Role of MRI in Intracavitary Brachytherapy for Cervical Cancer: What the Radiologist Needs to Know

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OBJECTIVE. Intracavitary brachytherapy has an important role in treating cervical cancer. MRI is the optimal imaging technique to visualize the intracavitary brachytherapy probes and MRI-guided intracavitary brachytherapy is expected to increase significantly over the next 5 years. The purpose of this article is to review what a radiologist needs to know about imaging brachytherapy probes including the MR technique, correct positioning of the probes, and associated complications.

CONCLUSION. MRI-guided intracavitary brachytherapy is an increasingly used therapy for the treatment of cervical cancer. This technique provides excellent visualization of intracavitary brachytherapy devices and allows accurate localization of residual tumor. It is important for radiologists to be familiar with the correct probe positioning as well as any potential complications.

Keywords: cervical cancer, intracavitary brachytherapy, MRI, oncologic imaging

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Cervical cancer is the second most common cause of cancer death in women worldwide. Early stage disease may be treated with surgery or radiotherapy, whereas locally advanced disease is treated with chemoradiotherapy [1–3]. Patients who undergo radiotherapy will have a combination of external beam radiotherapy (EBRT) and intracavitary brachytherapy. Intracavitary brachytherapy involves insertion of a brachytherapy probe into the cervix and uterus to deliver a high dose of radiation to a small targeted area (cervix and parametrium). Intracavitary brachytherapy has been shown to improve outcome in patients with advanced disease and reduce associated complications [4]. Imaging-guided intracavitary brachytherapy involves cross-sectional imaging with either MRI or CT of the brachytherapy probe after insertion.

The use of MRI for planning brachytherapy treatment was first reported in 1992 by Schoeppel and colleagues [5] and has since been considered the method of choice for imaging-guided brachytherapy [6, 7]. MRI-guided intracavitary brachytherapy allows accurate radiation dose optimization and enables a higher dose to be given to the target tissue. MRI accurately depicts the intracavitary brachytherapy probe and any associated complications. The use of MRI for imaging-guided intracavitary brachytherapy is expected to increase significantly over the next 5 years to allow highly individualized radiation therapy [8–11].

Inaccurately placed intracavitary applicators can perforate the uterus or vagina and also increase the dose to nontarget organs. An 8% perforation rate has been reported in probe insertions where the operator is confident of placement [12, 13]. MR images obtained after placement of the brachytherapy probe are optimally assessed by both a radiologist and a radiotherapist. The purpose of this article is to highlight what a radiologist needs to know about imaging brachytherapy probes with MRI and possible complications.

Imaging Protocol

The brachytherapy applicator is inserted by direct vision into the vagina in the operating theater while the patient is under general anesthesia. The device used in our institution is the Vienna ring applicator (Nucletron BV, Veenendaal). The probe tip should pass through the cervix and lie within the endometrial cavity. The patient is then brought to the MRI department for imaging. The intracavitary brachytherapy probe is MRI compatible and causes little artifact on spin-echo sequences.

At our institution, patients are imaged on a 1.5-T MR system (MR450, GE Healthcare). The protocol consists of axial T1-weighted

images and multiplanar T2-weighted images of the pelvis. All imaging is completed using an 8-channel cardiac array coil with the patient in the supine position. Sequences include the following: axial fast spin-echo (FSE) (field of view [FOV], 24 cm; matrix, 384 × 256; slice thickness, 5 mm; gap, 2.5 mm), sagittal fast recovery FSE (FOV, 24 cm; matrix, 384 × 256; slice thickness, 5 mm; gap, 2.5 mm), and coronal fast recovery FSE (FOV, 30 cm; matrix, 416 × 320; slice thickness, 5 mm; gap, 2.5 mm). We also perform an axial oblique T2-weighted FSE sequence for cervical cancer staging. Diffusion-weighted imaging is not performed because there is significant artifact from the probe.

Probe Positioning

The applicator tip of the intracavitary brachytherapy probe should be positioned within the endometrial cavity and is best seen on sagittal T2-weighted images (Fig. 1). In our institution, interstitial brachytherapy needles are used in conjunction with the intracavitary delivery device. The intracavitary device should ideally be positioned at the level of the tumor within the cervix, and the interstitial needles are placed in the upper vaginal vault centered on the tumor (Fig. 2). The intracavitary device and interstitial needles can be adjusted to deliver a focused dose of radiotherapy to the tumor based on the imaging findings [10, 14]. Surgical packing is placed in the vagina to hold the probe in place. This is seen as low-signal-intensity material around the probe and should not be mistaken for tumor (Fig. 3).

Incorrectly Positioned Probes

Inaccurate positioning of the intracavitary brachytherapy probe can result in perforation of the uterus or vagina. The tissues around the tumor are often more friable than usual because of preceding EBRT and therefore are more susceptible to damage. Perforation rates of more than 8% have been reported in operators who are confident of placement [12]. The most common perforations we have encountered are perforations of the posterior fornix of the vagina and the uterine fundus, which can easily be identified on T2-weighted sequences (Figs. 4 and 5). MRI has better soft-tissue resolution than CT, especially in the pelvis, and will show extraluminal positioning more accurately. Perforation may lead to direct trauma to the surrounding viscera, such as the bladder and bowel, and increases potential collateral dosing to these organs. Although we have encountered cases in which the probes were intimately located to loops of small bowel, bowel perforation did not occur in any of the patients (Fig. 6). An anterior perforation is less common but often will result in trauma to the bladder with possible fistula formation (Fig. 7).

Assessment of Residual Tumor Burden

The radiologist has a key role in assessing the presence of residual tumor. It is crucial to compare the current imaging studies with an intracavitary brachytherapy probe in situ with any previously performed studies. Ideally, MRI should be performed after EBRT but before intracavitary brachytherapy to establish a baseline assessment of the extent of remaining tumor before intracavitary brachytherapy. Axial and sagittal T2-weighted imaging sequences are the best sequences to visualize residual tumor with the intracavitary brachytherapy probes in place. It is important to highlight the dimensions of the tumor and location of the intracavitary device and interstitial needles relative to the position of the tumor (Fig. 8). Intraluminal tumor within the cervical canal may be compressed by the intracavitary device; however, accurate assessment of tumor burden is usually possible (Fig. 9). As with standard MRI for staging cervical cancer, the tumor is of high signal intensity relative to the low-signal-intensity cervical stroma.

Although dose optimization is of most relevance to the radiation oncologist, it is worth mentioning briefly. Accurate delineation of the tumor in multiple planes allows accurate assessment of the gross tumor volume (GTV) and clinical target volume (CTV) and therefore allows the radiotherapist to adjust the intracavitary dose on a patient-by-patient basis without increasing the dose to other pelvic organs, which are termed "organs at risk." This serves to improve local control without any increase in treatment-related morbidity and thereby facilitating greater target volume coverage at a higher dose [15, 16].

Ancillary Findings

The radiologist also plays an important role in identifying ancillary findings elsewhere in the pelvis. Because many of the patients will have undergone EBRT to the pelvis, mucosal thickening of the rectum and sigmoid colon are commonly identified. Some patients may be asymptomatic, but it is important to correlate with clinical symptoms to determine whether this finding represents radiation colitis (Fig. 10). Free fluid in the pouch of Douglas is a frequent finding in patients undergoing intracavitary brachytherapy, more prominent on the second cycle of treatment (Fig. 11).

Coexistent pelvic pathologic findings, including gynecologic and gastrointestinal diseases, are often seen in patients undergoing EBRT. We frequently identify new abnormalities that have developed during the short interval since the previous images were acquired before intracavitary brachytherapy (Fig. 12).

Conclusions

MRI-guided intracavitary brachytherapy is an increasingly used therapy for the treatment of cervical cancer. This technique provides excellent visualization of intracavitary brachytherapy devices and allows accurate localization of residual tumor. It is important for radiologists to be familiar with the correct probe positioning as well as any potential complications.

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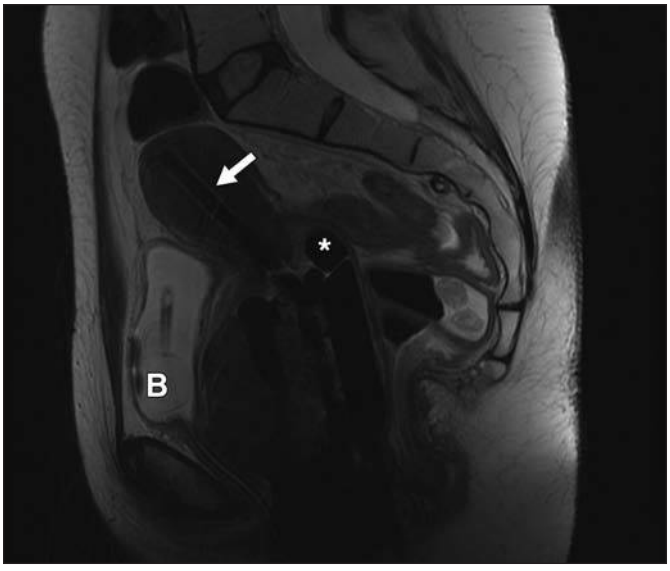

Fig. 1—45-year-old woman with cervical cancer. Sagittal T2-weighted MR image of pelvis shows that tip of applicator (*arrow*) is appropriately positioned in endometrial cavity. Intracavitary delivery device (*asterisk*) is placed in cervix. Urinary catheter is present within bladder (B).

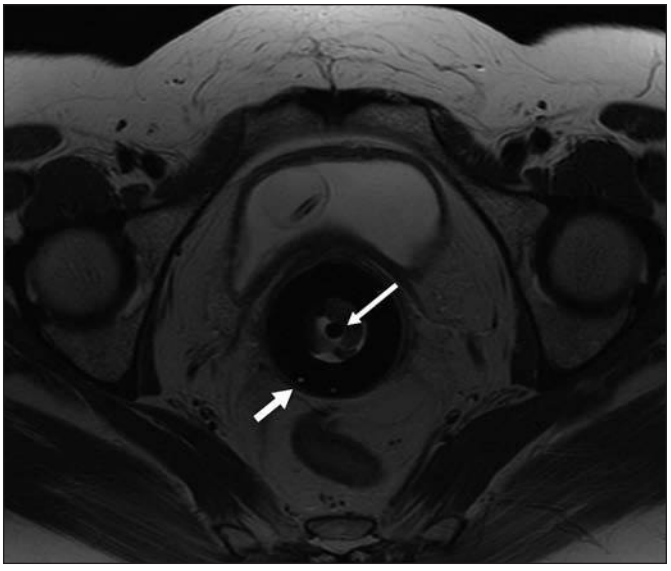

Fig. 2—53-year-old woman with cervical cancer. Axial T2-weighted MR image of pelvis shows that interstitial needles are appropriately positioned in upper vaginal vault (*short arrow*) with intracavitary device in cervix (*long arrow*).

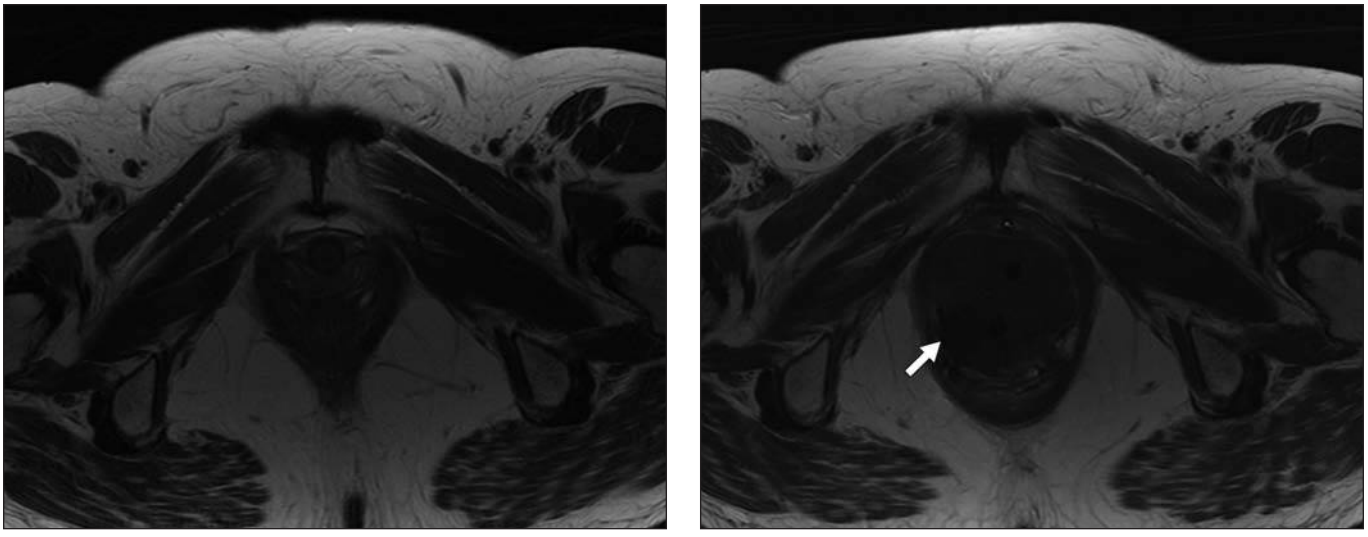

Fig. 3—46-year-old woman with cervical cancer.
A, Axial T2-weighted MR image obtained after patient underwent electron beam radiotherapy shows normal appearance of vagina before insertion of probe and packing.
B, MR image shows lower vagina expanded by low-signal-intensity surgical packing (*arrow*).

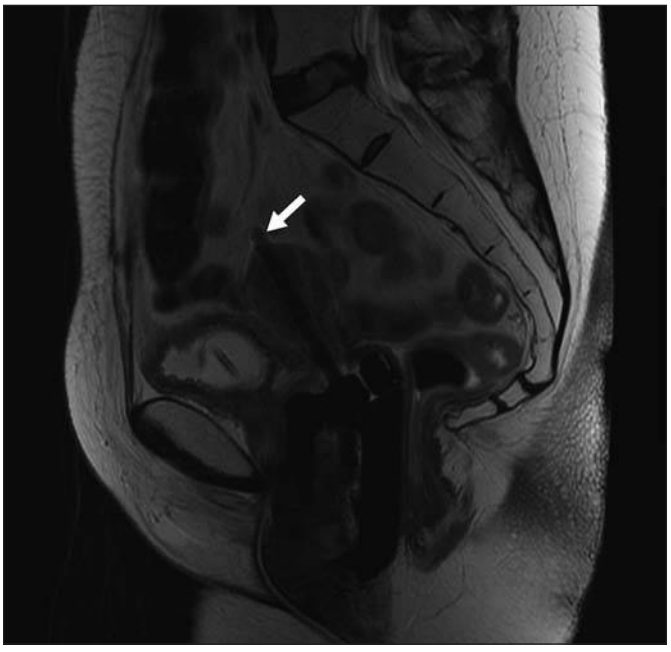

Fig. 4—47-year-old woman with cervical cancer. Sagittal T2-weighted MR image shows that applicator tip of intracavitary brachytherapy probe has perforated fundus of uterus (*arrow*).

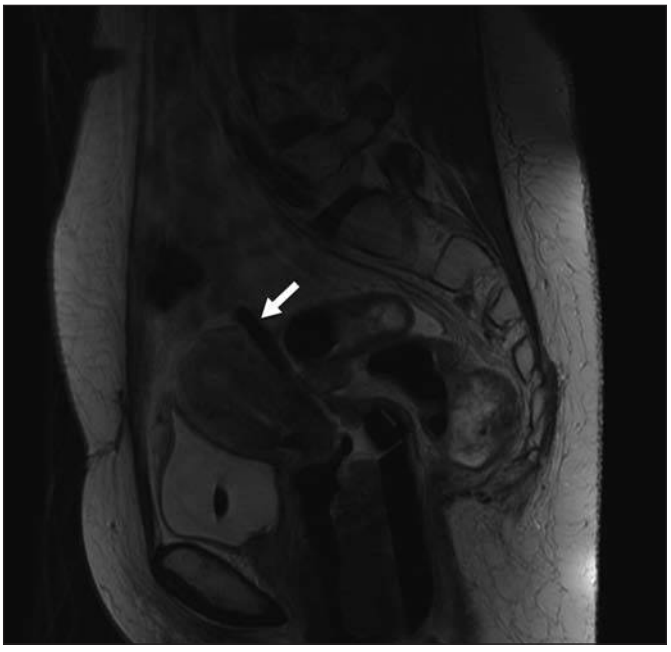

Fig. 5—56-year-old woman with cervical cancer imaged after insertion of intracavitary brachytherapy probe. Sagittal T2-weighted MR image reveals that intracavitary brachytherapy probe (*arrow*) has perforated posterior vaginal vault and applicator tip lies in pouch of Douglas.

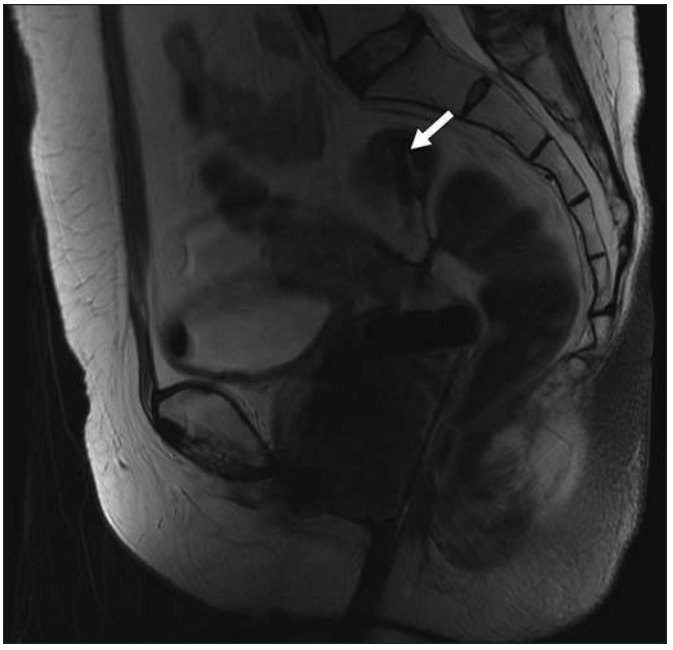

Fig. 6—39-year-old woman with cervical cancer. Sagittal T2-weighted MR image shows that probe (*arrow*) has perforated posterior fornix and is situated adjacent to loops of small bowel. Tip of probe is blunt and unlikely to perforate small bowel.

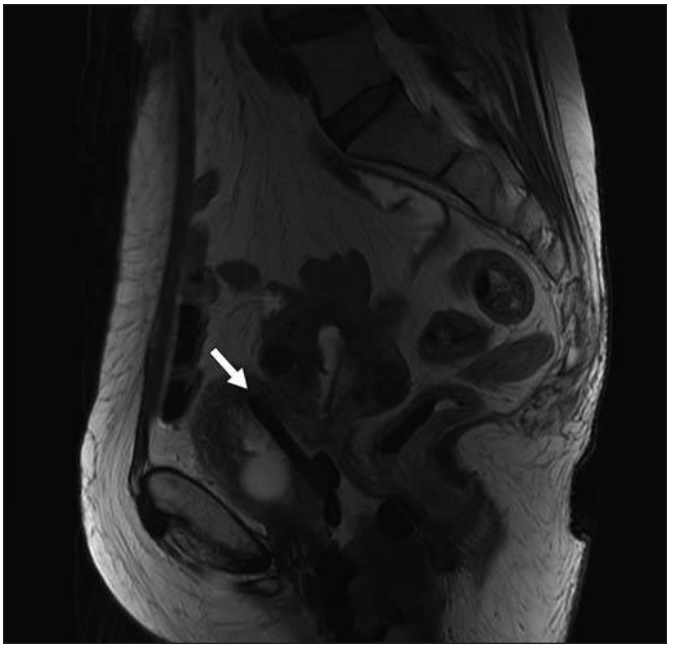

Fig. 7—58-year-old woman with cervical cancer. Sagittal T2-weighted MR image shows intracavitary brachytherapy probe (*arrow*) has perforated anterior wall of vagina and is positioned within bladder, creating traumatic fistula. Fistula healed spontaneously without significant complication.

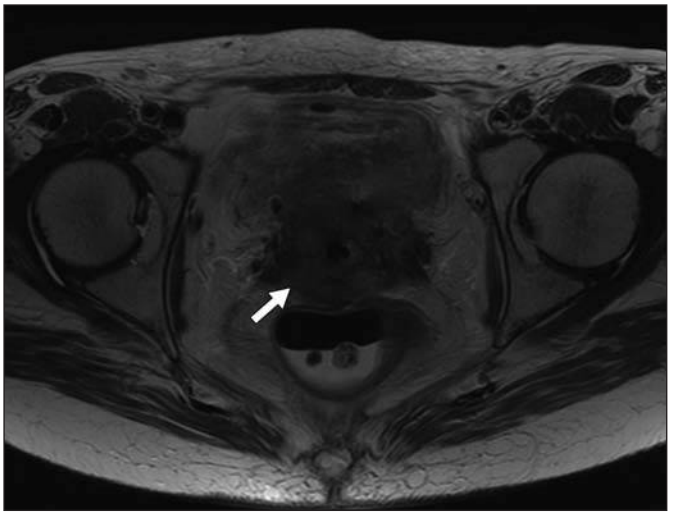

Fig. 8—35-year-old woman with cervical cancer. Axial T2-weighted MR image of pelvis at mid cervical level shows extensive high-signal-intensity tumor within posterior cervix. There is bilateral parametrial extension—in particular, on right side (*arrow*). Intracavitary device is adequately positioned in cervical canal. Multiplanar imaging allows radiotherapist to target dose to largest tumor volume (posterior right cervix).

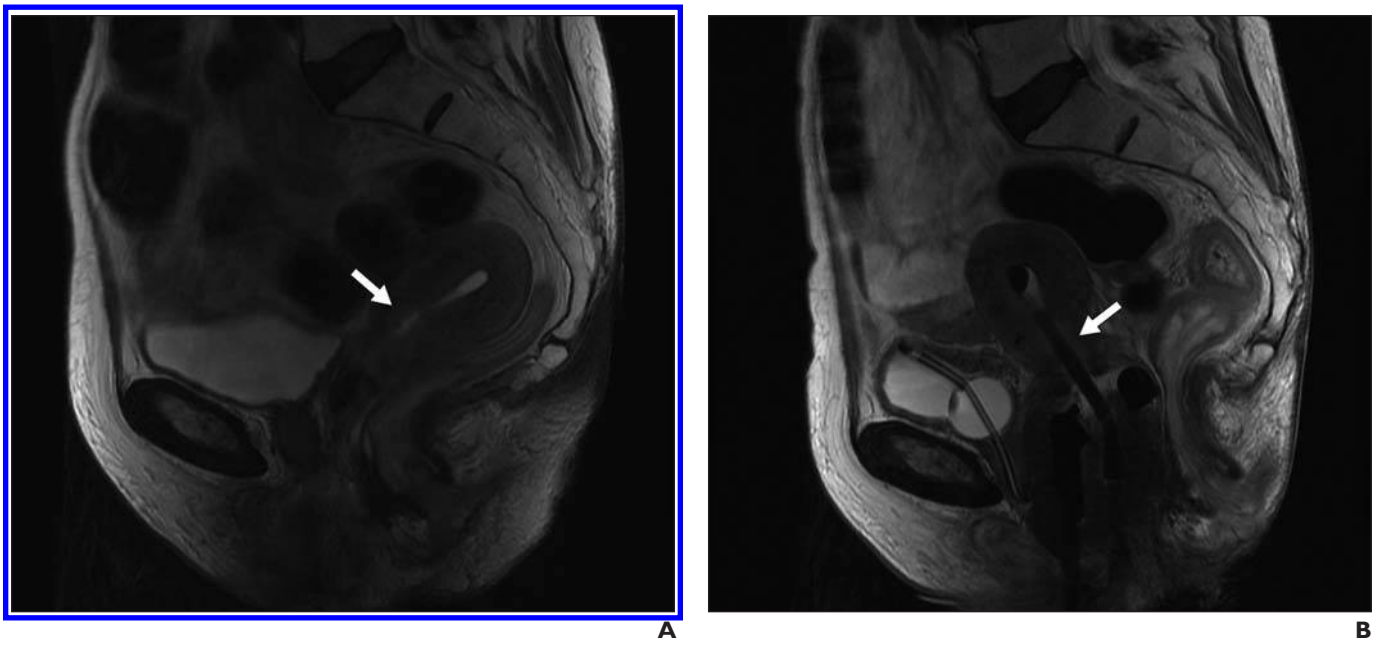

Fig. 9—51-year-old woman with cervical cancer.
A, Sagittal T2-weighted MR image of pelvis obtained during interval between external beam radiotherapy and intracavitary brachytherapy. Extensive high-signal-intensity circumferential tumor (*arrow*) is identified; however, there is no evidence of parametrial invasion.
B, MR image obtained after insertion of probe again shows residual high-signal-intensity tumor surrounding intracavitary device (*arrow*). Probe is correctly positioned relative to tumor.

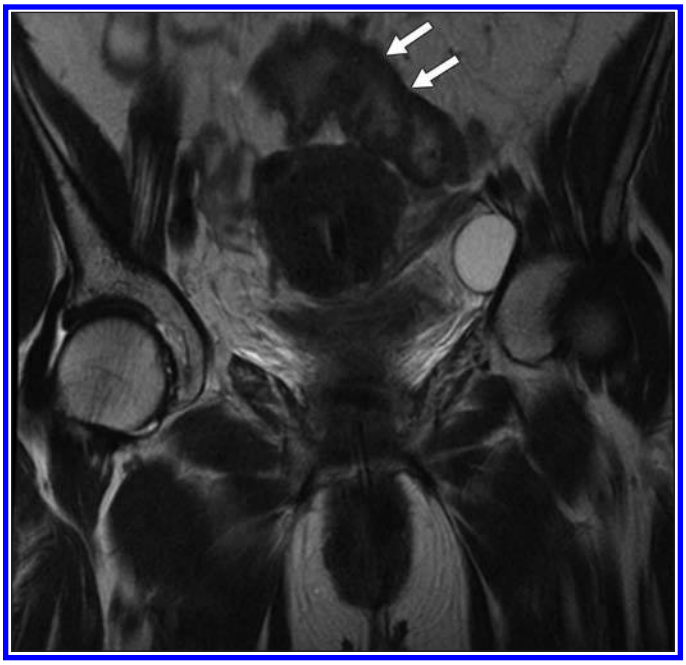

Fig. 10—44-year-old woman with cervical cancer. Sagittal T2-weighted MR image of pelvis shows diffuse sigmoid colitis (*arrows*) in patient undergoing intracavitary brachytherapy. Degree of mucosal edema is suggestive of radiation colitis and consistent with patient's symptoms of abdominal cramping and diarrhea.

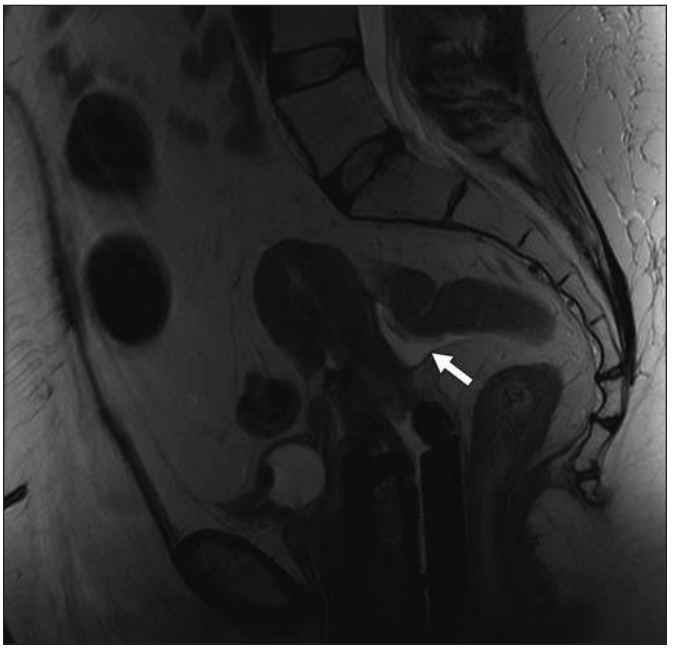

Fig. 11—45-year-old woman with cervical cancer. Sagittal T2-weighted MR image of pelvis shows free fluid in pouch of Douglas (*arrow*).

Fig. 12—50-year-old woman with cervical cancer. Coronal T2-weighted MR image of pelvis reveals bilateral hydrosalpinges (*arrows*). These hydrosalpinges developed during interval between external beam radiotherapy and intracavitary brachytherapy and are likely related to treatment.

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