MR imaging of FIGO stage I uterine cervical cancer: The diagnostic impact of 3T-MRI

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Learning objectives

To describe the technical challenges and advantages of MR imaging in evaluating FIGO stage I uterine cervical cancer at 3T.

To demonstrate usefulness of high-resolution T2-weighted images, high-resolution diffusion-weighted images (DWI), and 3D-dynamic contrast-enhanced MRI (3D-DCE-MRI) in the diagnosis of FIGO stage I uterine cervical cancer.

Background

MRI is a useful tool for the evaluation of uterine cervical cancer, however, small lesions are occasionally hard to demonstrate on MR examination at 1.5T. 3T-MRI can offer high-resolution MR images with increased matrix and reduced slice thickness due to increased signal-to-noise ratio (SNR). We present the diagnostic impact of 3T-MRI in evaluating early stage (FIGO stage I) uterine cervical cancer.

FIGO stage I uterine cervical cancer: (Fig. 1 on page 4)

Stage I cancer has invaded the cervix, but not growing outside the uterus. The cancer has not spread to nearby lymph nodes or distant sites. In stage IA, there is a very small amount of cancer, and it can be seen only under a microscope. Stage IA is subdivided into stage IA1 (the cancer is less than 3 mm deep and less than 7 mm wide) and stage IA2 (the cancer is between 3 mm and 5 mm deep and less than 7 mm wide). Stage IB cancers can be seen without a microscope, or can only be seen with a microscope if they have spread deeper than 5 mm into connective tissue of the cervix or are wider than 7 mm. Stage IB is subdivided into stage IB1 (the cancer is not larger than 4 cm) and stage IB2 (the cancer is larger than 4 cm).

In advanced-stage cervical cancer, MRI is a potent tool to assess the tumor size and extension into the parametrium or adjacent organs. Diagnosis of early-stage cervical cancer has usually been made using cone biopsy, however, MRI may be an alternative method for the detection of early-stage cancers, especially in older patients with atrophic cervices, or tumors invading higher portion of the cervix or deep in the stroma.

In routine MR examination of cervical cancers, T2-weighted imaging is the most useful sequence in tumor depiction and staging. Cervical cancer appears as a high intense mass within low intense cervical stroma on T2-weighted images. In stage I cancers, the mass is confined to the stroma and low intense stromal ring surrounding high intense
mass is completely intact (Fig. 2 on page 4). However, small stage IB1 diseases are often undetectable on usual T2-weighted images, and stage IA cancers are defined as microscopic diseases, which could not be demonstrated on usual MRI.

In this exhibit, we describe the technical challenges and advantages of MR imaging in evaluating FIGO stage I uterine cervical cancer at 3T: Usefulness of high-resolution T2-weighted images, high-resolution diffusion-weighted images, and 3D-dynamic contrast-enhanced MRI.

- High-resolution MRI at 3T

The increase in SNR at 3T offers high-resolution MR imaging. Anatomically detailed structures are visualized on high resolution MRI and may improve the diagnostic accuracies in differential diagnosis, in detecting small lesions, and in evaluating tumor extent for the cancer staging (Fig. 3 on page 5). In evaluating FIGO stage I uterine cervical cancer, high-resolution T2-weighted images are useful for demonstrating small cancerous foci with stromal desmoplastic reaction. High-resolution diffusion-weighted images (DWI) can detect small hypercellular cancerous foci with decreased apparent diffusion coefficient (ADC). 3D-dynamic contrast-enhanced MRI (3D-DCE-MRI) may reveal hypervascularity of micro-invasive cancer due to angiogenesis of cancer cells.

- Diffusion-weighted imaging (DWI)

DWI visualizes the local microstructural characteristics of water diffusion. In oncologic imaging, various malignant tumors may show high signal intensity on DWI due to their high cellularity and long T2 relaxation time. ADC measurement yields quantitative information regarding tissue structure based on the molecular motion of water. Malignant lesions with increased cellularity show low ADC values (Fig. 4 on page 6) (Fig. 5 on page 7), whereas relative hypocellular benign pathologies and normal structures tend to show higher ADC values.

- 3D-dynamic contrast-enhanced MRI (3D-DCE-MRI)

Dynamic contrast-enhanced MRI (DCE-MRI) can reveal the intra-tumoral angiogenic activity (Fig. 4 on page 6) (Fig. 5 on page 7). The increase in SNR, T1-prolongation, and high spectral resolution at 3T can offer excellent high-resolution 3D dynamic contrast-enhanced MR images with fat suppression. Not only contrast-enhanced small mass, but also increased vascularity along the mucosa reflecting angiogenesis of micro-invasive cancer cells may also be revealed on high-resolution 3D dynamic contrast-enhanced MR images at 3T.

3D-DCE-MRI Protocol:
Signa HDx 3T, GE

Sequence: LAVA (Liver Acquisition with Volume Acceleration), 3D-SPGR with fat suppression

FOV: 30cm; Matrix: 320*192, Slice thickness: 4 mm/ 2mm overlap

Images for this section:

Fig. 1:

[FIGO staging of early-stage cancer]

**Stage 0:** CIS /CIN III

**Stage I:** Confined to cervix

**Ia:** microscopic
- a1: < 3mm depth, < 7mm wide
- a2: 3 - 5mm depth, < 7mm wide

**Ib:** Clinically visible, (or > 5mm depth, > 7mm wide)
- b1: < 4cm
- b2: > 4cm

Fig. 1: Figure 1
Fig. 2: Figure 2

In younger women, squamocolumnar junction (SCJ) exists at portio vaginalis and cervical cancer tends to occur at portio with exophytic growth.

In older women, SCJ exists at cervical canal and cervical cancer tends to occur at higher portion with invasive growth.

Stromal ring is completely intact.
Fig. 3: Figure 3

Cervical cancer (Ib, adenocarc.)

1.5T vs 3T

T2WI@1.5T

T2WI@3T

Numerous small cysts suggesting adenocarc. are clearly demonstrated at 3T
Fig. 4: Figure 4

**Cervical cancer (Ib)**

- **T2WI**
- **DWI**
- **ADC map**

**Dynamic MRI**

- **Intense CE (+)**
- **High on DWI with low ADC**
- **Exophytic growing mass**
- **Wash out**
Fig. 5: Figure 5

Cervical cancer (Ib)

T2WI

Dynamic MRI (Early)

CE-fsT1WI

wash out

Intense CE (+)

Residual muscle layer

Poor contrast on T2WI

fsT2WI (short axis)

Disruption of stromal ring (+), No protrusion into parametrium

Very high on DWI due to hypercellular cancer cells

DWI
Imaging findings OR Procedure details

High-resolution T2-weighted imaging:

High-resolution T2-weighted image can reveal detailed anatomical structures and demonstrate the presence of minute parametrial invasion which may prevent understaging in stage II disease (Fig. 6 on page 10) (Fig. 7 on page 11).

On T2-weighted image, both cancer cells and the surrounding desmoplastic reaction, which is characterized by loose connective tissues with abundant fluid in the intercellular space, may appear as high intense area contrasted with low intense cervical stroma. In this context, small tumors without desmoplastic reaction may tend to be overlooked on T2-weighted images. High-resolution T2-weighted image at 3T can demonstrate even small stage Ib1 cancers, however, stage Ia cancers are hard to find.

High-resolution Diffusion-weighted imaging (DWI):

High-resolution DWI can detect small stage I cancers as very high intense areas. Not only squamous cell carcinomas but also other histologic types such as adenocarcinomas and adenosquamous cell carcinomas may appear as high intense areas reflecting their increased cellular density (Fig. 7 on page 11) (Fig. 8 on page 12). Small tumors, especially which invade higher portion of the cervix or deep in the stroma, could be clearly demonstrated on DWI (Fig. 9 on page 13) (Fig. 10 on page 14) (Fig. 11 on page 15). In some macroscopically undetectable stage Ia cancers, DWI may be able to demonstrate signal increase along the cervical mucosa reflecting local hypercellularity due to cancer cell proliferation (Fig. 12 on page 16) (Fig. 13 on page 17).

3D-dynamic contrast-enhanced MRI (3D-DCE-MRI):

Better contrast-enhancement due to the T1-prolongation and better fat suppression due to the increased separation of the fat and water resonant frequencies can offer high-quality 3D-DCE-MRI, which can visualize minute cancerous foci as intensely enhancing areas (Fig. 10 on page 14) (Fig. 11 on page 15) (Fig. 12 on page 16) (Fig. 14 on page 18).

Triratanachat et al. reported that microvessel densities of CIS and stage Ia cancer were significantly increased than those of control subjects due to angiogenesis of cancer cells (Fig. 15 on page 19). Although stage Ia cancer and carcinoma-in-situ (stage 0) may not form visible mass by colposcopic observation, 3D-DCE-MRI can demonstrate early contrast-enhancement along the mucosa reflecting atypical vascular proliferation in some cases (Fig. 13 on page 17) (Fig. 16 on page 20).
However, inflammation due to cervicitis or healing process after biopsy may also increase the mucosal vascularity and may show similar appearances on 3D-DCE-MRI (Fig. 17 on page 21).

Pitfalls:

Some benign cervical lesions may mimic cervical cancer. Cervical polyp is a benign hyperplastic lesion occupying the cervical canal. Cervical polyp may affect middle-aged women, and usually patients complain genital bleeding. On T2-weighted images the tumor appear may appear as high intense polypoid mass with low intense fibrous stalk. Small cysts may often observed with the mass. On DWI, the tumor may tend to show relative high ADC reflecting edematous, benign tissue (Fig. 18 on page 22). Cervical submucosal leiomyoma may occasionally mimic cervical cancer. Usual leiomyoma shows low signal intensity on T2-weighted images, and low to moderate signal intensity on DWI. However, some leiomyomas such as edematous or cellular leiomyomas may show high intensity on T2-weighted images. Edematous leiomyomas may show decreased signal intensity with high ADC and can be differentiated from cervical cancer. Cellular leiomyoma is a benign variation of leiomyoma with increased cell density. Due to its hypercellularity, cellular leiomyoma may show increased signal intensity on T2-weighted images. Cellular leiomyoma may not show very high intensity on DWI like cervical cancer, and may show intense contrast enhancement on post-contrasted T1-weighted images whereas cervical cancer tends to show "wash out" (Fig. 19 on page 23).

Images for this section:
**High-resolution T2WI**

3T MRI can offer thin slice (2-3 mm thickness) T2WI due to improved SNR.

- **Bone meta.**
- **Urinary bladder invasion**
- **Disruption of vaginal wall**
- **Parametrial invasion**

Tumor invasion into the parametrium or adjacent organs is clearly demonstrated on Thin slice short-axis plane of the uterine cervix:

**Fig. 1:** Figure 6
Fig. 2: Figure 7
**Fig. 3:** Figure 8

**Cervical cancer (Ib)**

**Villoglandular adenocarcinoma**

May affect portio vaginalis of young female with exophytic growth

Poor contrast on T2WI
Very high on DWI with ADC (0.45) reflecting hypercellularity

T2WI (short axis)  |  Corn biopsy  |  DWI
Cervical cancer (Ib)

Fig. 4: Figure 9

Slight high on T2WI, however, hard to evaluate the tumor extention

fsT2WI

DWI (sag)

Low ADC

High SNR at 3T can offer better DW images which demonstrate small cancer clearly as high intense area.

ADC map

Very high on DWI reflecting low ADC
Cervical cancer (Ib)

Very high on DWI
Intense CE on Dynamic MRI

T2WI  DWI  Dynamic MRI (Early)

Small slight-high area on T2WI

DWI and 3D-Dynamic MRI can demonstrate very small cancer

Fig. 5: Figure 10
Cervical cancer (Ib)

T2WI: slight high, Boundary unclear
Dynamic: Intense CE  High on DWI

Dynamic MRI (Early)

Fig. 6: Figure 11
Cervical cancer (IIa)

**Fig. 7:** Figure 12

- **T2WI**
- **DWI**
- **ADC map**

- **Intense CE (+)**
- **Small cancer extends along the mucosa**
- **Undetectable on T2WI**
- **High on DWI with low ADC**
**Cervical cancer (CIS)**

CIS (carcinoma in situ) - stage Ia cancers do not form visible mass and undetectable on T2WI

**Intense CE along the mucosa**

T2WI  | DWI  | Dynamic MRI (Early phase)

Undetectable on T2WI  | High on DWI

**Fig. 8:** Figure 13

**Fig. 13**

**DWI could demonstrate CIS - Ia cancer as increased signal intensity along the mucosa.**

**Dynamic study could reveal atypical vascular proliferation as intense mucosal enhancement.**
Cervical cancer (Ib)

Very small high intense mass on T2WI

Intense CE (+)

Even a very small mass shows intense contrast-enhancement on Dynamic MRI

Fig. 9: Figure 14
Angiogenesis of Cervical cancer

Angiogenesis may occur in tumors larger than 2 mm in diameter.

Mozaic  Atypical vessels

Colposcopy of microinvasive cancers

Fig. 10: Figure 15
Cervical cancers (CIS - Ia)

Fig. 11: Figure 16

Intense early enhancement along the cervical mucosa

Dynamic MRI (early phase)

Early mucosal enhancement reflects atypical vascular proliferation

Undetectable on T2WI
Fig. 12: Figure 17
Fig. 13: Figure 18
Fig. 14: Figure 19

Pitfall: Cervical submucosal leiomyoma

Small leiomyoma may mimic cervical cancer

Especially, cellular leiomyoma may show high intensity on T2WI/DWI

Intense CE on post-contrast T1WI is suggestive for leiomyoma, whereas cancer tends to show "wash out"
Conclusion

3T-MRI can provide useful information for the diagnosis of FIGO stage I uterine cervical cancer, especially in evaluating minute "hard to find" earlier stage lesion.

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References


