum. A bullous edema, as such, does not permit a case to be allotted to stage IV
IVA	Spread of the growth to adjacent organs
IVB	Spread to distant organs

FIGO = International Federation of Gynecology and Obstetrics

and the evaluation of lymphadenopathy (10-12). Generally, the clinical FIGO staging has an error rate of 29–33.3%, as compared with the surgical staging, with maximum errors occurring in stage IIA to IVA (50–67%) (13). When compared with the surgical staging, clinical staging presents understaging in 20% to 30% of cases in stage IB, 23% in stage IIB, and almost 40% in stage IIIB, whereas overstaging is observed in 64% of cases in stage IIIB (9, 14, 15). For these reasons, MR imaging may become a more accurate substitute for clinical staging of cervical carcinoma.

## ROLES OF MR IMAGING

MR imaging provides potentially superior spatial resolution and better ability for tissue characterization, as compared to ultrasound or CT. Thus, MR imaging is accepted as the most reliable imaging modality for the pre-treatment evaluation of cervical carcinoma (16). CT has some advantages which include rapid acquisition time, imaging during the peak vascular enhancement, and lack of bowel motion artifact; hence, it is implemented in preoperative staging and treatment planning for cervical carcinoma. However, CT has limitations in the detection of the primary tumor, depiction of parametrial invasion, and differentiation of the tumor and normal cervix. Radiation exposure and allergy to iodine contrast materials are the other limitations of CT (1, 17). For identification of primary tumor and stromal or parametrial invasion, MR imaging is significantly better than CT (12, 18, 19).

MR imaging is particularly suited for pelvic examination, because of the high intrinsic contrast of the normal relevant pelvic structures and generally high contrast between malignant and normal tissue due to rapid advancement in resolution, signal to noise ratio, motion compensation, and soft tissue contrast. It also accurately provides the tumor size or volume, shape, and direction of the primary tumor, local extension of the disease, and lymph node status, which helps the clinician in deciding the course of treatment, monitoring the treatment response, and detecting recurrent disease (20). The European Society of Urogenital Radiology (ESUR) guidelines recommend MRI for staging of tumors of stage IB1 and over, or of smaller tumors if trachelectomy is being considered. In addition, MR imaging is recommended as a tool of treatment during follow-up after

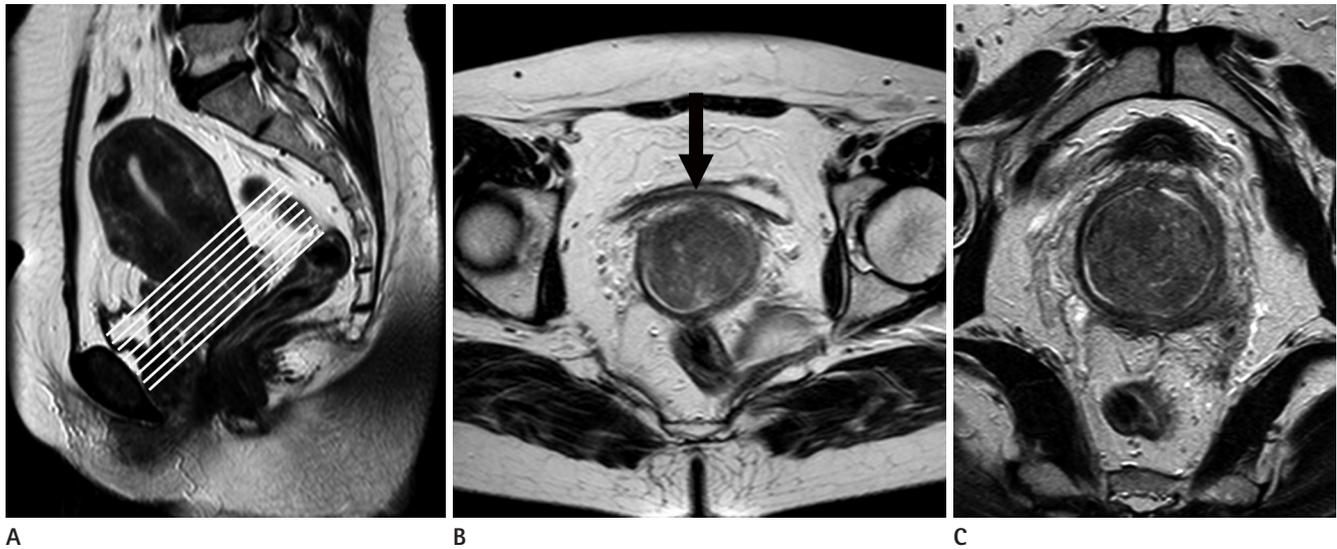
brachytherapy and chemoradiation treatment, and for detection of recurrent disease (21). Accurate tumor staging is essential to determine the treatment strategy. MR imaging is accepted as a primary imaging modality to assess the prognostic factors.

## MR SCANNING TECHNIQUES AND PROTOCOL

The standard MR sequences applicable to cervical carcinomas include multiplanar T2-weighted images of the pelvis, axial T1-weighted images, and axial T1-weighted or T2-weighted large field-of-view images of the abdomen and pelvis. T2-weighted images in two planes (usually axial and sagittal) are sufficient for most patients. T1-weighted scans are performed solely in the axial plane, to assess for metastatic lymph nodes, hydronephrosis, and bony lesions. Fat-suppressed sequences are helpful for the assessment of parametrial involvement. Dynamic contrast-enhanced (DCE) T1-weighted images help to identify smaller tumors, detect or confirm invasion of adjacent organs, and identify fistular tracts. To suppress bowel motion artifacts, an antiperistaltic agent is administered before scanning (21-23). High-resolution MR imaging of the cervical carcinoma is performed in the supine position using dedicated surface-array multichannel coils. Although 3.0-T MR scanner has the advantage of higher signal-to-noise ratio, as compared with 1.5-T MR scanner, field inhomogeneity at 3.0-T MR scanner seems inferior to that of an 1.5-T MR scanner. In recent literature, even if 3.0-T MR scanner provides high diagnostic accuracy in staging of cervical carcinoma, this accuracy is not significantly superior to that of the 1.5-T MR scanner (24, 25).

### T2-Weighted Images

T2-weighted images are essential to identify the primary tumor, and assess its extension to the uterus, parametria, and other adjacent organs. T2-weighted images in two orthogonal planes (sagittal and oblique) are recommended (25, 26). Oblique axial T2-weighted images must be acquired perpendicular to the long axis of the cervix, which provides a more accurate assessment of the stromal and parametrial invasion (Fig. 1) (27). The sagittal T2-weighted images are most useful for evaluation of uterine origin, and are crucial for staging in patients with cervical carcinoma. Coronal scans are often helpful for the depiction



**Fig. 1.** Axial oblique T2-weighted MR image.

**A.** Sagittal T2-weighted MR image shows a heterogeneous, intermediate signal intensity mass in the uterine cervix. Lines indicate scan direction of oblique axial images, which are obtained perpendicular to the long axis of cervix.  
**B.** Axial T2-weighted image shows that parametrial invasion is not clear in the anterior aspect of the cervix (arrow).  
**C.** Oblique axial T2-weighted image clearly excludes the extension to the parametria, which provides more accurate assessment of stromal and parametrial invasion, as compared with T2-weighted image.

of parametrial invasion (21).

### T1-Weighted Images

To detect gross lymphadenopathy, the MR evaluation of patients with cervical carcinoma should include axial T1-weighted images of the infrarenal paraaortic and iliac lymph node chains. T1-weighted images are also helpful for evaluating the presence of hydronephrosis and bone metastases. Both T1- and T2-weighted images can be used for these evaluations (21).

### Contrast-Enhanced T1-Weighted Images

The role of contrast-enhanced MR images in staging cervical carcinoma is not clear. Preliminary studies report similar findings on contrast-enhanced T1-weighted images and T2-weighted images, with an overall increase in staging accuracy using enhanced images. However, literature suggests there is no improvement in staging with contrast medium administration. Contrast-enhanced T1-weighted images may be helpful in specific problem solving situations, or for excellent tumor-muscle differentiation when combined with fat suppression techniques (28). Although dynamic imaging with contrast medium is not routinely recommended for cervical carcinoma, the application of contrast medium increases the contrast between cancerous tissue and normal cervical stroma, and improves tumor detec-

tion and localization. The ESUR guidelines indicate the consideration for contrast enhancement in cervical carcinomas in cases of small lesions that can be considered for trachelectomy, and for the detection of tumor recurrence (Fig. 2). Additionally, contrast enhancement is useful in differentiating recurrent cancer and radiation fibrosis after post-radiation treatment, as well as identification of bladder or rectal wall invasion, or delineation of fistulas (Fig. 3) (21, 28).

Many studies have assessed the predictive role of pre-treatment tumor enhancement. Tumor enhancement or an increase in signal intensity within the first two weeks of treatment are associated with better tumor regression, local control, disease-free survival, and overall survival (29, 30). Although controversial, semiquantitative analysis from a time-signal intensity curve or quantitative analysis from some parameters using DCE-MRI, such as  $K^{trans}$  and  $V_e$ , may be useful in predicting treatment response and monitoring therapeutic changes to concurrent chemoradiotherapy (CCRT), in patients with cervical carcinoma (29-31).

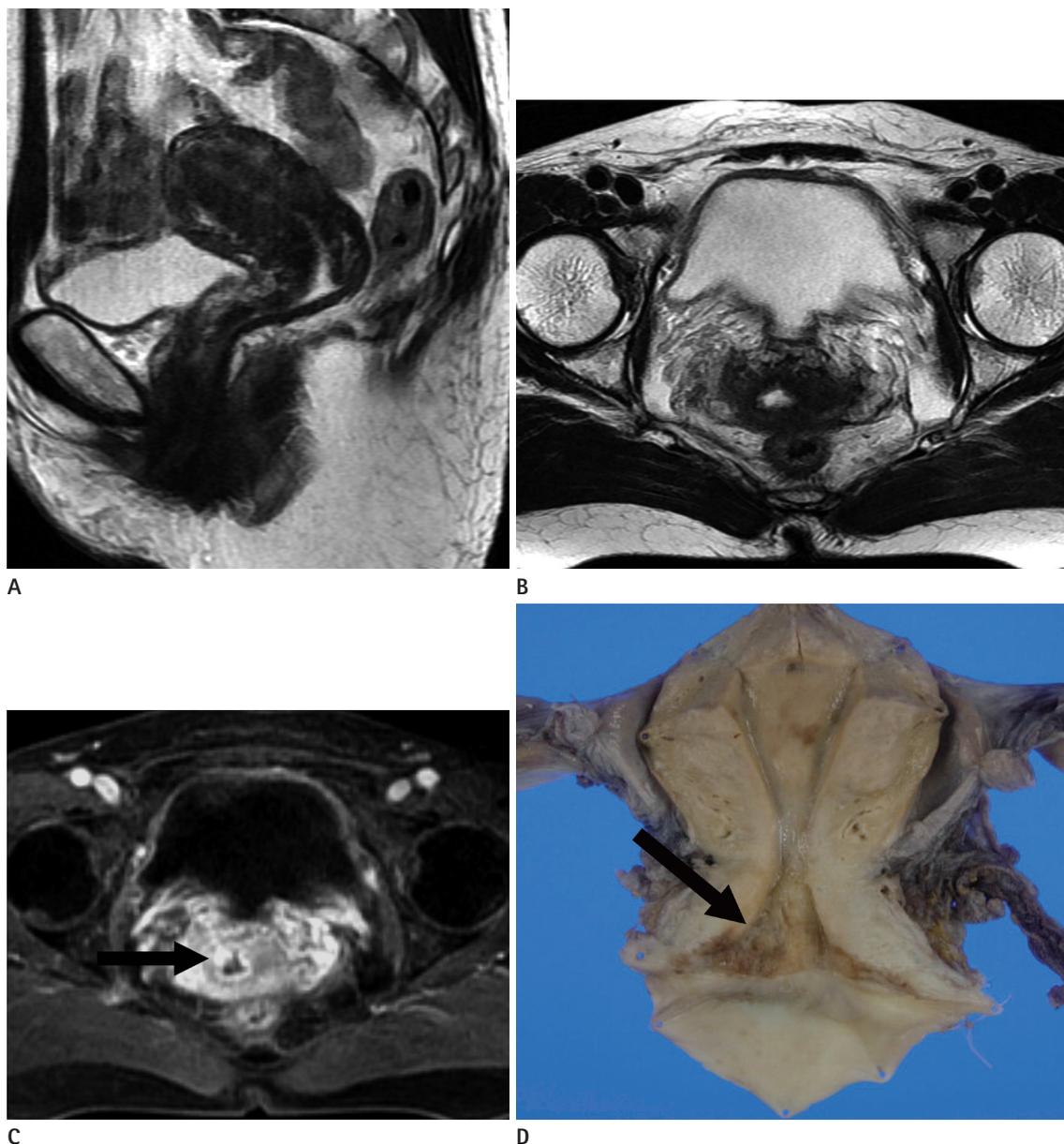
### Diffusion-Weighted Imaging

Diffusion-weighted imaging (DWI) is emerging as a very promising technique for the evaluation of uterine cervical carcinoma. DWI obtained in the sagittal and axial oblique planes

demonstrate cervical carcinoma as areas of high signal intensity, with increased conspicuity (32). The apparent diffusion coefficient (ADC) maps with different b-values are used as a quantitative expression of diffusion restriction. Although a b-value higher than  $500 \text{ s/mm}^2$  is necessary for the precise evaluation of ADC in the female pelvis, the b-values vary among different institutions when evaluating cervical carcinoma. One paper reported that the diagnostic accuracy for the differentiation of

malignant and benign cervical tissues was high for all b-value combinations, without any statistical difference among the combinations (33). However, the ideal b-value combinations for ADC calculation of the cervix are not established.

ADC values differentiate a cervical carcinoma from normal cervical tissue. Cervical carcinoma has significantly lower ADC value, as compared to the normal cervix (Fig. 4) (34). Preliminary studies demonstrate the ability of ADC to distinguish his-



**Fig. 2.** Stage IB1 cervical carcinoma in a 59-year-old woman.

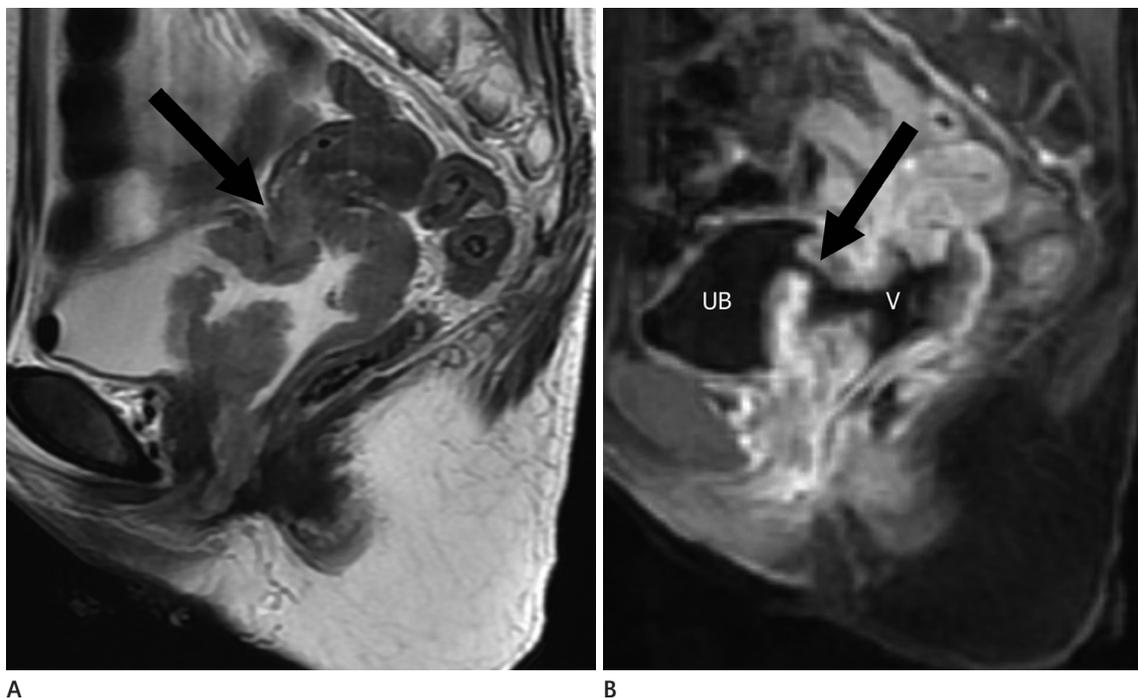
**A, B.** Sagittal (**A**) and axial (**B**) T2-weighted MR images show no abnormal signal intensity lesions in the uterine cervix.

**C.** Axial contrast-enhanced T1-weighted MR image shows a small enhancing tumor (arrow) in the cervix.

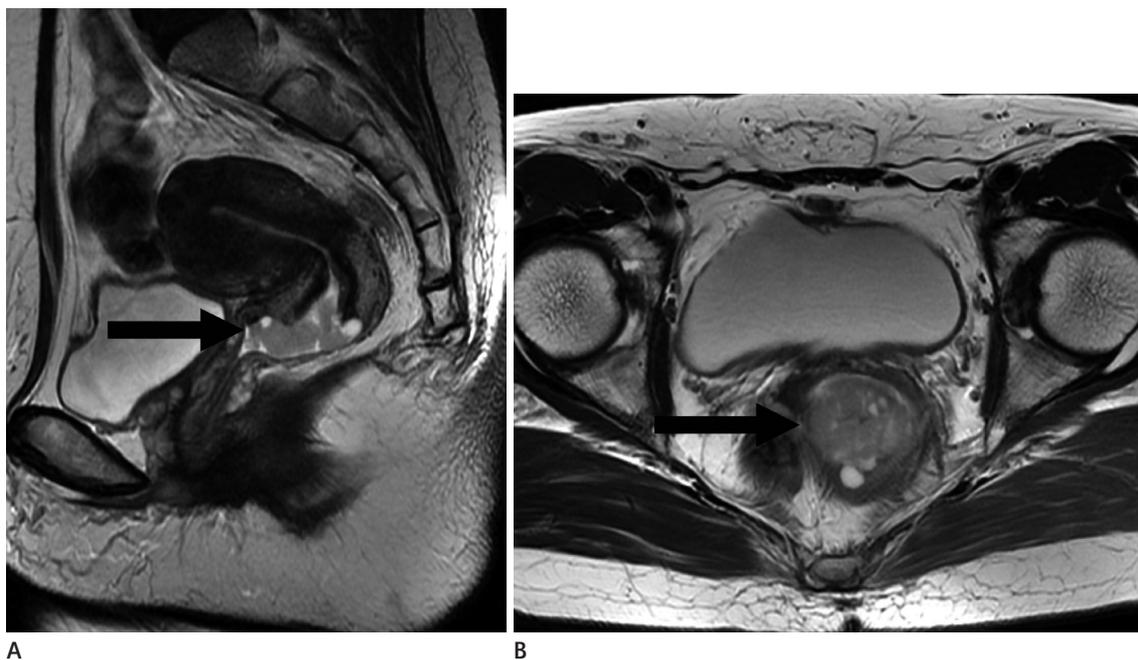
**D.** A photograph of gross specimen of the uterine cervix reveals a small nodular mass (arrow) within the endocervix, which is staged as IB1 disease after radical hysterectomy.

tological grade and subtype of cervical carcinoma (35, 36). Well differentiated tumors show higher ADC values than poorly differentiated tumors. While one study reported ADC of squamous

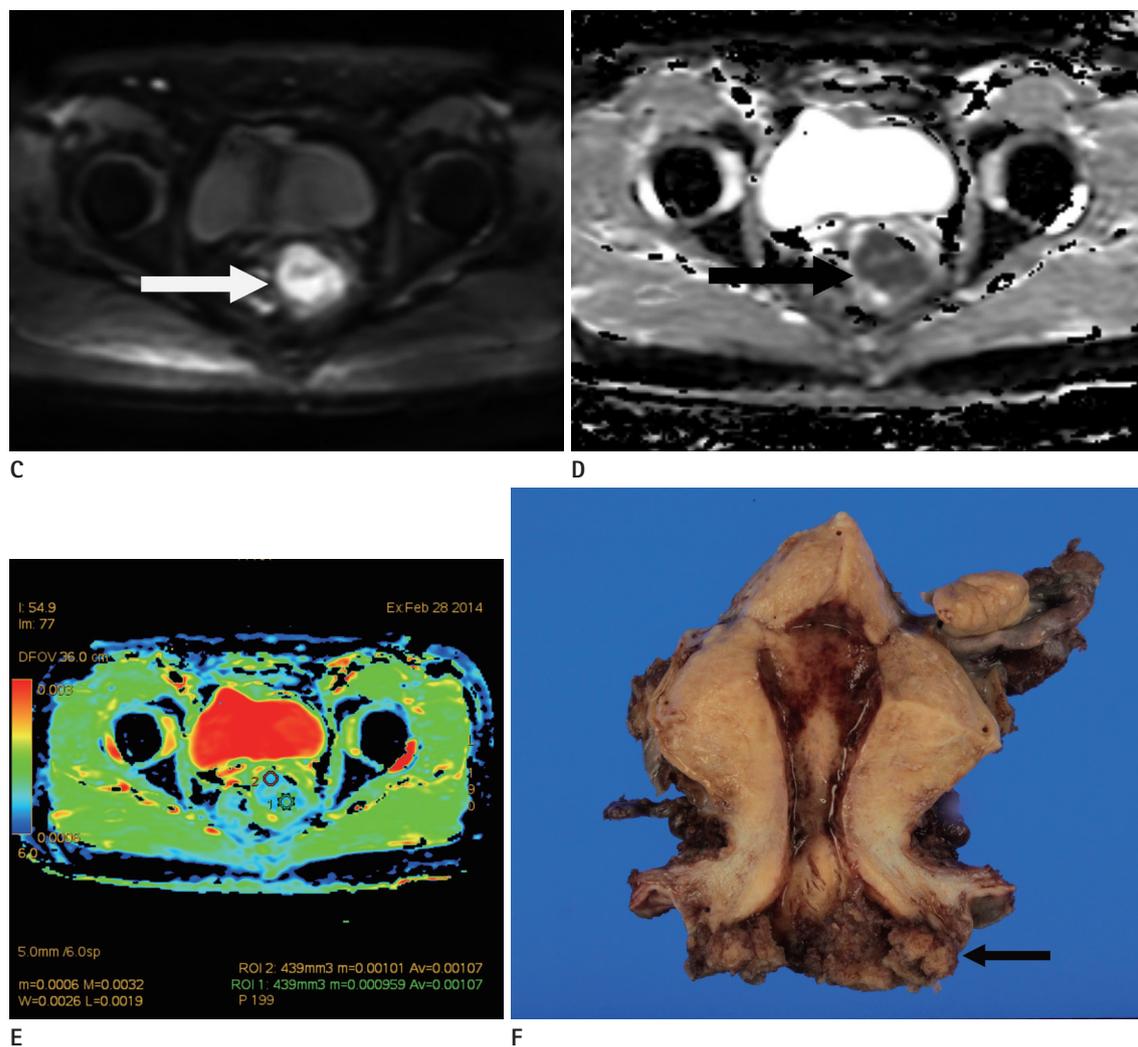
cell carcinomas to be lower than adenocarcinomas (35), another study indicated no difference in ADC between different histological subtypes (36); further studies should be required to



**Fig. 3.** Stage IVA cervical carcinoma in a 58-year-old woman. **A.** Sagittal T2-weighted MR image shows a bulky tumor (arrow) with invasion to the posterior wall of the bladder. **B.** Sagittal contrast-enhanced T1-weighted MR image clearly demonstrates an enhancing mass with fistulous tract (arrow) between the urinary bladder (UB) and vagina (V), a finding indicative of vesicovaginal fistula.



**Fig. 4.** Stage IB1 cervical carcinoma in a 51-year-old woman. **A, B.** Sagittal (**A**) and axial oblique (**B**) T2-weighted MR images show an exophytic hyperintense mass (arrows) arising from external os of the uterine cervix, without parametrial invasion.



**Fig. 4.** Stage IB1 cervical carcinoma in a 51-year-old woman.

**C-E.** Axial DWI (**C**) and ADC (**D, E**) maps show a hyperintense mass (white arrow) with diffusion restriction (black arrow) and decreased mean ADC value ( $1.070 \times 10^{-3} \text{ mm}^2/\text{s}$ ).

**F.** A photograph of the gross specimen of the uterine cervix demonstrates a polypoid mass with exophytic growing from external os of the uterine cervix (arrow).

ADC = apparent diffusion coefficient, DWI = diffusion-weighted imaging

assess the significance. ADC values using DWI may be helpful in detection of residual tumor or suspicious lymph nodes after CCRT (35-38). Furthermore, ADC values can predict and monitor treatment response of tumors, which may occur before conventional morphologic changes (34-37). The mean ADC of cervical carcinoma increases during and after CCRT, such that early changes in ADC can be used for predication of early therapeutic response. Recent studies demonstrate that the pre-treatment ADC of patients with complete response are lower than that of patients with partial response. Also, the pre-treatment ADC values of all patients correlate negatively with the percentage size reduction of the tumor after 2 months of CCRT. A possible

explanation for these observations is that tumors with high pre-treatment ADC values are likely to be more necrotic than those with low ADC values (34-39). However, whether the pre-CCRT mean ADC value of cervical cancer could be a reliable predictor of treatment response to CCRT, has so far not been determined. Although the pre-CCRT mean ADC value of a tumor does not significantly correlate with treatment response, the mid-CCRT ADC value or change of the ADC value during CCRT, compared with pre-CCRT, has been reported to be significantly correlated with treatment response (37, 39).

## MR FINDINGS AND STAGING

MR anatomy of the normal uterine cervix is best delineated on T2-weighted image, as it appears in three distinct layers of the cervix. Viewing from center to periphery, these are intermediate to high signal intensity mucosa, low signal intensity fibrous stroma, and intermediate signal intensity outer smooth muscle layer. T2-weighted images clearly show the high signal intensity lesion contrasted with low signal intensity cervical stroma (1, 20).

MR imaging has no role in evaluating the vast majority of cases of cervical carcinoma (i.e., CIS), since these lesions are not visible on MR images. Similarly, stage IA diseases (microinvasive lesions) are difficult to identify by MR imaging. Larger lesions are easily appreciated, and accurate measurement of tumor volumes can be performed (40-42). MR imaging has consistently high rates of staging accuracy for cervical carcinoma, with reported overall accuracy rates of 76% to 90% (40-43).

### Stage I

Stage I is limited to the uterine cervix. Stage IA is confined to the cervix, and is subdivided into IA1 (stromal invasion 3 mm or less in depth, and 7 mm or less in horizontal spread) and IA2

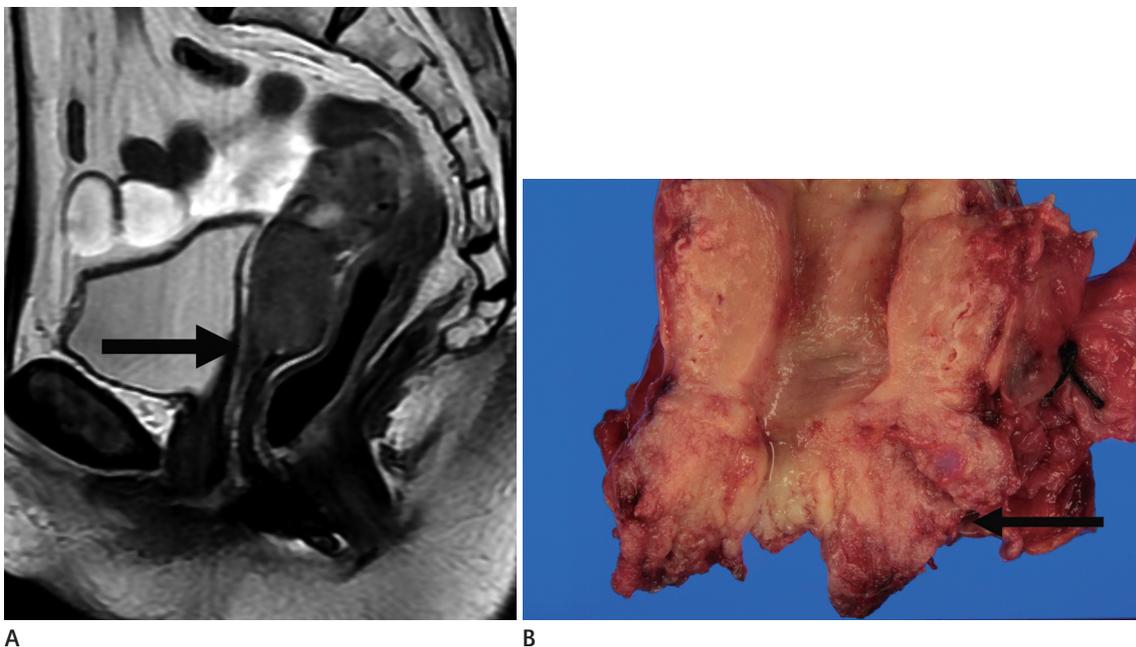
(stromal invasion more than 3 mm but not more than 5 mm, with a horizontal spread 7 mm or less). The stage IA tumor is therefore a microscopic lesion not visible on MR imaging. Intermediate to high signal intensity lesion compared with the cervical stroma on T2-weighted images, is clinically stage IB or higher. Stage IB is subdivided into IB1 ( $\leq 4$  cm) and IB2 ( $> 4$  cm), based on tumor size (7). MR imaging has a high accuracy rate of close to 90% in the assessment of tumor size. This accuracy is important, because clinical examination is unreliable for determination of tumor size, especially in endocervical lesions (13).

### Stage II

Stage II is defined as the tumor extension beyond the cervix. At stage IIA, the tumor infiltrates the upper two-thirds of the vagina, which is seen as segmental loss of the normally observed T2-hypointense vaginal wall. According to revised FIGO staging, the tumor size of  $\leq 4$  cm is stage IIA1, and  $> 4$  cm is stage IIA2 (Fig. 5) (7).

### Parametrial Invasion

The presence of an intact hypointense fibrous stromal ring with a thickness of  $> 3$  mm on T2-weighted image has a high neg-

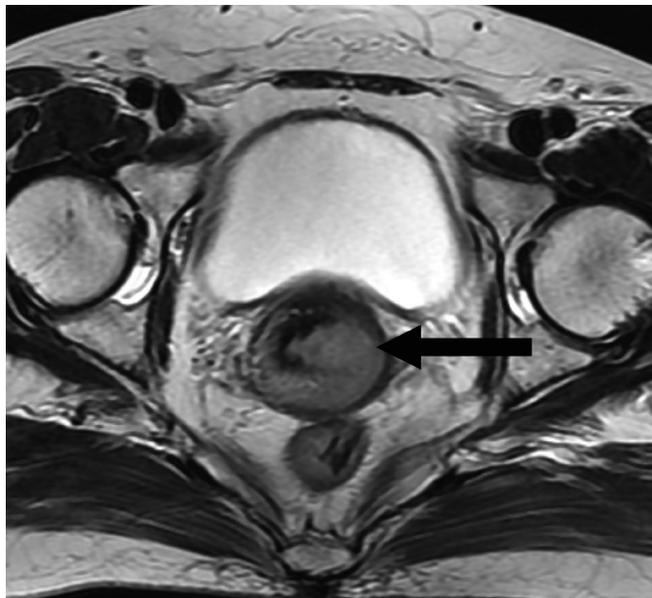


**Fig. 5.** Stage IIA2 cervical carcinoma in a 63-year-old woman.

**A.** Sagittal T2-weighted MR image shows a hyperintense exophytic growing mass with extension to the upper half of the anterior vaginal wall (arrow).

**B.** A photograph of the gross specimen of the uterine cervix reveals an ill-defined, infiltrative mass (4.5  $\times$  2 cm) with extension to the upper anterior vagina (arrow), after radical hysterectomy.

ative predictive value for parametrial invasion, ranging between 94% and 100% (43). Stromal invasion is considered to occur due to disruption of the hypointense stromal ring (Fig. 6). In addition to the stromal invasion, a reliable sign of parametrial invasion is the nodular or irregular signal intensity lesion extending into the parametrium (Fig. 7) (16, 20, 21, 44). Other reliable MR findings of parametrial invasion include distortion of the cervix with displacement to the side of parametrial inva-

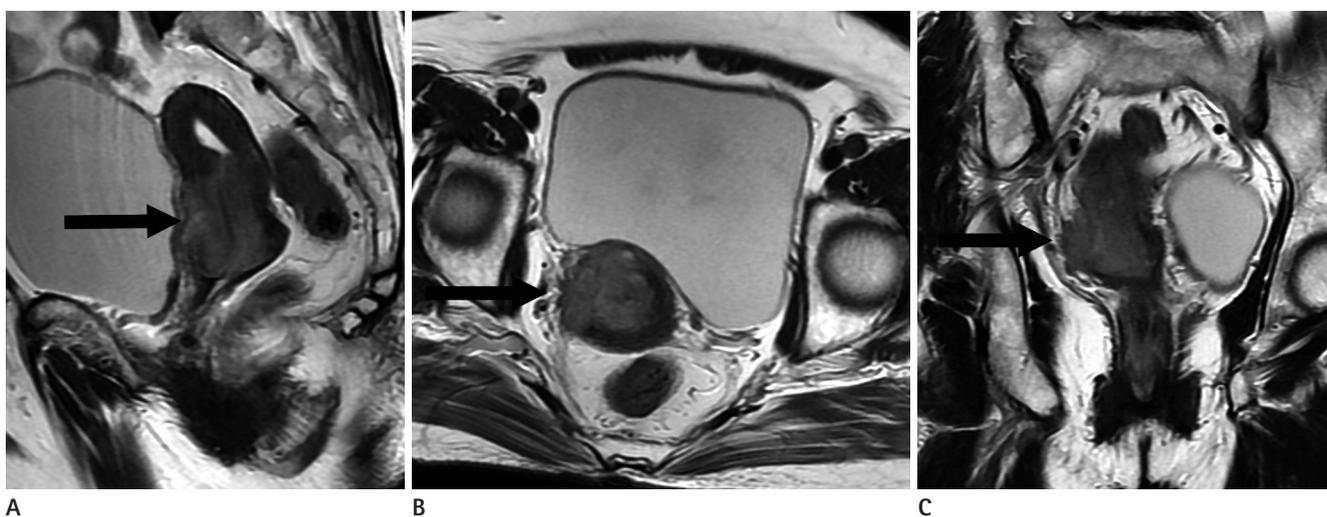


**Fig. 6.** Stage IIB cervical carcinoma in a 63-year-old woman. Axial T2-weighted MR image shows an intermediate signal intensity mass with focal disruption of hypointense stromal ring in the left side (arrow), a finding indicative of stromal invasion.

sion, irregular interface between the tumor and the parametrium, and enhancement of the soft tissue lesion in the parametrium encasing the parametrial vessels and/or extending along the uterosacral ligaments (13). More advanced tumors can grow along the uterosacral ligaments anterolateral to the rectum and the cardinal ligaments to the pelvic side wall (1). The accuracy of MR imaging in depicting parametrial invasion varies from 77% to 96% (40, 44, 45). Hemorrhage following cervical biopsy can cause false positives. Also, edema or inflammation due to tumor compression in larger tumors can lead to overstaging at MR imaging (Fig. 8) (16).

#### Vaginal Invasion

Disruption of the low signal intensity vaginal wall with high signal intensity thickening on T2-weighted imaging and enhancement on contrast-enhanced T1-weighted imaging is considered as vaginal invasion (Fig. 9). Vaginal invasion per se is clinically obvious, and therefore not a critical determination for MR imaging. However, it is important to distinguish between exophytic growth expanding the vaginal fornices and parametrial spread. The thin low signal intensity wall on T2-weighted images are effaced if the vaginal tunica muscularis is invaded (1, 20). MR imaging is highly sensitive and has an accuracy of 93% in depiction of vaginal extension (46).



**Fig. 7.** Stage IIB cervical carcinoma in a 77-year-old woman.

**A.** Sagittal T2-weighted MR image shows a relatively ill-defined, hyperintense mass (arrow) in the cervix.

**B, C.** Axial oblique (**B**) T2-weighted MR image shows disruption of hypointense ring and spiculated tumor-parametrial interface, a finding consistent with parametrial invasion (arrow). This finding is also clearly seen on coronal (**C**) T2-weighted MR image (arrow).

**Stage III**

Stage III extends to the lower one-third of the vagina or pelvic side wall, with associated hydronephrosis or nonfunctioning kidney. Stage IIIA is the involvement of the lower third of the vagina without extension to the lateral pelvic wall. Stage IIIB is considered if the tumor is  $\leq 3$  mm from the pelvic side wall, causes hydronephrosis, infiltrates the obturator internus, pyriformis or levator ani muscles, encases the iliac vessels, and destroys the pelvic bones, indicating pelvic wall invasion (Fig. 10) (12, 16).

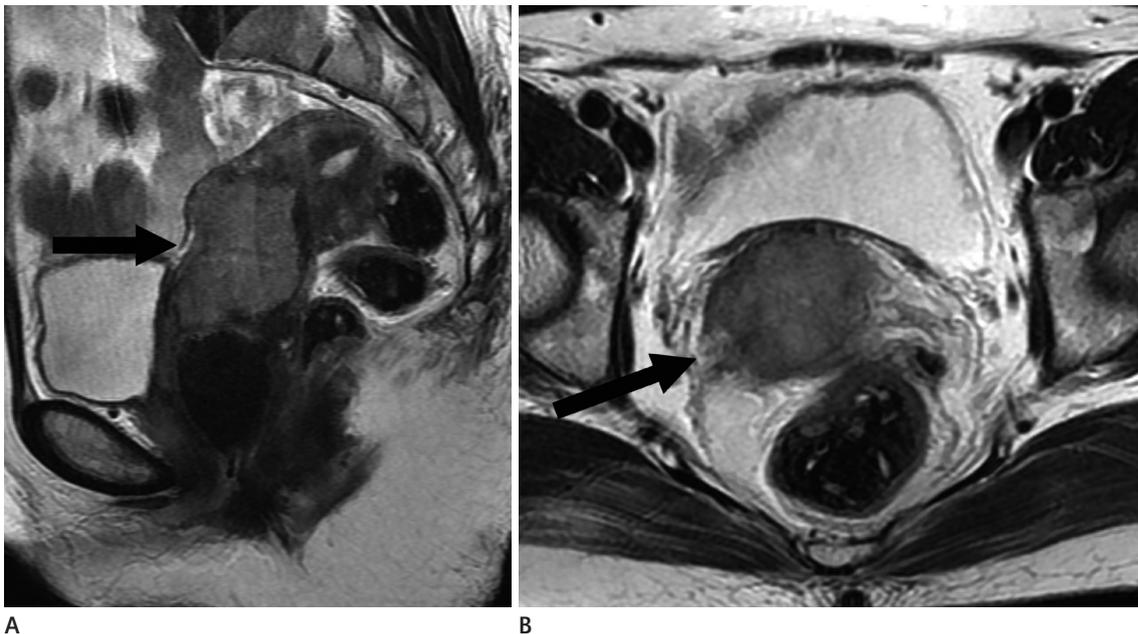
**Stage IV**

In stage IV tumors, invasion of the bladder or rectal mucosa, or distant metastasis is observed on MR imaging. Stage IVA is when the bladder or rectal invasion is considered based on the presence of focal or diffuse disruption of the normally observed low signal intensity wall on T2-weighted images, irregular or nodular wall, and presence of an intraluminal mass (Fig. 11) (27). Bladder invasion is more common than rectal invasion due to the bare area on the bladder wall posteriorly, and the presence of rectovaginal septum separating the posterior fornix from the rectum (13). Although direct invasion of the rectum is uncommon, uterosacral ligaments are the preferential route for rectal wall invasion (Fig. 12). False positives can result from bullous

edema of the bladder, since the edema may mimic bladder wall invasion. However, it can be differentiated by the presence of an intact mucosa of the bladder and with DCE-MR imaging (16).



**Fig. 9.** Stage IIIA cervical carcinoma in a 64-year-old woman. Sagittal T2-weighted MR image shows a hyperintense mass and extension to anterior upper and lower vaginal wall (arrows), which is a favorable finding of vaginal invasion. However, hypointense posterior wall of the bladder is intact.



**Fig. 8.** Stage IB2 cervical carcinoma in a 46-year-old woman.

**A.** Sagittal T2-weighted MR image shows a lobulated hyperintense mass (arrow) in the endocervix.

**B.** Axial T2-weighted MR image shows irregular and spiculated tumor-parametrial interface (arrow), suggestive of clinical stage IIB disease. However, this lesion was overstaged and proven stage IB2 after radical hysterectomy.

DCE-MR imaging improves the accuracy of bladder and rectal invasion, as compared to T2-weighted images (1). MR imaging is reliable and highly accurate (99%) in detecting bladder invasion, with a sensitivity of 83% and a specificity of 100% (1, 47). Stage IVB is defined as distant spread of tumor to the lung, liver, bones, peritoneum, and paraaortic or inguinal lymph node metastases, although the latter do not change the FIGO staging system (1, 16, 23).

## EVALUATION OF LYMPH NODE INVOLVEMENT

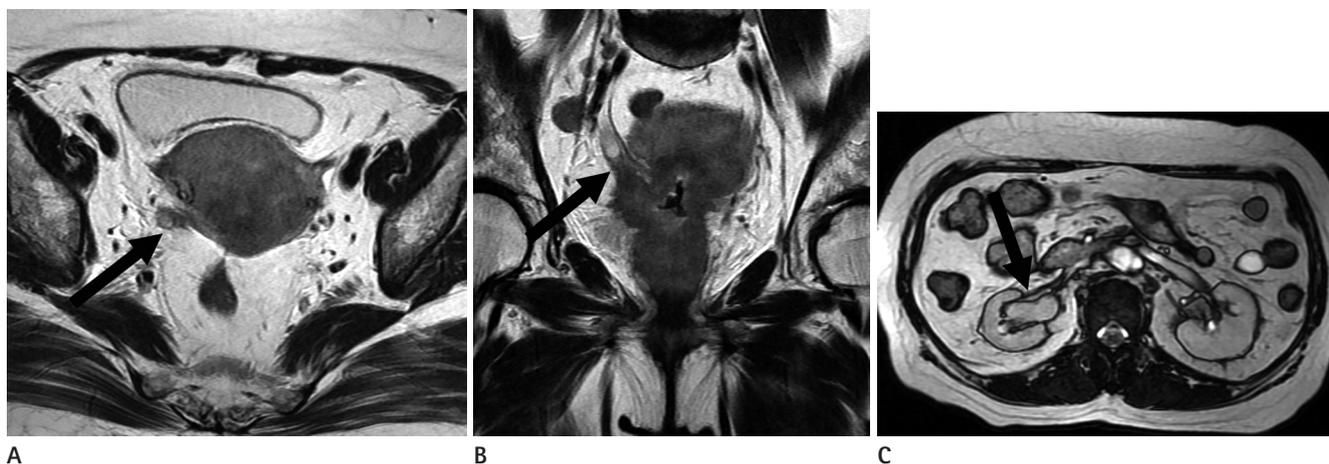
In patients with cervical carcinoma, lymph node metastasis occurs prior to the involvement of pelvic lymph nodes, which subsequently spreads to retroperitoneal and supraclavicular lymph nodes. Paracervical and parametrial lymph nodes are the first to be drained, followed by spread to external iliac lymph nodes by lateral route, internal iliac lymph nodes by hypogastric route, and lateral sacral and sacral promontory lymph nodes by presacral route. All three routes eventually drain into the common iliac lymph nodes, possibly leading to paraaortic lymph nodes involvement, representing distant metastatic disease (48).

Although the FIGO staging system does not include lymph node involvement for cervical carcinoma, it is one of the important prognostic factors, and presence of a positive lymph node indicates poor prognosis at all stages. This is particularly evident in early cervical carcinoma (49). The 5-year survival de-

creases from 89% to between 48% and 57% in the presence of lymph node metastasis in cervical carcinoma (13). Presence of paraaortic or inguinal lymph node metastasis is classified as stage IVB disease. Identification of diseased lymph node on imaging



**Fig. 11.** Stage IVA cervical carcinoma in a 48-year-old woman. Sagittal T2-weighted MR image shows tumor extension into the posterior wall of the bladder and anterior wall of the rectosigmoid colon, findings consistent with bladder and rectal invasion (arrows).



**Fig. 10.** Stage IIIIB cervical carcinoma in a 75-year-old woman.

**A, B.** Axial (**A**) and coronal (**B**) T2-weighted MR images show intermediate signal intensity mass in the cervix, extending into the right lower ureter (arrows).

**C.** Axial T2-weighted MR image obtained at the renal hilar level shows hydronephrosis (arrow) in the right kidney.

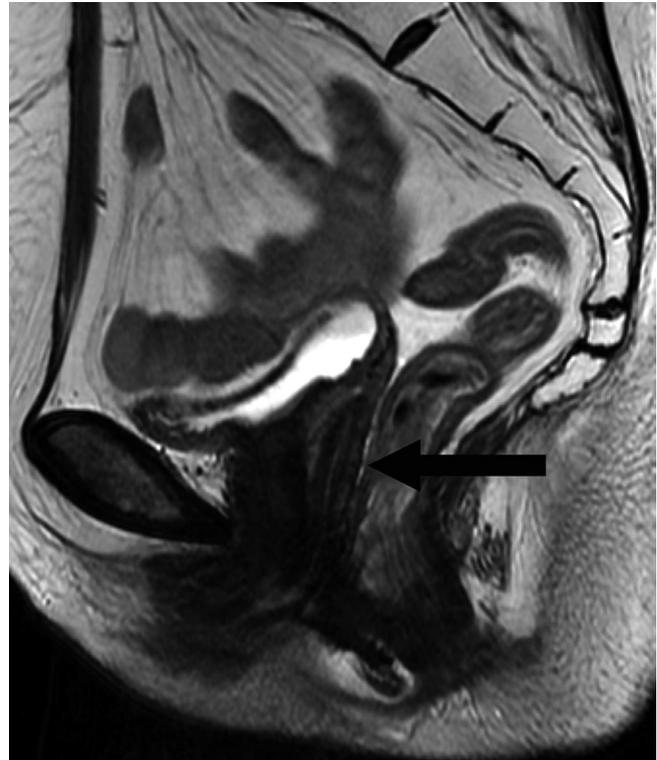
is based on size. A lymph node with short axis diameter > 10 mm is considered abnormal. However, CT and MR imaging fail to differentiate the reactive enlargement from malignant lymph node, and more importantly, cannot detect micrometastases in normal sized lymph nodes (17, 50).

The accuracy of MR imaging ranges from 88% to 89% for the detection of lymph node involvement. However, it has a low sensitivity (24–70%), because of its inability to detect metastasis in normal sized lymph nodes, or the poor ability of lymph node staging to differentiate reactive lymphadenopathy from malignant lymph nodes (51, 52). MR lymphography with ultrasmall superparamagnetic iron oxide increases the sensitivity (90–100%) of lymph node metastasis detection by MR imaging, without loss of specificity (95%) (52, 53). Fluorodeoxyglucose positron emission tomography/CT has a higher sensitivity (57.6%) in detecting lymph node metastasis, as compared with MR imaging (30.3%) (52).

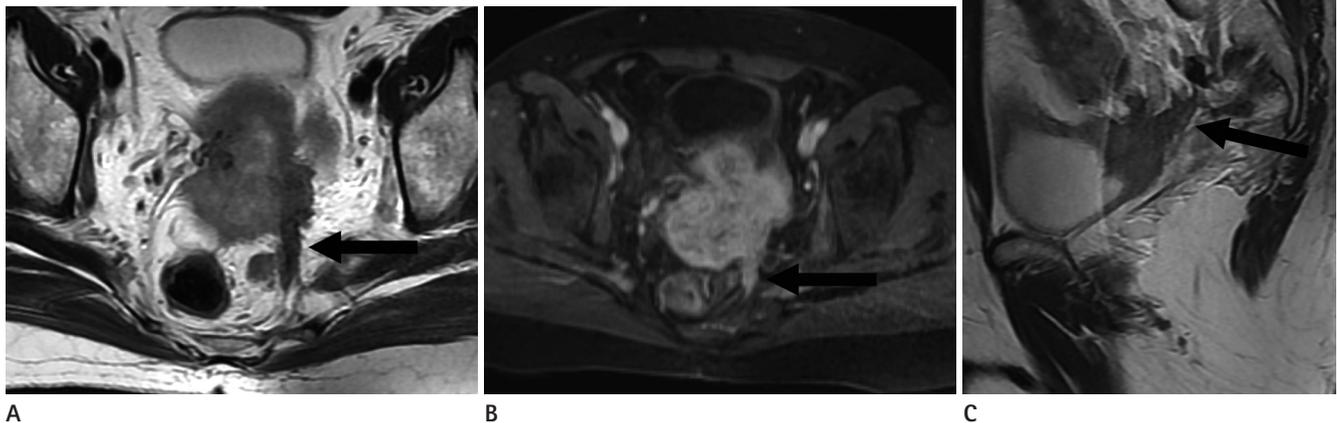
### MR EVALUATION OF TUMOR RESPONSE TO TREATMENT

With proper therapy, the mortality rate for most cervical carcinomas, i.e., noninvasive carcinoma, is virtually zero. The 5-year survival for invasive carcinoma is 80% to 93% for stage I, 58% to 63% for stage II, 32% to 35% for stage III, and 15% to 16% for stage IV disease (54). MR imaging can influence the treatment

protocol, and be used to identify important prognostic factors such as tumor volume, status of parametrium, pelvic side wall invasion, presence of metastatic lymphadenopathy, and spread to local and distant organs, thus aiding to determine palliative



**Fig. 13.** Total hysterectomy for stage IA1 cervical carcinoma in a 73-year-old woman. Sagittal T2-weighted MR image shows absence of the uterus with no abnormal signal intensity mass in the vaginal cuff and normal appearing smooth, low signal intensity vaginal wall (arrow).



**Fig. 12.** Stage IVA cervical carcinoma in a 52-year-old woman.

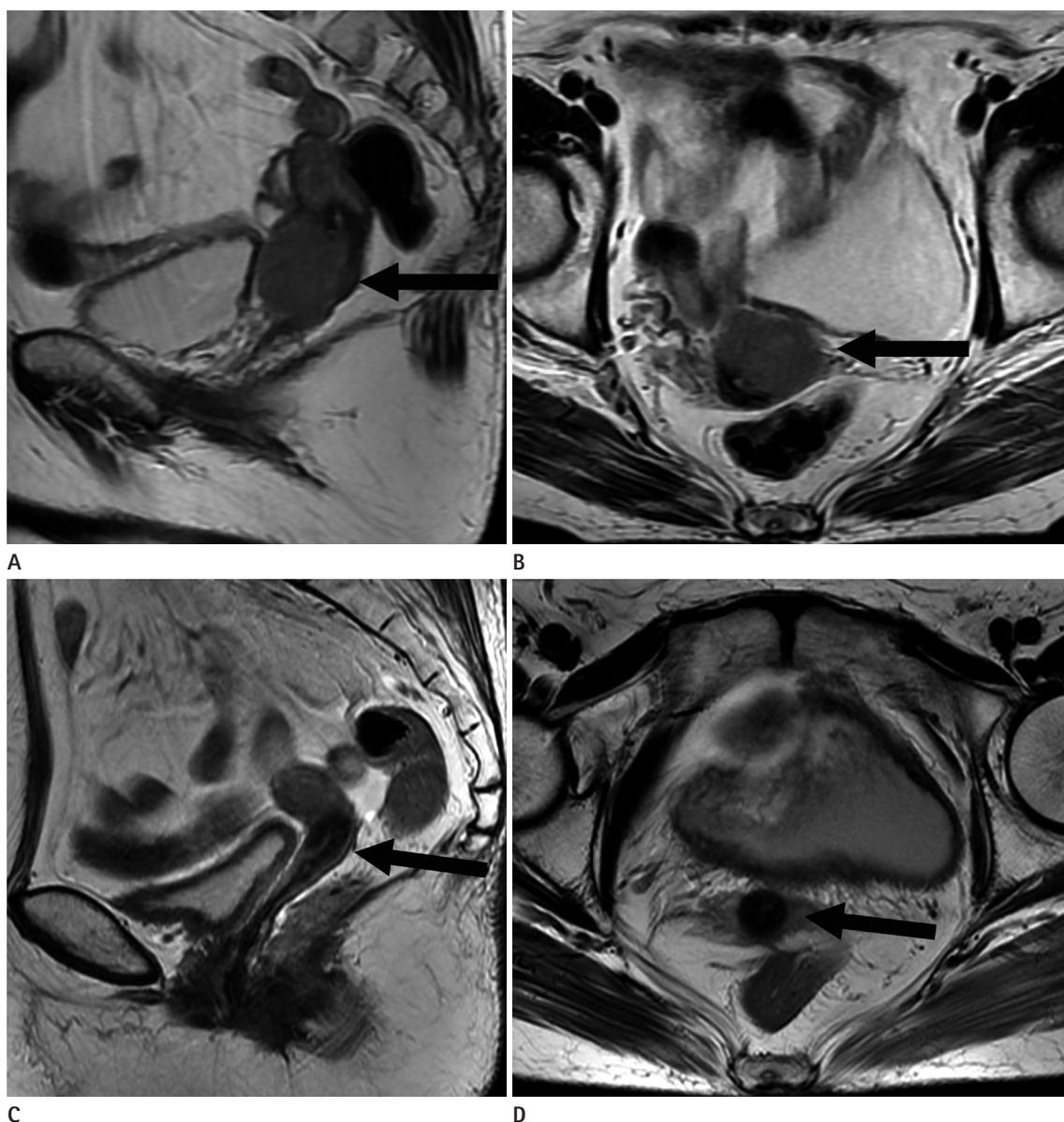
**A, B.** Axial T2-weighted (**A**) and contrast-enhanced T1-weighted (**B**) MR images show an intermediate signal intensity mass with extension to the uterosacral ligament (arrow) posteriorly.  
**C.** Coronal T2-weighted MR image shows tumor invasion to the posterior wall of the bladder as well as the uterosacral ligament (arrow).

or curative treatment (20).

In stage IA1, the rates of parametrial invasion and pelvic lymphadenopathy are  $\leq 1\%$ . Thus, standard treatment is simple hysterectomy or careful observation after adequate cone biopsy. In stage IA2, modified radical hysterectomy with pelvic lymph node dissection or radiotherapy is recommended, due to the increased risk of lymph node metastasis up to 28% (16). Stages IB1 and IIA1 are treated either with radical hysterectomy and pelvic lymph node dissection, or combined external beam radi-

ation and brachytherapy; both treatments are confirmed as equally effective. Concurrent chemotherapy with cisplatin has shown to improve patient survival (13). Pelvic irradiation and brachytherapy with concurrent chemotherapy is recommended for stage IB2, IIA2, and IIB to IVA. Patients with stage IVB may be treated with chemotherapy, with or without pelvic irradiation (13, 55).

Tumor response evaluation to treatment can be assessed by clinical examination, PAP smear analysis, and post-treatment



**Fig. 14.** Complete response after radiation treatment for stage IIB cervical carcinoma in a 67-year-old woman.

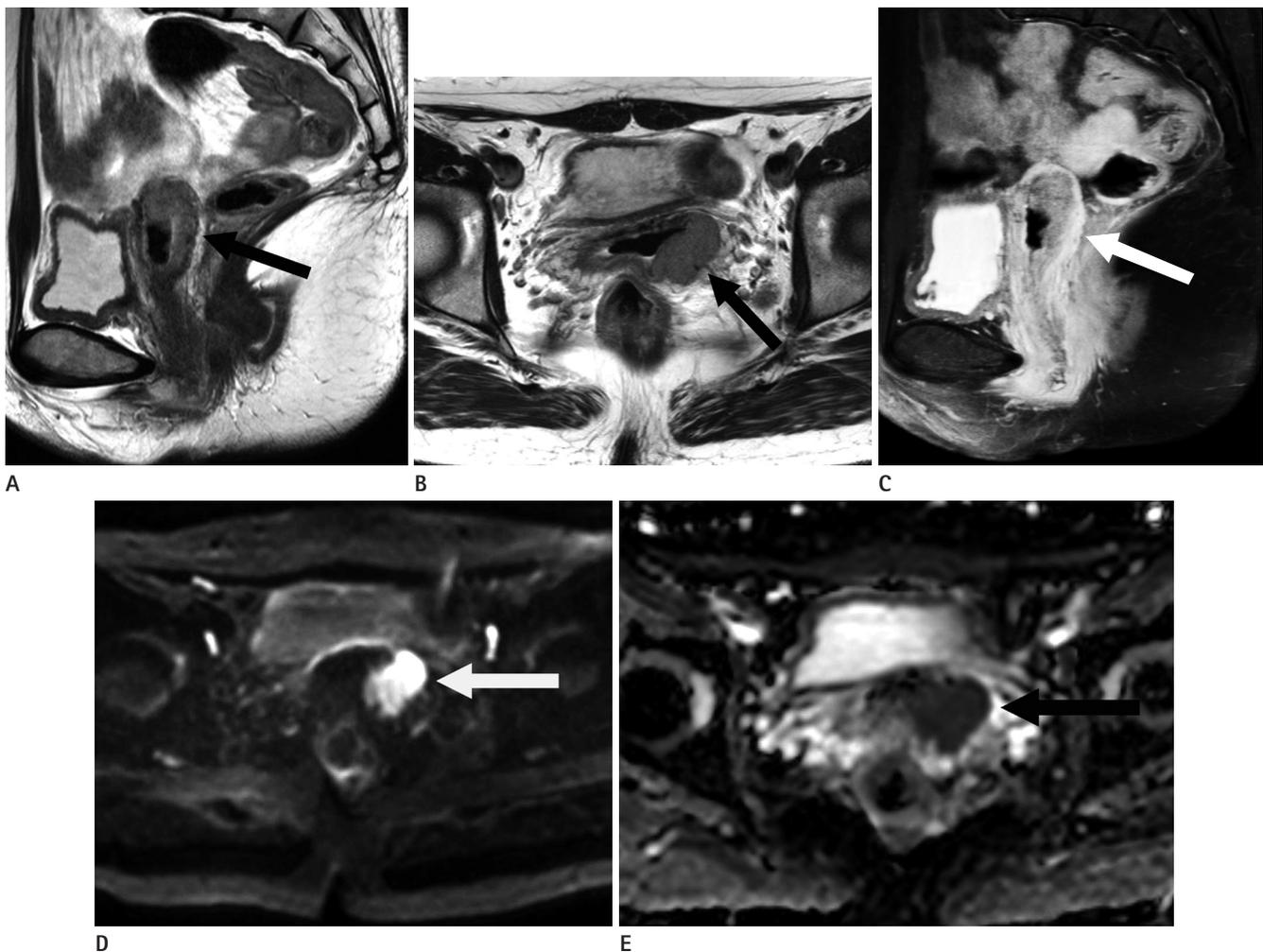
**A, B.** Pre-treatment sagittal (**A**) and axial (**B**) T2-weighted images show an intermediate signal intensity mass (arrows) with invasion to the upper vagina and parametrium, a finding indicative of stage IIB disease.

**C, D.** Following radiation treatment, sagittal (**C**) and axial (**D**) T2-weighted images show diffuse, homogeneous low signal intensity cervical stroma, and reconstitution of the normal zonal anatomy in the uterine cervix (arrows), a finding consistent with complete response.

MR examination (21). MR appearance after hysterectomy includes absence of the uterus, formation of the vaginal fornix by a linear soft tissue configuration, and normal vaginal wall with a smooth, low signal intensity muscular wall on T2-weighted MR images (Fig. 13). In some cases, a low signal intensity fibrotic scar is seen on T2-weighted MR images (55). In cases of complete response following radiation therapy, the uterine cervix demonstrates the reconstitution of a normal zonal anatomy, homogeneous low signal intensity cervical stroma on T2-weighted images, and homogeneous and delayed enhancement of the cervix after contrast medium administration, which are reliable indicators of tumor-free cervix (Fig. 14) (21, 55). An early (2–3

months) and significant decrease in the signal intensity and volume of the tumor indicates a favorable response to radiation therapy, and a high probability of complete remission (56). Thus, an early, non-invasive and accurate depiction of cancer recurrence is essential for proper selection of salvage treatment versus palliation, improved survival and quality of life (16).

Cancer recurrence is the development of local tumor regrowth or distant metastasis at least 6 months after regression of the treated lesion. Tumor size or volume, stage, the histologic grade of the tumor, depth of stromal invasion, and the lymph node status at presentation are the risk factors for tumor recurrence (55). About 90% of cervical carcinomas recur within 3 years of initial



**Fig. 15.** A 42-year-old woman with a recurrent cervical cancer after surgical treatment.

**A, B.** Following radical hysterectomy, sagittal (**A**) and axial (**B**) T2-weighted MR images show intermediate signal intensity mass in the vaginal cuff (arrows).

**C.** Post-contrast T1-weighted MR image shows good enhancement of the mass in the vaginal cuff (white arrow), a finding consistent with a recurrent cancer.

**D, E.** Axial DWI (**D**) and ADC (**E**) maps show a hyperintense mass (white arrow) with diffusion restriction (black arrow) in the corresponding area. ADC = apparent diffusion coefficient, DWI = diffusion-weighted imaging

treatment, typically in the pelvis at the vaginal cuff, cervix, parametrium, pelvic side wall, bladder, and rectum (Fig. 15) (57). It is important to differentiate between post-radiation fibrosis and recurrent tumor. T2-weighted MR images have high sensitivity (90–91%) but low specificity (22–38%) for recurrent disease in the uterine cervix (58, 59). DCE MR images increase the accuracy by identifying the early enhancing, intermediate to high signal intensity recurrent mass lesion on T2-weighted images (60).

## CONCLUSION

MR imaging is very helpful for preoperative staging, assessing prognostic factors, and optimizing treatment planning, although it has not been incorporated into the FIGO staging system. It also provides assessment of lymph node involvement, evaluation of tumor response to treatment, and differentiation of recurrent cancer from post-radiation changes.

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## 자기공명영상을 이용한 자궁경부암의 병기결정: 최신지견

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자궁경부암은 전 세계적으로 3번째로 많은 여성암이고, 흔한 사망 원인이다. 침습성 자궁경부암의 사망률은 의외로 높다. 따라서 암의 조기 발견과 정확한 병기결정, 그리고 치료가 매우 중요하다. 2009년 개정된 International Federation of Gynecology and Obstetrics (이하 FIGO) 병기는 치료 결정에 흔히 이용되지만 부정확한 경우가 많이 있다. 정확한 암 병기결정은 치료 계획 수립에 매우 중요하다. 자기공명영상은 비록 자궁경부암의 FIGO 병기결정에 포함되어 있지는 않지만, 암의 국소 병기결정과 침범 범위, 림프절 전이의 평가에 유용하다. 이러한 이유로 자기공명영상은 자궁경부암의 임상 병기결정에 보다 정확한 대체검사법으로 받아들여지고 있다. 또한 암의 수술적 치료나 항암방사선요법에 대한 치료 반응을 평가하는 데에도 도움을 준다. 본 종설은 자궁경부암을 평가하기 위한 자기공명영상의 역할과 검사 프로토콜을 간략히 알아보고, 암의 자기공명영상 소견과 병기결정, 그리고 치료 후 반응의 평가를 알아보고자 한다.

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