Cervical carcinoma: role of MRI in detection, staging and follow-up.

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Learning objectives

• To illustrate normal cervical anatomy on MRI, describe staging criteria for cervical carcinoma and review the role of MRI in treatment monitoring.

Background

• Cervical carcinoma is the third most common gynecologic malignancy (after endometrial and ovarian cancer) and one of the most frequent causes of death in women. The average age at diagnosis is about 50 years, with peaks at 38 and 62 years. In most cases this tumor is developed from the squamo-columnar junction zone, which can migrate from external os of cervix to endocervical canal; this process is age-dependent. The squamo-columnar junction zone is located exocervically in young females and in these cases cervical carcinoma grows predominantly exophytically and large parts of the tumor extend inferiorly into the vagina. In older women with atrophic cervices the squamo-columnar junction is located in the endocervical canal. Tumors occurring inside the endocervical canal account for approximately 20% of cervical carcinomas, more commonly involve the supravaginal portion of the cervix, and frequently extend laterally through the cervical wall. Normal zonal anatomy of uterine cervix and MR criteria for different stages of cervical carcinoma and tumor response on therapy are presented at the exhibit.

• The most widely used staging system of cervical carcinoma is the FIGO (International Federation of Gynecology and Obstetrics) classification, which is based on findings at clinical examination, chest radiography, excretory urography, cystoscopy, colposcopy, proctosigmoidoscopy and barium enema findings. Findings obtained with cross-sectional imaging are not taken into consideration in determining the FIGO stage. Because of that FIGO staging system is sometimes inaccurate and there is poor evaluation of tumor size and volume, parametrial involvement and nodal metastases. It is widely known that the presence of metastatic lymph nodes is crucial for prognosis. Assessment of stage of cervical cancer is very important because approximately 30% of women with invasive cervical carcinoma die as a result of inadequate primary treatment and as a result recurrent disease. For these reasons in our hospital we use two classification FIGO and TNM (table 1); obtained criteria correlate much better with the prognosis and let to choose the most adequate treatment.

Table 1. Correlation between TNM and FIGO classifications

<table>
<thead>
<tr>
<th>TNM</th>
<th>FIGO</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tis</td>
<td>0</td>
<td>Carcinoma in situ</td>
</tr>
<tr>
<td>-----</td>
<td>----</td>
<td>------------------</td>
</tr>
<tr>
<td>T1</td>
<td>I</td>
<td>Carcinoma confined to the cervix</td>
</tr>
<tr>
<td>T1a1</td>
<td>IA1</td>
<td>Stromal invasion no greater than 3 mm in depth and no wider than 7 mm diameter</td>
</tr>
<tr>
<td>T1a2</td>
<td>IA2</td>
<td>Stromal invasion greater than 3 mm but no greater than 5 mm in depth and no wider than 7 mm in diameter</td>
</tr>
<tr>
<td>T1b1</td>
<td>IB1</td>
<td>Lesions confined to cervix and greater than Stage IA, but no greater than 4 cm in size</td>
</tr>
<tr>
<td>T1b2</td>
<td>IB2</td>
<td>Lesions confined to cervix and greater than 4 cm in size</td>
</tr>
<tr>
<td>T2</td>
<td>II</td>
<td>Carcinoma extends beyond the cervix. Tumor can involve the upper 2/3 of vagina, corpus of the uterus, but does not extend to the pelvic wall</td>
</tr>
<tr>
<td>T2a</td>
<td>IIA</td>
<td>No obvious parametrial involvement</td>
</tr>
<tr>
<td>T2b</td>
<td>IIB</td>
<td>Parametrial involvement</td>
</tr>
<tr>
<td>T3</td>
<td>III</td>
<td>Carcinoma involves pelvic sidewall or lower 1/3 of vagina. Hydronephrosis or a non-functioning kidney</td>
</tr>
<tr>
<td>T3a</td>
<td>IIIA</td>
<td>No extension into the pelvic sidewall but involvement of the lower 1/3 of the vagina</td>
</tr>
<tr>
<td>T3b</td>
<td>IIIIB</td>
<td>Extension into the pelvic sidewall or hydronephrosis or non-functioning kidney</td>
</tr>
<tr>
<td>T4</td>
<td>IV</td>
<td>Carcinoma extends beyond the true pelvis or has</td>
</tr>
</tbody>
</table>
clinically involved the mucosa of the bladder and/or rectum

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>T4a</td>
<td>Spread of the tumor into adjacent pelvic organs</td>
</tr>
<tr>
<td>M0</td>
<td>Without distal metastases</td>
</tr>
<tr>
<td>T4b M1</td>
<td>Distal metastases</td>
</tr>
<tr>
<td>N0</td>
<td>Without lymph nodes involvement</td>
</tr>
<tr>
<td>N1</td>
<td>Involvement lymph nodes</td>
</tr>
</tbody>
</table>

### Imaging findings OR Procedure details

#### MRI study technique and protocol

- The presentation is based on analysis of 125 MRI cases of uterine cervical carcinoma. Examinations were performed with 1.5 T state-of-the art MR-systems and phased-array surface coils. Gynecologic history should be obtained prior to the MRI examination. It's very important to know information on the phase of the menstrual cycle or postmenopause, datasets on pregnancies, on previous pelvic surgery or radiochemotherapy. Patient is asked to fill bladder at the moment of MRI scan without having the discomfort of voiding urgency during the procedure.

- The MRI examination begins with a localizer scan in transverse, sagittal and coronal orientation. Imaging protocol included T1 and T2-weighted (T1W and T2W), fat-suppression sequences and 3D gradient-echo sequences with contrast enhancement. The first T2W sequence should be acquired in the sagittal plane and covers the uterus and vagina to the pelvic floor. Transversal T1- and sagittal T2W FSE sequences with large FOV allow to evaluate all pelvic organs - cervix and corpus of the uterus, ovaries, vagina, bladder, rectum, pelvic lymph nodes, pelvic bones and lumbar vertebra. The sagittal T2W images may serve to plan the transverse angulated T2W sequence. Imaging protocol includes two high-resolution FSE T2W sequences in the oblique plane - parallel and orthogonal to the main axis of the cervical canal. Because of the high spatial and contrast resolution T2W high resolution sequences allow to depict zonal anatomy of the cervix in detail and give an excellent visualization of neoplastic lesions, their location, size, shape and the relationship among the lesions and the adjacent organs. The imaging field in transverse orientation extends from the fundus uteri or ovaries to the pelvic floor. Coronal T2- fat sat sequence images are finally for evaluating para-aortic and other groups of enlarged lymph nodes. Involvement of the pelvic floor muscles in advanced tumors is evaluated on coronal T2- fat sat sequence images too.
• In most cases contrast medium doesn't improve staging accuracy. Intravenous administration of contrast medium allows distinction between viable tumor and areas of necrosis, recurrent tumor and posttreatment changes. However, it has not been shown to increase diagnostic performance in tumor depiction, in the definition of the depth of stromal invasion, or in the evaluation of early parametrial involvement. Rarely contrast medium can help confirm tumor extension to the pelvic sidewall or into the adjacent organs.

• For staging of cervical carcinoma MR datasets were correlated with FIGO and TNM criteria. Usage of MRI results for selection of treatment and follow-up is presented.

**Zonal anatomy of the cervix**

• The cervix is the cylindrical part of the uterus inferior to the isthmus and is separated from the corpus by the internal os, which corresponds to a slight constriction visible externally and at which level the uterine vessels enter the uterus. The junction is demarcated histologically by a change of epithelium from glandular (corpus) to columnar (cervix). The internal os is connected to the external cervical os by the endocervical canal, which is lined by multiple mucosal folds and measures 8 mm at its widest point. The external os is marked histologically by the junction of squamous and columnar epithelium.

• The cervix is divided by the vaginal fornices into the supravaginal and intravaginal parts. The intravaginal part is covered by squamous cell epithelium. The endocervical canal is covered by columnar epithelium. The cervical stroma consists of fibrous connective tissue (80%), of smooth muscle (15%) and elastic tissue. Only in the upper portion of the cervix smooth muscle dominate, forming a sphincter.

• The normal cervix is 3 cm long and has a diameter of 2-2.5 cm. On T1W images the cervix shows uniform intermediate signal intensity. Zonal anatomy of the cervix is best displayed on T2W images. On high-resolution T2W sequences the cervix demonstrates three to four distinct zones. The sagittal orientation allows visualization of the cervix from the internal to the external os including the anterior and posterior lips of the cervix. Centrally a hyperintense zone representing the mucus within the endocervical canal can be seen. This is followed by an inner area of high signal intensity representing the endocervix, which is composed of columnar epithelium as well as central mucus. The combined thickness of the endocervical canal and mucosa ranges from 2 to 3 mm. Surrounding the endocervix is the hypointense fibrous stroma of the cervix of 3-8 mm thickness, which has a high concentration of elastic fibrous tissue. The inner dense fibrous stroma is continuous with the junctional zone of the corpus. The layer of smooth muscle is continuous with the outer myometrium of the uterine corpus and appears of medium signal (Fig.1). In the axial plane, perpendicular to the endocervical canal, the cervix is displayed as a round structure with a target appearance because of the typical zonal anatomy (Fig.2). Gadolinium administration leads to enhancement of the inner mucosal epithelium and the paracervical tissue, whereas the cervical stroma shows more
gradual enhancement. The fibrous stroma enhances at a slower rate relative to the outer zone of smooth muscle.

**MR imaging of the cervical cancer**

- The role of MR imaging in the diagnostic workup of cervical carcinoma is not to prove the presence of tumor, which is accomplished by biopsy or cytology, but to exactly define the tumor extension.

- The most useful sequence for evaluation of cervical cancer is T2W, which provide a high soft-tissue contrast for optimal differentiation of tumor from normal cervical stroma and adjacent organs. Typically cervical cancer appears on T2W images as hyperintensive lesions and is easily distinguishable from the normal low signal intensity surrounding cervical stroma.

**Stage I**

- According to FIGO and TNM classification stage I cancer is confined to the cervix. In stages IA1, IA2, size of the lesion is very small, and it can be detected only under a microscope. Such preinvasive disease usually cannot be identified with MR imaging due to small size. The cervical stroma appears normal on T2W images - the normal hyperintensive endocervix is surrounded by hypointense cervical stroma, which consists of connective tissue and smooth muscle.

- **Stage IB** cancer is still confined to the cervix but is characterized by invasive local growth. Stage IB1 (diameter <4 cm) and stage IB2 (diameter>4 cm) are distinguished on the basis of their size. Small stage IB1 diseases are often undetectable on T2W images, and like a stage IA, could not be demonstrated on MR imaging. Never the less stage IB2 and in some cases stage IB1 can be visualized without a microscope - there are the earliest stage that can be demonstrated by MR imaging. Transverse and sagittal T2W depict cervical carcinoma as a high signal intensity lesion within the intermediate signal intensity cervical stroma (Fig.3, 4).

**Stage II**

- In stage II the cervical cancer grows beyond the cervix and can involves the upper 2/3 of vagina, corpus of the uterus, but does not extends to the pelvic wall.

**Stage IIA** is characterized by vaginal (less than 2/3) or uterus infiltration in the absence of parametrial involvement. To evaluate localization, size of the tumor, depth of cervical stroma infiltration and extension advanced-stage tumor into the uterus (Fig.5) and vagina T2-weighted images in sagittal and transverse plane are the most informative sequences. On T2W images, vaginal involvement is indicated by loss of normal low signal intensity of the vaginal wall or hyperintense thickening and segmental disruption of the vagina (Fig.6). After contrast injection tumor shows homogenous and earlier than the normal stroma enhance.
Stage IIB cervical cancer is characterized by parametrial infiltration in the absence of extension to the pelvic sidewall and the lower third of vagina. MRI is the only noninvasive modality that allows adequate evaluation of parametrial infiltration. Parametrial invasion on stage IIB is better analyzed with use of axial-oblique T2W images perpendicular to the cervical axe. In most cases with parametrical involvement, full-thickness stromal invasion is present. On these images, the lesion spreads on parametrium and we can see that hypointensive stromal ring surrounding tumor is completely or partly disrupted (Fig.7). Speculated and irregular tumor/parametrium interface and broad full-thickness infiltration of the supravaginal cervix are the signs of the early microscopic parametrial invasion.

- In partial stromal invasion the uninvolved cervical tissue is demonstrated as a hypointense peripheral stripe. The presence of this stripe with a thickness >3 mm is a very specific parameter for the exclusion of parametrial invasion (Fig.8). In situation of complete disruption of the low signal intensity cervical ring the exclusion of parametrical involvement is more difficult. However, when the vaginal fornices are intact, the tumor is likely confined to the cervix.

Stage III

- On stage III tumor involves the lower third of the vagina or extends to the pelvic sidewall or causes hydronephrosis or hydroureter.

- On IIIA stage of cervical cancer imaging findings are the same as for stage IIA but tumor extends to the lower third of the vagina (Fig.9). Commonly tumor spreads in continuity from the upper 2/3 to the lower 1/3 of the vagina. Tumors masses cause disruption and thickening of the vaginal wall that extends to the lower third of the vagina. Due to their necrotic changes the large tumors show variable enhanced and often are surrounded by an enhancing rim.

- On IIIB stage tumor extends to the pelvic sidewall or causes hydronephrosis or hydroureter (Fig.10). Cervical cancer can reach the pelvic sidewall by continuous lateral growth through the parametrial tissue. Tumor extends to either the cardinal ligament or the pelvic musculature (internal obturator, levator ani, pyriform muscles) or the iliac vessels. T2W images demonstrate high signal intensity of parametrial tissue, pelvic muscles, low signal intensity of the cortical bone, or thickening of the vascular wall or ureteral wall. Hydronephrosis can be diagnosed if tumor is incasing the ureter, leading to dilatation of the ureter and renal pelvis.

Stage IV

- If cervical carcinoma invades the bladder mucosa (Fig.11) or rectum (Fig.12), or extends beyond the true pelvis it is consistent with stage IVA. On T2W normal hypointense posterior bladder wall or anterior rectum wall is disrupted or segmental thickened by hyperintense tumor, have irregular contours and tumor mass into the lumen. Direct infiltration of the rectum is rarely found, because the rectum is separated by the pouch
of Douglas. More frequently rectal involvement occurs by tumor spread along the uterosacral ligaments.

**Distant metastases** are characteristic of stage IVB cervical cancer in the FIGO classification and stage M1 in the TNM classification. Distant metastases most commonly affect the lungs and are less frequent in the liver, peritoneum, and skeleton.

**Lymph node metastases**

- Lymph node metastases are not included and don’t change the FIGO stage. For this reason in our hospital we use two classification FIGO and TNM; obtained criteria correlate much better with the prognosis and let to choose the most adequate treatment. Cervical carcinoma spreads to the parametrial lymph nodes first, followed by the obturator nodes and the iliac lymph node chains. To identify enlarged lymph nodes we use axial T1-weighted images and coronal T2-fat sat sequence (Fig.13). Imaging should be extended cranially to the kidneys for revealing retroperitoneal adenopathy and hydronephrosis. The determination of metastatic involvement of lymph nodes is based on their size. The most widely used size criteria for lymph node involvement is a short-axis diameter > 1 cm. The highest problem with MRI is inability to identify metastasis in normal-size lymph nodes.

**Recurrent cervical carcinoma**

- Recurrent cervical carcinoma may be found in up to 20% of cases. Approximately 30% of women with invasive cervical carcinoma die as a result of recurrent or persistent disease. MRI and CT perform comparably to detect distant recurrence, whereas MRI likely performs better at detecting recurrence in the pelvis. The presence of completely low signal intensity stroma around the endocervical canal after the treatment in most cases excludes recurrence (Fig.14).

On T2W images the presence of high signal intensity mass is highly suspicious of recurrent tumor (Fig.15). In contrast to recurrent tumor, late fibrosis demonstrates low signal intensity on T2W images without enhancement after administration of contrast material. Early fibrosis, because of acute inflammation, edema and high degree of vascularization, can display intermediate signal on T2W images and show contrast enhancement, and may be difficult to distinguish from recurrent tumor.

Typical manifestation of recurrent tumor is a recurrent pelvic mass (in the vaginal cuff, cervix, parametrium and pelvis sidewall) and lymphadenopathy; less common sites of recurrence are solid organs (liver, lung or bones) and peritoneal carcinomatosis.

**Images for this section:**
T2W images in sagittal plane. The cervix is displayed with its high signal intensity endocervical canal representing the endocervical mucosa and mucus (A), its low signal intensity inner stroma (B) and its intermediate signal intensity outer cervical stroma (C).

**Fig. 1:** Normal zonal anatomy of the uterine cervix, sagittal plane.
T2W images in oblique plane - orthogonal to the main axis of the cervical canal - to the periphery the endocervical canal is surrounded by low signal intensity inner stroma (A) and intermediate signal intensity outer stroma (B). The endocervical canal is lined by mucosal folds (C).

**Fig. 2:** Normal zonal anatomy of the uterine cervix, transverse-oblique plane.
T2W transverse-oblique (A) and sagittal (B) images, demonstrating high signal intensity tumor of endocervical canal, no exceeding 2.3 cm in its greatest diameter making it a radiological IB1 tumor.

**Fig. 3:** Cervical cancer, stage IB1 (FIGO), T1b1N0M0 (TNM)
T2W sagittal image of radiological IB2 tumor – the greatest diameter is 4.3 cm. There is a normal medium signal intensity cervical tissue around the hyperintensive tumor indicating that it is confined.

**Fig. 4:** Cervical cancer, stage IB2 (FIGO), T1b2N0M0 (TNM).
On sagittal T2W image, cervical cancer is seen as a high signal intensity mass with infiltration of the uterus (arrows).

**Fig. 5:** Cervical cancer, stage IIA (FIGO), T2aN0M0 (TNM) uterus involvement.
Fig. 6: Cervical cancer, stage IIB (FIGO), T2bN0M0 (TNM); vaginal, uterus and parametrium involvement.
On axial-oblique T2W images perpendicular to the cervical axe full-thickness stromal invasion is present, the lesion spreads on parametrium, hypointensive stromal ring surrounding tumor is partly disrupted (arrows). There are enlarged lymph nodes in paravesical tissue (thick arrows).

**Fig. 7:** Cervical cancer, stage IIB (FIGO), T2bN1M0 (TNM).
On axial-oblique T2W image the presence of stripe of normal low intensity cervical stroma (arrows) with a thickness >3 mm is a very specific parameter for the exclusion of parametrial invasion.

**Fig. 8:** Cervical cancer, stage IIA (FIGO), T2aN0M0 (TNM)
Sagittal T2W images demonstrate tumor extending down anterior and posterior walls of the vagina with abnormal increasing signal intensity, thickening and disruption of the vaginal walls (arrows).

**Fig. 9:** Cervical cancer, stage IIA (FIGO), T3aN1M0 (TNM).
On T2W coronal image hydroureter and hydronephrosis due to cervical cancer are seen.

**Fig. 10:** Cervical cancer, stage IIIB (FIGO), T3bN1M0 (TNM).
On sagittal T2W image normal hypointense posterior bladder wall is segmental thickened by hyperintense tumor and have irregular contours.

**Fig. 11**: Cervical cancer, stage IV (FIGO) T4N1M0 (TNM), bladder invasion.
Sagittal T2W image demonstrate a cervical tumor extending into the rectum. Normal hypointense rectum walls are disrupted, thickened by hyperintense tumor, have irregular contours and tumor mass into the lumen.

**Fig. 12:** Cervical cancer, stage IV (FIGO), T4N1M0 (TNM), rectum invasion.
T2W axial images show enlarged parametrial, internal and external iliac lymph nodes (arrows).

**Fig. 13:** Cervical cancer, stage IIB (FIGO), T2bN1M0 (TNM); lymph node involvement.
**Fig. 14**: Full regress of tumor after radiation therapy.
Fig. 15: Recurrent tumor in the vaginal cuff.

Sagittal T2W images demonstrate a high signal intensity mass in the vaginal cuff (arrow).
Conclusion

MR imaging is the most reliable pretherapeutic modality for the detection or exclusion of parametrial spread, lymph node assessment, and evaluation stages of cervical carcinoma.

It can be used to identify other important prognostic factors, such as tumor volume and involvement of the adjacent organs.

MR imaging plays a most important role in selecting patients for surgery or radiation therapy and in following up tumor response to therapy.

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