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*REVIEW ARTICLE*

# Magnetic resonance imaging and its value in the staging of cervical carcinoma – Comparison of magnetic resonance imaging and pathological images with FIGO staging system

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## Summary

*Cervical carcinoma is the third most common gynaecologic malignancy and is typically seen in younger women, often with serious consequences. The International Federation of Gynaecology and Obstetrics (FIGO) staging system provides worldwide epidemiologic and treatment response statistics. Magnetic resonance imaging (MRI), although not included officially in that system, plays an integral role in the evaluation of patients with cervical carcinoma. After the histological diagnosis has been made, MRI is recommended for noninvasive evaluation of tumor extent, often helping in designing optimal therapy.*

*MRI renders excellent soft tissue contrast, allowing direct tumor visualization and assessment of tumor volume, depth of penetration, and extension to adjacent tissues. MRI obviates the use of invasive procedures such as cystoscopy and proctoscopy, especially when there is no evidence of local extension. MRI staging, when available, is invaluable for identifying important prognostic factors and optimising treatment strategies.*

*The objective of this review is to discuss the MRI staging of the uterine cervical carcinoma, to propose a comprehensive, clinically relevant MRI examination for the assessment of uterine cervical carcinoma, and to present the correlation between MRI and pathologic imaging in comparison to the FIGO staging system.*

**Key words:** cervical carcinoma, magnetic resonance imaging, tumour staging

## Introduction

Carcinoma of the uterine cervix is the third most common cancer in women, following breast and colorectal cancer. The incidence peaks in middle age and ranges from 10 to 100 new cases/100000 population/year worldwide, depending on the socioeconomic status of the different countries [1]. However, it is the most common gynecologic malignancy in women younger than 50 years of age.

Cervical carcinoma most frequently develops at the level of the squamocolumnar epithelial junction. Twenty percent of tumors, however, lie totally within the endocervical canal and are difficult to examine clinically [2]. Many factors affect long-term prognosis of patients with cervical carcinoma: histopathologic stage, lymph node status, tumor volume, lymph vascular space involvement, parametrial spread, resection margins, and clinical condition [3].

Cervical cancer is staged according to the FIGO classification system. FIGO staging is clinical and based on physical examination (inspection, palpation, and biopsy), laboratory studies, and roentgenographic evaluation (chest X-ray, intravenous pyelogram, and barium enema). Clinical FIGO staging is limited with reported errors of 26% in stage IB, 45% in stage IIA, 60% in stage

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IIB, 66% in stage IIIA, and 95% in stage IIIB [4,5]. Its limitations increase with more advanced tumors.

Imaging is not the method for diagnosing cervical carcinoma. When the diagnosis is established by histology, imaging can be used for assessing morphologic features of prognostic importance, such as tumor size, parametrial invasion or lymph node dissemination. On clinical examination, tumor size may be overestimated in exophytic lesions, and underestimated in endophytic lesions [2]. Another factor is the depth of stromal invasion - the greater the invasion, the more inaccurate the clinical examination. Imaging can be complementary to clinical examination and can follow either FIGO or TNM staging guidelines [6,7].

Improvements in technology, resulting in better image quality, offer noninvasive evaluation of tumor size, depth of penetration, and disease extent; thus imaging can play a role in facilitating better treatment options and ultimately affect patient prognosis. Imaging should be looked upon as complementary to, rather than competitive with, the other methods of morphologic evaluation.

Although many imaging methods are included in the process of staging of cervical carcinoma, the method with greatest advantages is MRI. It is noninvasive, direct imaging, using multiple planes with excellent soft tissue contrast [8-11].

The objective of this review is to discuss the MRI staging of the uterine cervical carcinoma, propose a comprehensive, clinically relevant protocol of examination of the disease, and to present the correlation between MRI and pathologic imaging in comparison to the FIGO staging system.

## Anatomy

Since the advent of MRI, several groups have reported its ability to delineate normal anatomy of the female pelvis, comparing the images with freshly removed uterine specimens [12]. On the T2WI the uterine wall can be separated into 3 layers: the inner and outer myometrium, and the endometrium. The myometrium has intermediate signal intensity with a width of 1.5-2.0 cm. Just between the intermediate signal of the myometrium and the high intensity layer of the endometrium, there is one low signal band representing the so-called junction line zone. Both layers of the endometrium - basic and functional - represent themselves with a homogeneous high intensity signal.

The normal cervix has lower signal intensity than the normal myometrium, which is explained with its relatively higher proportion of fibrous connective tissue. On T1 weighted images (WI) the normal endocervix has low signal intensity and the surrounding glandular and stromal tissue shows higher signal intensity. On T1WI discrimination between these anatomical structures can be difficult. On T2WI the normal endocervix has two separate zones. The central zone representing the endocervical glands has its high signal intensity due to the presence of mucus, as reported by Hricak et al. [13]. On T2WI a second zone, visible as a wide band of low signal intensity, surrounds the central zone. This low signal intensity can be explained by the glandular and stromal (collagen) tissue of the endocervix [14]. However, the ability of MRI to image the cervix as a separate structure as compared with the adjacent uterine corpus allows one to diagnose cervical abnormalities based on alterations in signal intensity rather than on changes in size, as in the case of computed tomography (Figure 1a, 1b and 2) [12,13].

Paracervical tissue surrounds the cervix later-

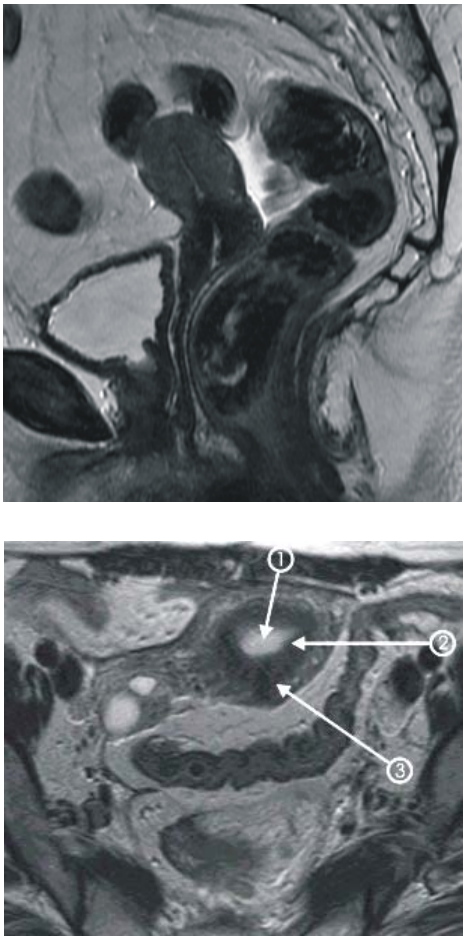



**Figure 1.** Normal MRI anatomy of the uterus and the vagina in sagittal (A) and axial (B) planes by a fast-spin echo sequence. Note the zonal anatomy of the uterus and the relationship of the cervix to the vaginal fornix. Endometrium has high (1), junctional zone low (2), and myometrium intermediate signal intensity (3). Note the follicles of the right ovary (seen on the axial image).

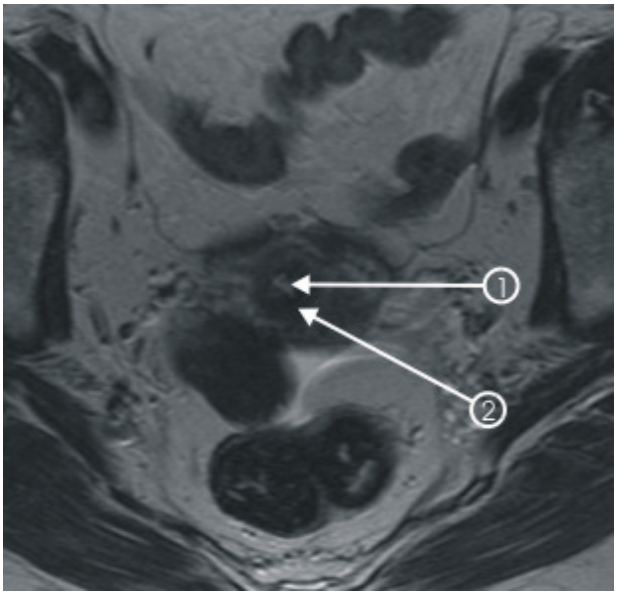
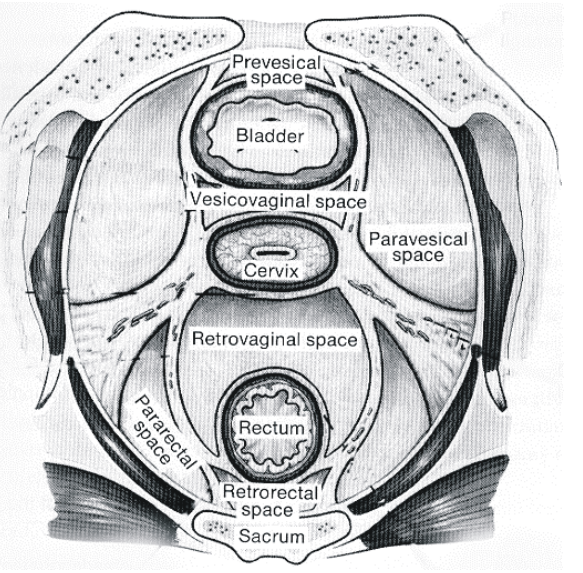
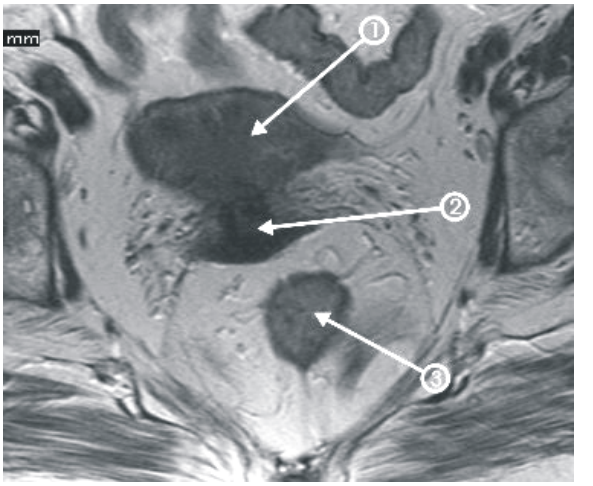



**Figure 2.** Fast-spin echo images with clear delineation of the cervical anatomy: low signal intensity (2) with central high signal (1) due to the cervical mucosa.




A




B

**Figure 3.** A: schematic representation of the pelvic anatomy at the level of the uterine cervix in axial plane. B: normal MRI at the same level as in A, in a 35-year-old volunteer. The axial image shows precisely the anatomic location and demarcation of the uterus (1), cervix (2) and the posteriorly located rectum (3). There is excellent depiction of anatomic details in the lower pelvis.

ally. This tissue is called parametrium and engages the parametrial structures of the lower uterine segment. Parametrial signal intensity is not uniform due to variable consistence of different tissues such as fat, vascular structures, and ligaments. On T1WI the parametrium has intermediate signal intensity, due to highly vascular connective tissue, and cannot be distinguished from the cervix. On T2WI the parametrium has high signal intensity, and a second echo image of a dual-echo sequence with very high signal intensity from slow-flowing blood is often demonstrated.

The normal vaginal anatomy is best visible on T2WI. The vaginal epithelium has high signal intensity and can be separated from the low intensity vaginal wall. Three different parts (important for the tumor staging purposes) can be differentiated in the vagina – lateral vaginal fornices (upper vagina), level of the bladder base (middle vagina) and urethral level (lower third) (Figure 3a and b).

## MRI protocol

Our routine staging protocol includes sagittal and axial T2-weighted fast spin-echo imaging of the pelvis with 5 mm-thick slices, and T1WI with 8 mm slices of the pelvis and the abdomen to the level of the renal hilum. 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 [15]. 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 better contrast between the gynecologic organs and the surrounding tissues. MR urography may be performed in cases of hydronephrosis, depending on the findings. Gadolinium (Gd) is administered intravenously only in large tumors with suspected bladder or rectal invasion and before and/or after radiotherapy. Patients should fast for 4 hours prior to the examination to avoid poor image quality from bowel movement.

Our reports include the tumor stage, tumor size (including the 3 orthogonal diameters), tumor volume, and lymph node evaluation (Figure 4).

## Morphology of cervical carcinoma

On T2WI cervical carcinoma appears as a high-signal intensity mass that can be distinguished from the normal low-signal intensity stroma [16-18]. On T2WI tumour location, diameter, depth of cervical stromal invasion, and extension of tumour to the uterine corpus are accurately demonstrated. However, surrounding tissue oedema can be difficult to differentiate from tumour invasion [19]. In T1WI the uterus appears homogeneous, and these contribute little to the identification of neoplasia. Proton density-weighted images offer much greater tissue differentiation.

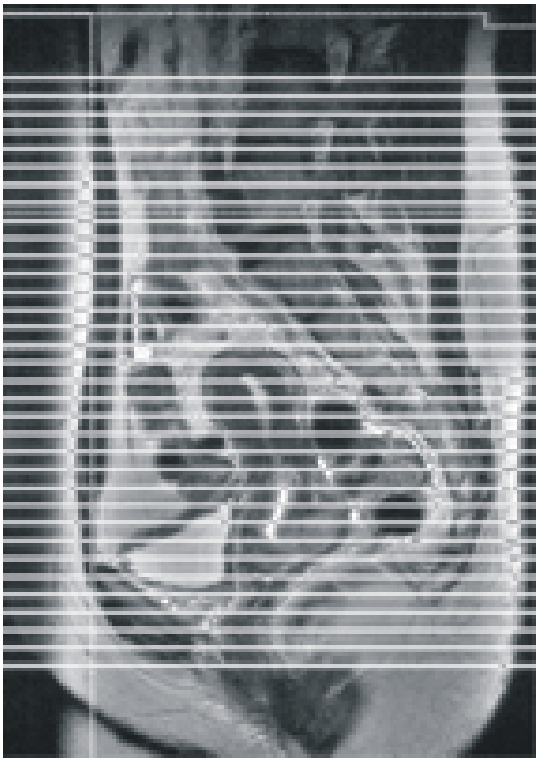
Cervical cancer can be differentiated clearly from the surrounding tissues in 3 dimensions on MRI. The method is better than CT, which is limited in the direct demonstration of small cervical cancers, due to its inferior soft tissue contrast, and it has a tendency to overestimate parametrial spread [2,20,21]. The use of Gd-DTPA does not increase the diagnostic accuracy of tumour depiction. Various degrees of enhancement are seen, often making the tumour isointense with the surrounding cervical tissue. Tumour heterogeneity, however, is well demonstrated after Gd-DTPA administration, allowing differentiation between viable tumor and areas of necrosis.

The prognosis of patients with cervical cancer is clearly related to tumor size [22]. Accurate estimation of tumor size by clinical examination is often difficult and is highly subjective. On the contrary, MRI allows an objective, exact assessment of the tumor dimensions. T2WI are superior to T1WI for this purpose. Single maximum diameters from MR scans have repeatedly shown a high correlation with pathology, with one report indicating an accuracy of 93% in estimating tumor size within 0.5 cm [23]. Tumor volume offers more objective information than size because the tumor's configuration is also taken into account. Quantitative tumor assessment can be performed based on the 3 maximum diameters and the ellipsoid equation (Figure 5).

## Tumor staging

Cervical cancer is staged according to either the Tumor-Node-Metastasis (TNM) or the FIGO classification system [2]. The prognostically important lymph node status is not included in the latter.

MRI staging is mainly based on the FIGO staging criteria. It provides a more complete pretreatment assessment of the tumor and complements the clini-



T1 COR
- Anatomical orientation
- Retroperitoneal lymph nodes
- Evaluation of the kidneys
- Evaluation of pelvic floor and parametrial fat plane

T2 WI
- Differentiates the tumor from the neighboring tissues
- Characterizes the structure of the tumor and the lymph nodes

T2 SAG
- Demonstrates the relationships between the tumor and lower uterine segment and the vagina
- Demonstrates the relationships between the tumor and urinary vessels and/or anterior rectal wall

**Figure 4.** Sagittal localizer shows the position of the axial sections covering the distance between the middle part of both kidneys and the pubis. The Table summarizes the benefits from different projections and techniques (weighted images).

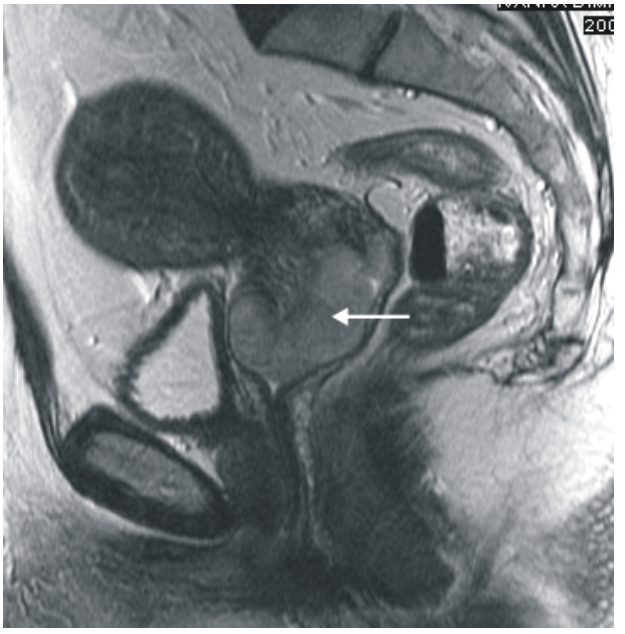


**Figure 5.** Cervical carcinoma in a 54-year-old patient. The tumor (arrow) shows high signal intensity in T2WI and is sharply delineated from the normal cervical stroma.

cal findings when making individual treatment decisions (Table 1) [10,24-26].

*Stage 0* are all carcinomas *in situ*. They are not visualized with imaging methods.

*Stage I* are invasive tumors confined to the cervix.

*Stage IA* is diagnosed only by microscopy. Stromal invasion with a maximum depth of 3 mm measured from the base of the epithelium and a horizontal spread of 7 mm or less [26]. The size of superficial lesions is underestimated with MRI, probably due to the poor contrast between the relative signal intensity of the tumor and the similar signal intensity of the cervical epithelium or because of artifacts such as blood clots after biopsy (Figure 6) [27].

*Stage IB* is the smallest tumor, which could be identified on MRI. This is a lesion of relatively high-signal intensity extending from the prominent high-signal epithelium to the low-signal cervical stroma which is less than 7 mm in axial diameter and less than 5 mm in depth [28]. The outer low-intensity cervical stroma is always seen, and the signal intensity and symmetric configuration of the parametrium remain normal. The T1WI and paracervical fat planes remain sharp and distinct (Figure 7a-d) [21,29].

*Stage II* cervical carcinoma invades beyond uterus but not to pelvic wall or to lower third of the vagina.

In *Stage IIA*, the tumor mass extends to the upper two-thirds of the vagina. Disruption of the hypointense vaginal wall with hyperintense thickening on T2WI and contrast material enhancement on T1WI are signs of vaginal invasion. Tumor extension to the vagi-

**Table 1.** FIGO staging classification of cervical carcinoma

| | |
|---|---|
| *0* | *Carcinoma in situ* |
| *I* | *Cervical carcinoma confined to the cervix* |
| IA | invasive carcinoma diagnosed only by microscopy. Stromal invasion with a maximum depth of 3 mm measured from the base of the epithelium, and a horizontal spread of 7 mm or less. |
| IB | clinically visible lesion confined to the cervix or microscopic lesion greater than T1A1/IA2. |
| *II* | *Cervical carcinoma invades beyond the uterus but not to the pelvic wall or to the lower third of the vagina* |
| IIA | tumor involves the upper third of the vagina. |
| IIB | tumor with parametrial invasion. |
| *III* | *Tumor extends to the pelvic wall and/or involves the lower third of the vagina, and/or causes hydronephrosis or non-functioning kidney* |
| IIIA | tumor involves the lower third of the vagina, no extension to the pelvic wall. |
| IIIB | tumor extends to the pelvic wall and/or causes hydronephrosis or non-functioning kidney. |
| *IV* | *Tumor with extension from the true pelvis* |
| IVA | tumor invades the mucosa of the bladder or rectum, and/or extends beyond the true pelvis (bullous edema is not sufficient to classify a tumor as T4). |
| IVB | tumor with distant metastases. |

**Figure 6.** Low-power histological specimen of a microinvasive (stage IA) squamous cell carcinoma of the cervix.

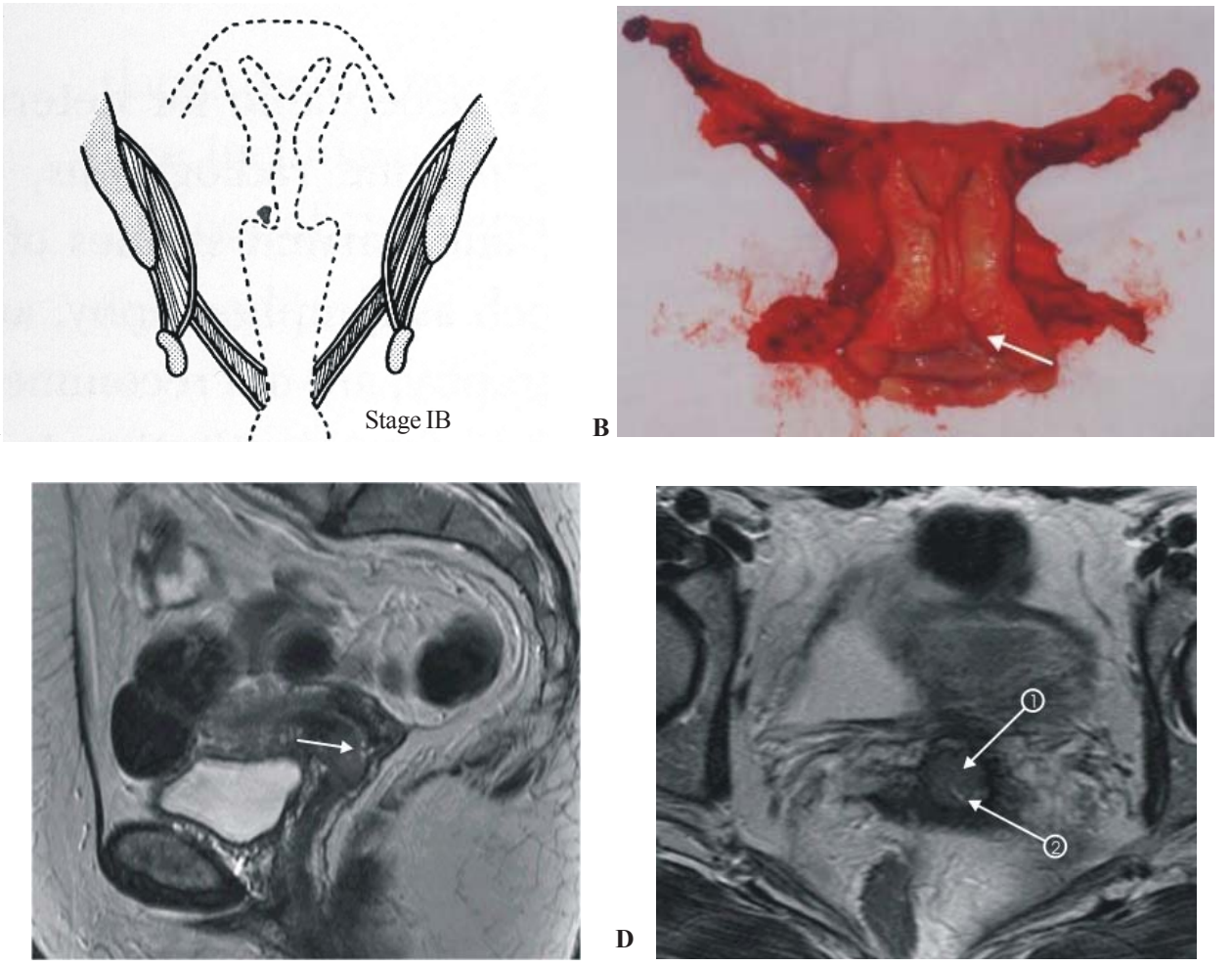



**Figure 7.** A: schematic representation of stage IB cervical cancer. B: pathological specimen of stage IB cervical cancer (arrow). C: sagittal T2WI of the same patient shows a small, slightly hyperintense carcinoma (arrow) in the anterior part of the cervix. D: additional axial T2WI demonstrates a central hyperintense tumor (1), in contrast to the hypointense cervical stroma (2).

na can be reliably excluded with MRI. False-positive results can occur in patients with large exophytic tumors or lymphedema and venous congestion (Figure 8a-d).

In *Stage IIB,* parametrial extension is diagnosed using both T1 and T2WI. Axial planes are often the most useful in assessing the parametria [30]. When the outer cervical stroma is preserved on MRI, the parametria are considered not to be involved. The specificity of MRI in these circumstances is 100%. When the full thickness of the cervical stroma is replaced by tumor, the rate of false-positive interpretation is high, leading to a specificity of only 50%. When the tumor extends into the lower uterine segment and completely invades the cervical stroma, parametrial extension is present in 94% [31].

Assessment of both morphologic and signal intensity alterations indicating parametrial tumor spread include an irregular lateral margin, prominent parametrial strands, eccentric parametrial enlargement, and loss of periparametrial fat planes on T1WI and/or abnormally high-intensity signal in the involved parametrium on T2WI [32,33]. With the application of these criteria, Sheu et al. [31] found that the accuracy in the assessment of parametrial invasion by MRI is as high as 96.7%, which is similar to the results of previous studies by Janus et al. and Subak et al. who reported 86-94% accuracy rate (Figure 9a-d) [23,34].

*Stage III* lesions are usually bulky tumors and are easily visualized on MRI scans. In stage III the cervical tumor extends to the pelvic wall and/or involves the lower third of the vagina.

In *Stage IIIA* disease, the tumor extends to the lower third of the vagina. The MRI criteria are the same as in stage IIA except the level of vaginal and parametrial invasion. An usual finding is hydroneph-

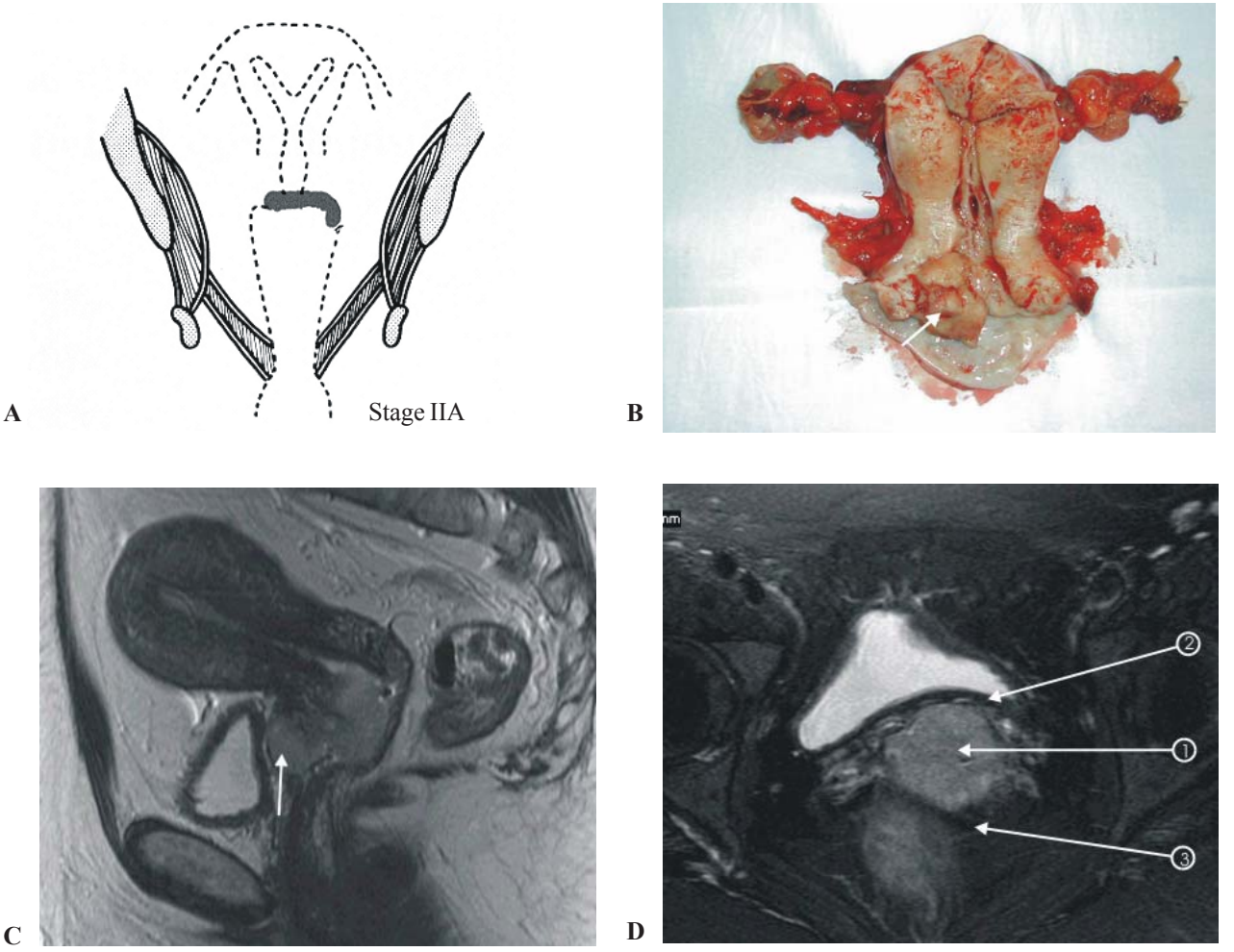



**Figure 8.** A: schematic representation of stage IIA cervical cancer. B: pathological specimen of stage IIA cervical cancer (arrow). C: sagittal T2WI of the same patient shows a large exophytic tumor invading the anterior vaginal fornix (arrow). D: axial T2 FS WI demonstrates the tumor (1) in the transverse plane. Note the homogeneous fat planes of the pelvis and the free retrovesical (2) and prerectal spaces (3).

rosis or nonfunctioning kidney (Figure 10a-d).

In *Stage IIIB* disease, there is extension to the pelvic sidewall (with or without hydronephrosis) and the normal, low intensity pelvic muscles (levator ani, pyriformis, or obturator internus muscle) are disrupted on T2WI. The MRI findings are the same as for IIB, but the extension is beyond the lateral margin of the cardinal ligament [35]. Patients with tumor extension to the origin of the uterine artery and vein at MRI or with ureteral obstruction at the level of the tumor are not suitable for operation. Even when there is no invasion of the soft tissue or bony structures of the pelvic sidewall at MRI, these patients have stage IIIB disease for clinical purposes (Figure 11a and b).

In *Stage IV,* the tumor invades the urinary bladder or rectal wall and/or extends beyond the true pelvis.

In *Stage IVA* disease, the carcinoma extends beyond the true pelvis, involving the urinary bladder or rectum. MRI can reliably rule out invasion of the bladder or rectal wall. The loss of normal low-signal intensity of the bladder or rectal wall on T2WI in addition to the loss of normal fat planes are very suggestive of neighboring organ involvement. With the above mentioned criteria Seung and Han found a sensitivity of 83% and specificity of 100%, based on the MRI of 300 patients with cervical carcinoma [36]. They stated that MRI can eliminate the need for cystoscopy or rectosigmoidoscopy in most patients. If MRI findings regarding bladder involvement are equivocal, cystoscopy should be performed, even though it can miss early invasion of the bladder wall. Bullous edema of the bladder wall, apparent as high-signal zone on proton-density WI, can be secondary to early tumor invasion or lymphedema [36]. The application of contrast material does not improve the assessment of infiltration of the bladder or rectum wall compared with

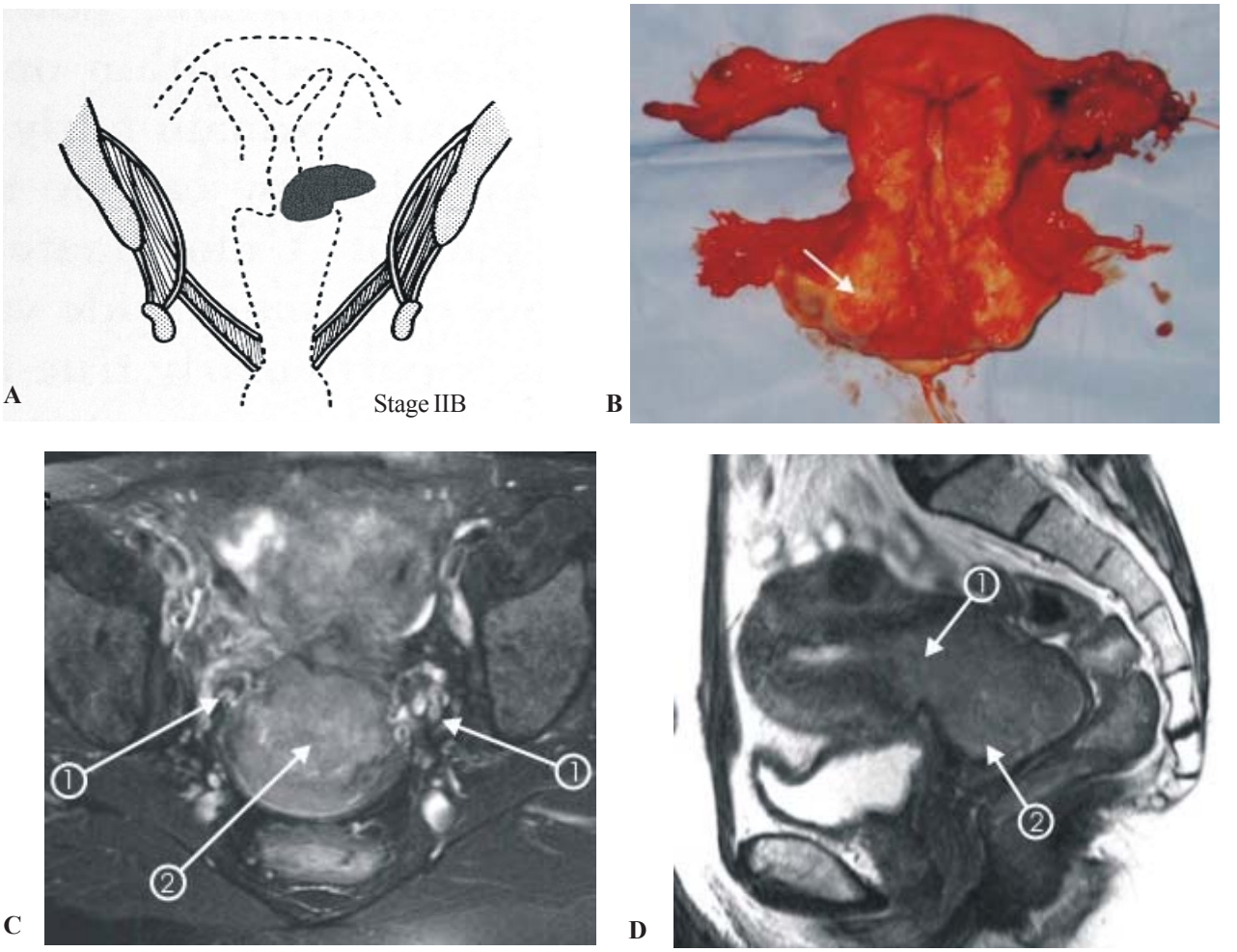



**Figure 9.** A: schematic representation of stage IIB cervical cancer. B: pathological specimen of stage IIB cervical cancer (arrow) in a 56-year-old woman. C: axial T2 FS WI of the same patient shows bulky tumor (2), which replaces the cervical stroma and protrudes laterally with extension toward both parametria (1). D: sagittal T2 image demonstrates the longitudinal extension of the tumor. There is involvement of the lower uterine segment (1) and the upper third of the vagina (2).

conventional T2WI (Figure 12a-d).

*Stage IVB* defines a tumor with distant metastases (Figure 13a and b).

## Lymph node assessment

The presence of malignant lymph nodes is a grave prognostic factor. They are detected more frequently with increasing stages and are often associated with an increase in tumor volume. Pelvic nodes are included in the typical lymphatic spread of cervical cancer. An increase of stage also leads to a greater involvement of infiltrated nodes along the common iliac vessels and para-aortic area. Para-aortic lymph node metastases, even in early stages, indicate a systemic occult spread and are associated with a high rate of extrapelvic metastases and poor prognosis. Tumor-bearing lymph node tissue, however, may not cause nodal enlargement. Imaging of metastatic lymph nodes in cervical cancer to date has relied on morphologic criteria alone. They include size, shape, location, and grouping of lymph nodes detected. Even in small but rounded lymph nodes, central areas of necrosis, or a conglomeration of lymph nodes are suggestive of metastases [37,38]. Neither CT nor MRI can differentiate hyperplastic from malignant nodal enlargement (Figure 14a-c) [21].

## Conclusion

Diagnosis of cervical cancer is based on gynecological examination in combination with cytologic-histopathologic findings. Imaging is not useful for screening because preinvasive cancers will not be

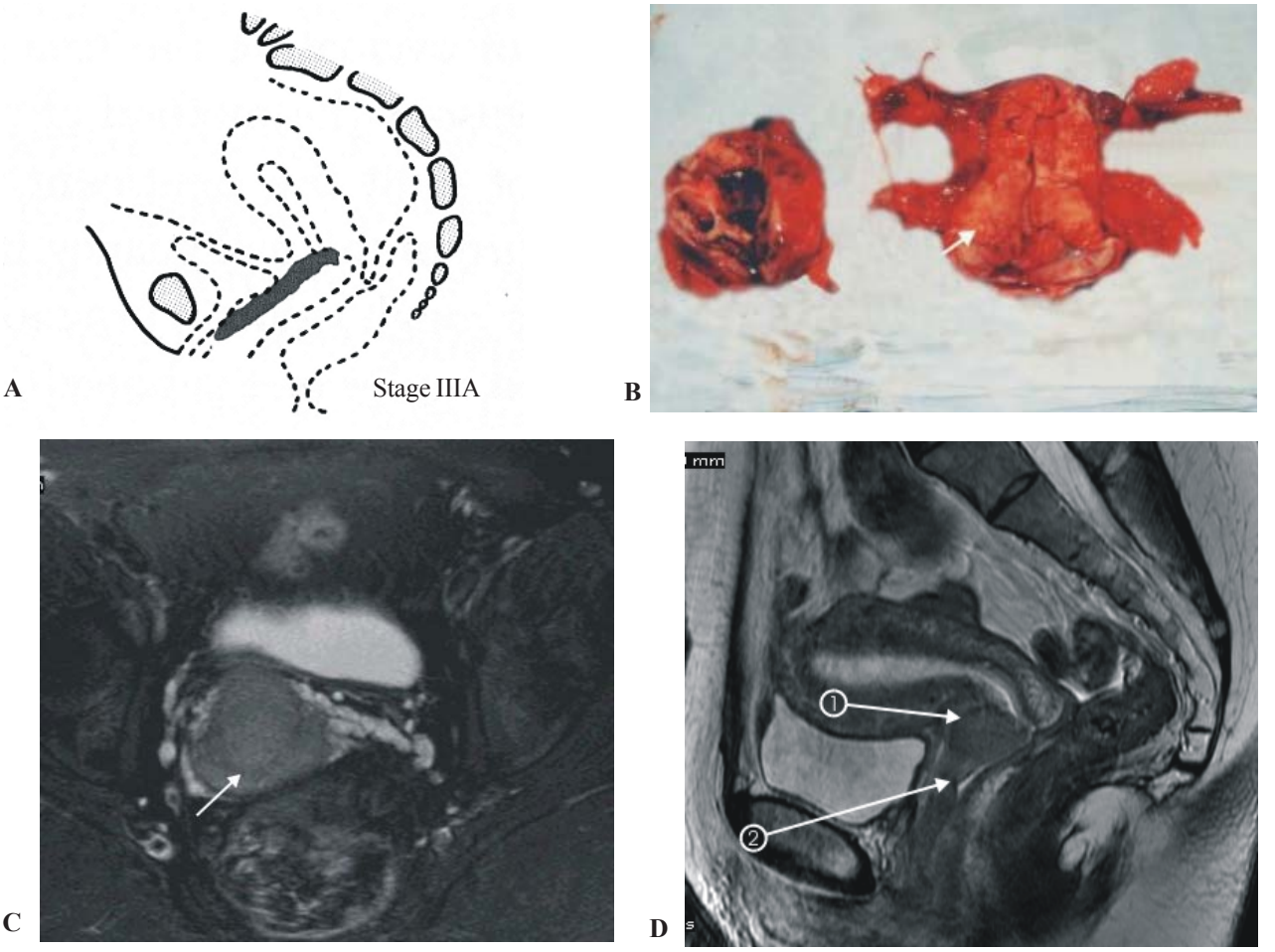



**Figure 10.** A: schematic representation of stage IIIA cervical cancer. B: pathological specimen of stage IIIA cervical cancer (arrow) in a 56-year-old woman. C: axial T2 FS WI of the same patient shows bulky tumor protruding laterally (arrow). D: sagittal T2 image demonstrates the longitudinal extension of the tumor (1). There is involvement of the whole anterior vaginal wall (2).

detected. Small invasive cancers can be missed even with state-of-the-art equipment. Imaging has been widely advocated, however, for patients with cervical tumors larger than 0.5cm in diameter on clinical examination. MRI can provide important information in these cases about the tumor size and configuration, its vascularization, its local extension, lymph node enlargement, and metastases. These findings and the patient's condition are used together to design a tailored therapy that can include surgery, primary radio-

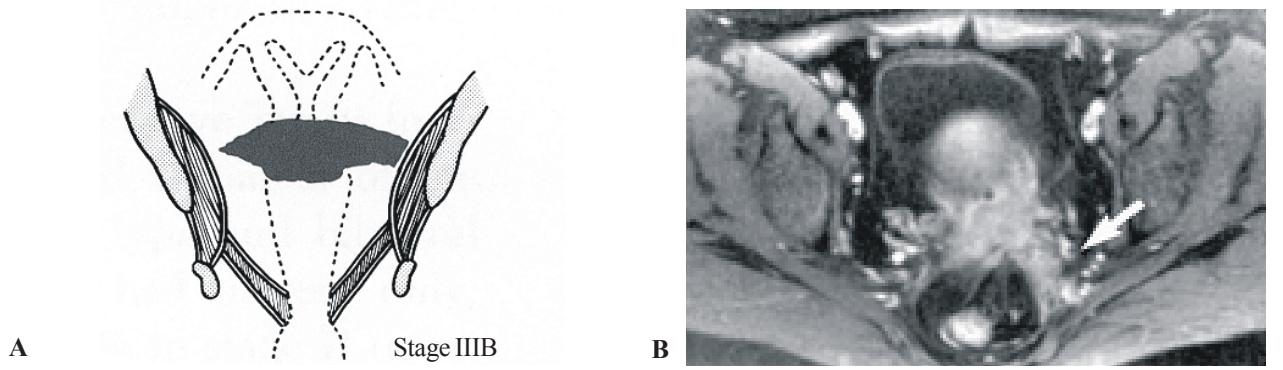
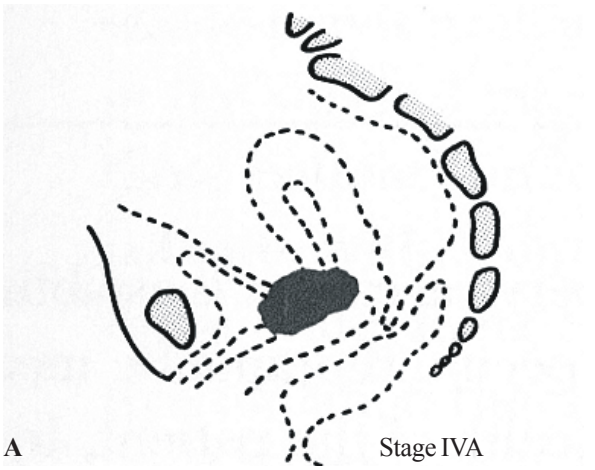



**Figure 11.** A: schematic representation of stage IIIB cervical cancer. B: post contrast axial T1WI in a 62-year-old woman demonstrates a large tumor (arrow), extending into both parametria and the sacro-uterine ligaments.

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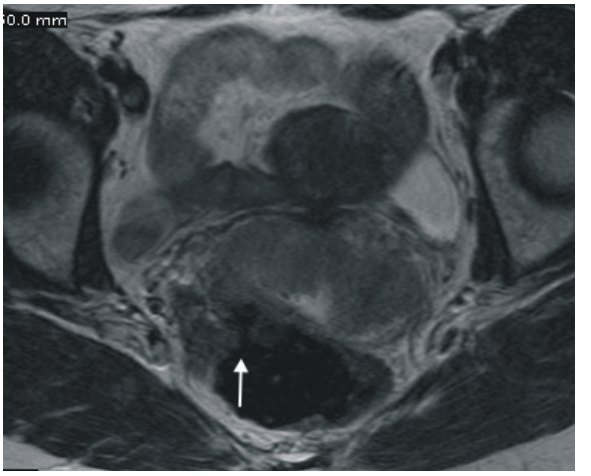

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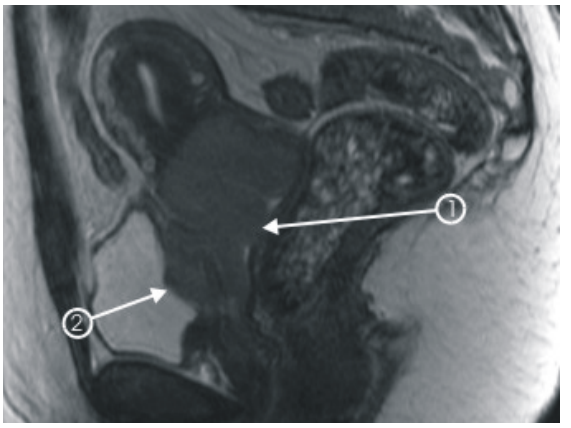


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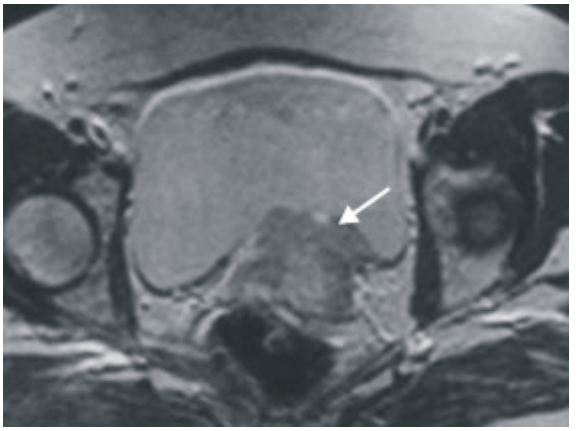
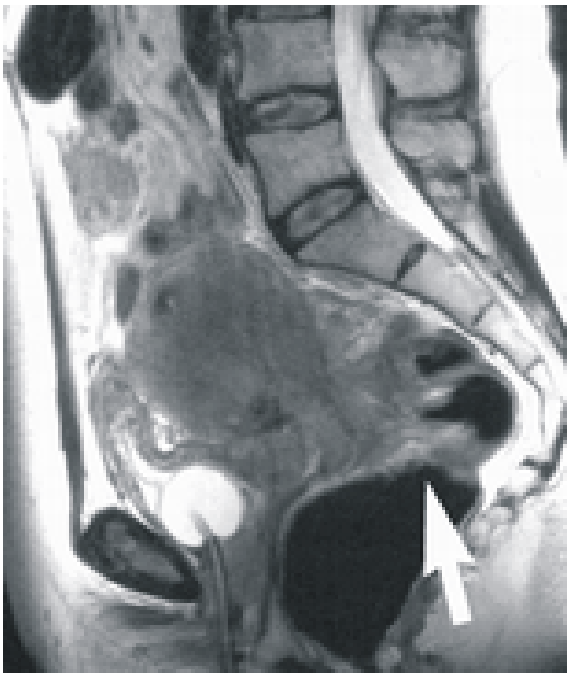


D

**Figure 12.** A: schematic representation of stage IVA cervical cancer. B: axial T2WI shows a large tumor with exophytic component and direct extension into the rectal wall (arrow). C: sagittal T2WI in another patient demonstrates a large exophytic tumour, abutting the anterior rectal wall (1) and replacing the retrovesical space (2). D: axial T2WI of the same patient (C) clearly shows the invasion in the posterior vesical wall (arrow).



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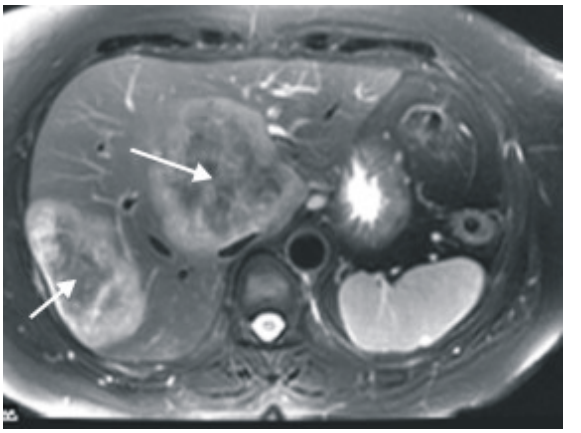
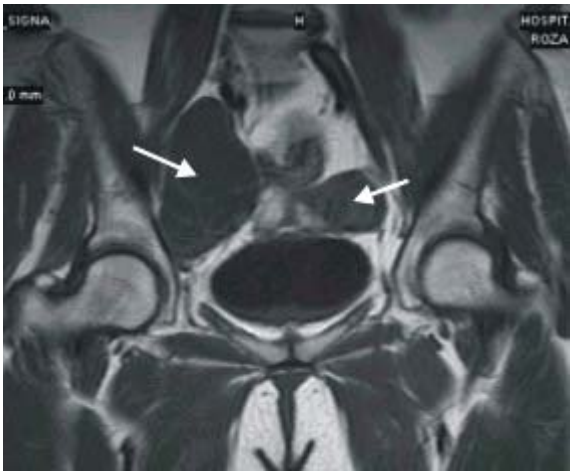


B

**Figure 13.** A: sagittal T2WI reveals irregularity of the rectal wall and a mass protruding into the lumen of the bowel (arrow). B: except the local aggressiveness of the tumour, the images of the liver show several parenchymal metastases (arrows).

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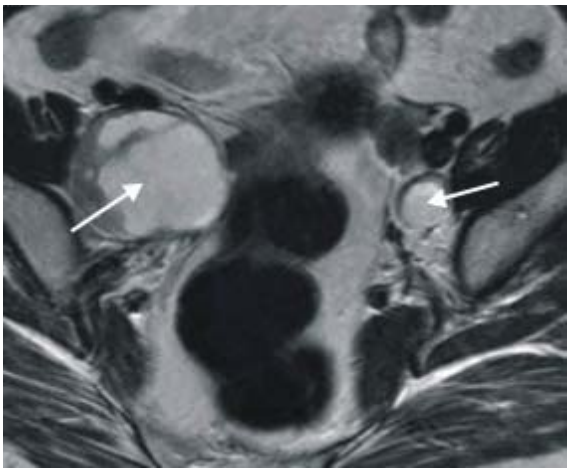

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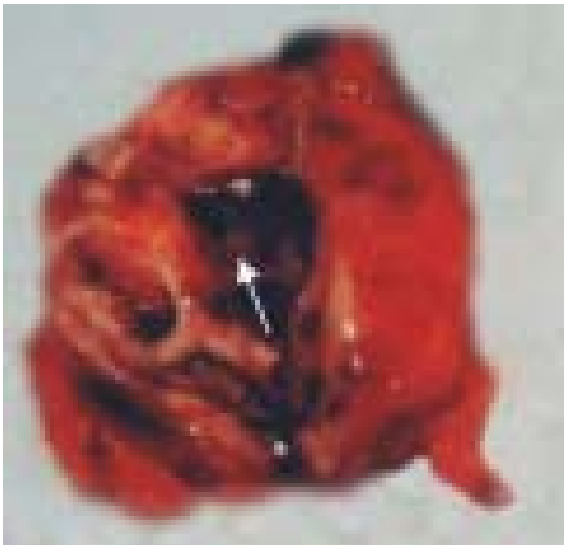

C

**Figure 14.** A: coronal T1WI shows enlarged bilateral parailiac lymph nodes (arrows) in a 46-year-old patient with stage IIIA cervical carcinoma. B: in axial T2WI, large zones of central necrosis are seen in both sides (arrows). C: the macroscopic specimen of the same patient demonstrates the enlarged, right-situated lymph node with central cavitations (arrow).

therapy, and/or chemoradiotherapy.

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