MR imaging of intracavitary brachytherapy probes for cervical cancer: What a radiologist needs to know

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Learning objectives

1. Review the role of Magnetic Resonance (MR) imaging for positioning of intracavitary brachytherapy (ICBT) probes in cervical cancer.

2. Detail the sequences and system requirements for imaging of BT probes.

3. Illustrate the correct positioning of BT probes within the cervix on MR.


5. Review cases of malpositioned probes and incidental findings.
Background

Cervical Cancer Treatment:

The treatment options for cervical cancer include surgery, radiotherapy and chemotherapy (or a combination). The course of treatment depends on the stage at presentation [1]. Tumour staging is generally classified by the FIGO staging system, which has recently been revised [2]. A standard approach involves surgery alone for Stage 1A. For stages IB and IIA, either surgery or radiotherapy can be considered. Of these two options, there is no treatment of choice in terms of overall or disease-free survival. The optimum therapy for each patient should take account of clinical factors such as menopausal status, age, medical illness, histological type, and cervical diameter to yield the best cure with minimum complications [3]. In some cases, radiotherapy may be used prior to surgery to debulk the tumour. Tumours of stage IIB and above receive chemoradiotherapy alone.

It is beyond the scope of this exhibit to discuss the surgical treatment options or chemotherapy regimens.

Brachytherapy and Imaging Schedule:

Patients who undergo radiotherapy will have a combination of external beam radiotherapy (EBRT) and intracavitary brachytherapy (ICBT). EBRT delivers radiation to the whole pelvis. Intracavitary brachytherapy involves delivery of a high dose of radiation to a small, targeted area i.e. the cervix and surrounding tissues (parametrium, vagina) while reducing the dose to the adjacent organs. It results in increased local control and survival with lower toxicity. EBRT is administered for five days a week, usually for several weeks. In our institution, four fractions of intracavitary brachytherapy are then administered over a period of two weeks, commencing the week after the last fraction of EBRT.

The patient has a pelvic MRI the week before brachytherapy is due to start. This is to assist with brachytherapy planning, which is performed by the radiation oncologists and medical physicists. MR was first reported for brachytherapy treatment planning in 1992 by Schoeppel [4] and has since been widely reported as being the current method of choice for image based brachytherapy [5] due the better inherent contrast resolution compared with CT. The MRI plays a crucial role in delivering the brachytherapy as it enables exact location of the tumour. The MR imaging also gives extensive information about surrounding tissues and possible complications (such as probe malpositioning).
The patient is admitted to hospital on the day that ICBT is due to start and the brachytherapy applicator is inserted under direct vision into the vagina in theatre, with the patient under general anaesthetic. The probe tip should pass through the cervix and lie within the endometrial cavity. The interstitial needles are positioned in the upper vagina and the cervical os. The centre of the needles should ideally be positioned at the level of the tumour within the cervix. A CT with bladder contrast medium followed by an MR is performed, the images fused and final planning occurs. The probe position is best appreciated on the sagittal T2W sequence.

The patient then returns to the radiotherapy department and has their first fraction of ICBT. They return to the ward following this and are on strict bed rest until the following day. The next morning, a repeat CT scan is performed to ensure that the applicator position has not changed significantly. This is followed by the second fraction of ICB. The applicator is then removed and the patient can return home.

In our institution, interstitial needles are being used in conjunction with the intracavitary applicator. This technique was developed in Vienna and uses the needles to focus the radiation beam and allows for an increase in target coverage, treated volume, and total dose without increasing the dose to critical structures. The process is repeated a week later.

**MRI Protocol**

The ICBT probe is MRI compatible and causes little artefact with turbo spin echo sequences. Our sequence protocol for MR imaging of the pelvis consists of T2-weighted fast spin echo sequences on a 1.5-T MR imager (Signa Excite; GE Medical Systems, Milwaukee, Wis) using the phased-array torso coil. Standard T2W imaging is performed in the coronal, axial and sagittal. For standard cervical cancer staging, we also use an axial oblique plane however this is not required for ICBT probe evaluation. Diffusion weighted imaging cannot be performed as there is significant artefact from the probe.
**Imaging findings OR Procedure details**

*The radiologist has a key role in assessing the position of the ICBT probe.*

**Checklist for radiologist**

1. *Where is the probe positioned*
2. *Location of residual tumours*
3. *Ancillary findings*
4. *Complications of probe insertion*

**Probe positioning**

It is essential to check that the BT is correctly positioned within the vagina, cervix and uterus. A sagittal, coronal and axial T2W sequence are performed. The applicator tip is positioned within the endometrial cavity, a correct position is shown in Figure 1 on page 8 and Figure 2 on page 8 (arrow). A catheter is placed within the bladder (b). The BT delivery device (*) is positioned in the upper vaginal vault. The BT rods are then adjusted to deliver a focused dose of radiotherapy to the tumour based on the imaging findings.

**Figure 3** on page 9 is an axial T2W sequence showing the delivery device positioned in the upper vaginal vault. The BT rods are inserted into the small holes seen peripherally in the BT device.

**Figure 4** on page 10 is a further axial imaging showing the BT applicator tip within the endometrial cavity.

**Figure 5** on page 11 again shows a correctly positioned applicator tip, incidental note is made of diffuse adenomyosis (dotted line).

**Figure 6** on page 12 shows a correctly positioned probe with a catheter within the urinary bladder. Note that the applicator tip does not have to extend to the fundus of the uterus.

**Assessment of residual tumour burden:**
The radiologist has a key role in assessing the presence of residual tumour. It is essential to compare the current imaging to any previously performed studies. The positioning of the BT rods is dependent on where the bulk of the disease is situated.

**Figure 7** on page 13 and **Figure 8** on page 14 show a high signal intensity mass in the posterior cervix consistent with extensive residual disease (arrows).

In **Figure 9** on page 15, there is a large high signal intensity mass extending into the bladder anteriorly and cervix posteriorly consistent with a large cervical tumour. **Figure 10** on page 16 is a diffusion weighted sequence showing the invasive tumour (arrows). **Figure 11** on page 17 and **Figure 12** on page 18 are images from the same patient after the probe has been inserted. Again the large tumour is noted (complete arrows - tumour, broke arrow - BT probe). In figure 12, a tumour spicule is noted extending to the rectum posteriorly (*). Diffusion imaging cannot be performed with a BT probe in position due to severe blooming artefact from the probe.

**Figure 13** on page 19 shows a large circumferential high signal intensity tumour mass in the cervix. The diffusion weighted image correlates with the initial T2W imaging (**Figure 14** on page 20). The same case was imaged after the BT probe was inserted. Note the significant change in orientation of the cervix and uterus. The sagittal and axial imaging clearly show the residual tumour allowing accurate positioning of the BT rods (**Figure 15** on page 21 and **Figure 16** on page 22).

**Incidental findings:**

The radiotherapist who is treating the patient may be familiar with the anatomy of the cervix and probe positioning however ancillary findings are often overlooked.

**Figure 17** on page 23 shows diffuse sigmoid colitis (arrow) in a patient undergoing ICBT for cervical cancer. The patient had undergone external beam radiotherapy prior to BT. The colitis is likely a radiation colitis.

A left sided ovarian cyst (arrow) and diffuse adenomyosis (dotted line) are present in a patient undergoing ICBT **Figure 18** on page 24.

Free fluid in the pouch of douglas is a frequent finding in patients undergoing ICBT, more prominent on the second cycle of treatment **Figure 19** on page 25 (arrow).
**Figure 20** on page 26 Shows a lymphocele in the left adnexa (arrow) in patient who had a lymphadenectomy prior to ICBT.

Extensive sigmoid diverticulosis is seen is a patient referred for ICBT **Figure 21** on page 27 (arrow).

**Incorrectly positioned probes:**

The BT probe positioning is described in the first section. Often the cervix has undergone previous external beam radiation and the tissue is extremely friable. An incorrectly positioned probe is not uncommon. Most probes will be repositioned to avoid collateral radiation damage.

If the probe is positioned too far anteriorly it will perforate the anterior fornix of the vagina and subsequently the bladder. The probe must be removed and BT deferred (**Figure 22** on page 28 and **Figure 23** on page 29).

When the probe is inserted too far it will perforate the fundus of the uterus (**Figure 24** on page 31). In most cases it is removed and reinserted however ICBT in patients with prior hysterectomy almost inevitably perforate the residual cervical stump (**Figure 25**) on page 32.

In our experience the most frequent site of the perforation is the posterior fornix of the vagina (**Figure 26** on page 33). In general there is little sequelae associated with this injury and some radiotherapists will continue treatment without repositioning, however this is an area of debate among clinicians. Occasional however the probe can perforate the rectum or small bowel. **Figure 27** on page 34 shows a probe perforating the posterior wall of the uterus and perforating the small bowel.
Images for this section:

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Conclusion

MRI gives excellent visualization of intracavitary brachytherapy devices. Probe position and residual disease are readily visible. It is important that radiologists are familiar with these devices and understand the potential complications. Our checklist summarizes the pertinent MR findings.

Checklist for radiologist

1. Where is the probe positioned
2. Location of residual tumours
3. Ancillary findings
4. Complications of probe insertion
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1. High dose rate brachytherapy for carcinoma of the cervix (NICE guidance), 2006.