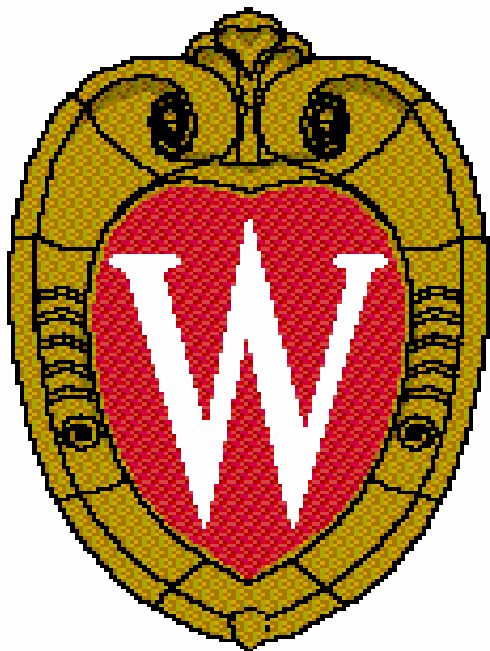


Volume-image Guidance for Intracavitary Brachytherapy for Cancer of the Cervix



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Conflict of Interest

That the author knows of, he has no conflicts of interest for this presentation.

Learning Objectives

1. To understand the roles of various imaging modalities in intracavitary cervical brachytherapy.
2. To understand the requirements for volume-imaged based intracavitary brachytherapy
3. To understand the recommendations of the intersociety group on image-guided cervical intracavitary brachytherapy.

Let's Start with the Obvious

Reasons to Move to Volume-image Guidance

- We have come to expect to prescribe treatments based on target volumes
- Radiographic imaging fails to delineate soft tissues - either target or organs at risk.
- Thus only with volume imaging can we assess or control treatments with the control we are use to in external-beam radiotherapy.

Oh, Yes

By volume imaging we mean modalities that can:

- Form a three-dimensional image.
- Display “adequate” soft tissue contrast.

And More Obvious Stuff

What are the Goals in Imaging

1. Localize the source positions.
2. Localize the target.
3. Localize the organs at risk.
4. Determine the relationships between all the above.

Volume Image-guided Brachytherapy

We have been doing this for a long time in some sites.

- Prostate, since about 1983 (Ritter et al.) using CT.
- Prostate, since about 1984 (Holms et al.) and pancreas, using ultrasound.
- Gynecological interstitial (also since about 1983) using CT, and MR since about 2000 (Erickson et al.).

So let's talk about where things are newly developing:
Cervical intracavitary brachytherapy.

Radiographic Localization

- Can use a Foley Bulb in the trigone of the bladder with about 7 cc of dilute contrast medium.
 - One problem is that only cardinal points are easily located unambiguously.
 - This location does not represent the hottest part of the bladder.
 - » That usually falls about 2 cm superior.
 - » The highest dose often is about 2-4 *times* the dose at the bulb.

Radiographic Localization - 2

- Can use several methods to determine the dose to the rectum.
 - Can inject dilute barium contrast medium and withdraw it, and then some air.
 - » Following the path of the rectum is difficult for those who have not trained in barium enemas.
 - » Again, unambiguous localization of points is difficult.
 - Can use rectal markers.
 - » They tend to lie on the posterior wall while the anterior wall is at greater risk.
 - » Stiff markers can move the rectum, flimsy ones are difficult to push deep.

Radiographic Localization - 3

- (Rectal Dose Continued)
 - Can use a detector to measure rectal dose.
 - » Again, rigid probes distort reading, flaccid ones fall to the posterior.
 - Can use the ICRU rectal point.
 - » Doesn't usually represent the maximum rectal dose, which, again often is 2-4 cm cephalad.
 - » The maximum dose is up to 3 times the ICRU point (but more often closer than the ICRU bladder dose).
- None of this localizes the superior bowel - an organ very much at risk.

Radiographic Localization - 4

Intracavitary brachytherapy source localization with radiograph is easy, clear and accurate. For this, radiograph is unmatched.

Three-dimensional Treatment Planning

We've always done three-dimensional planning. That is not new.

Positron Emission Tomography

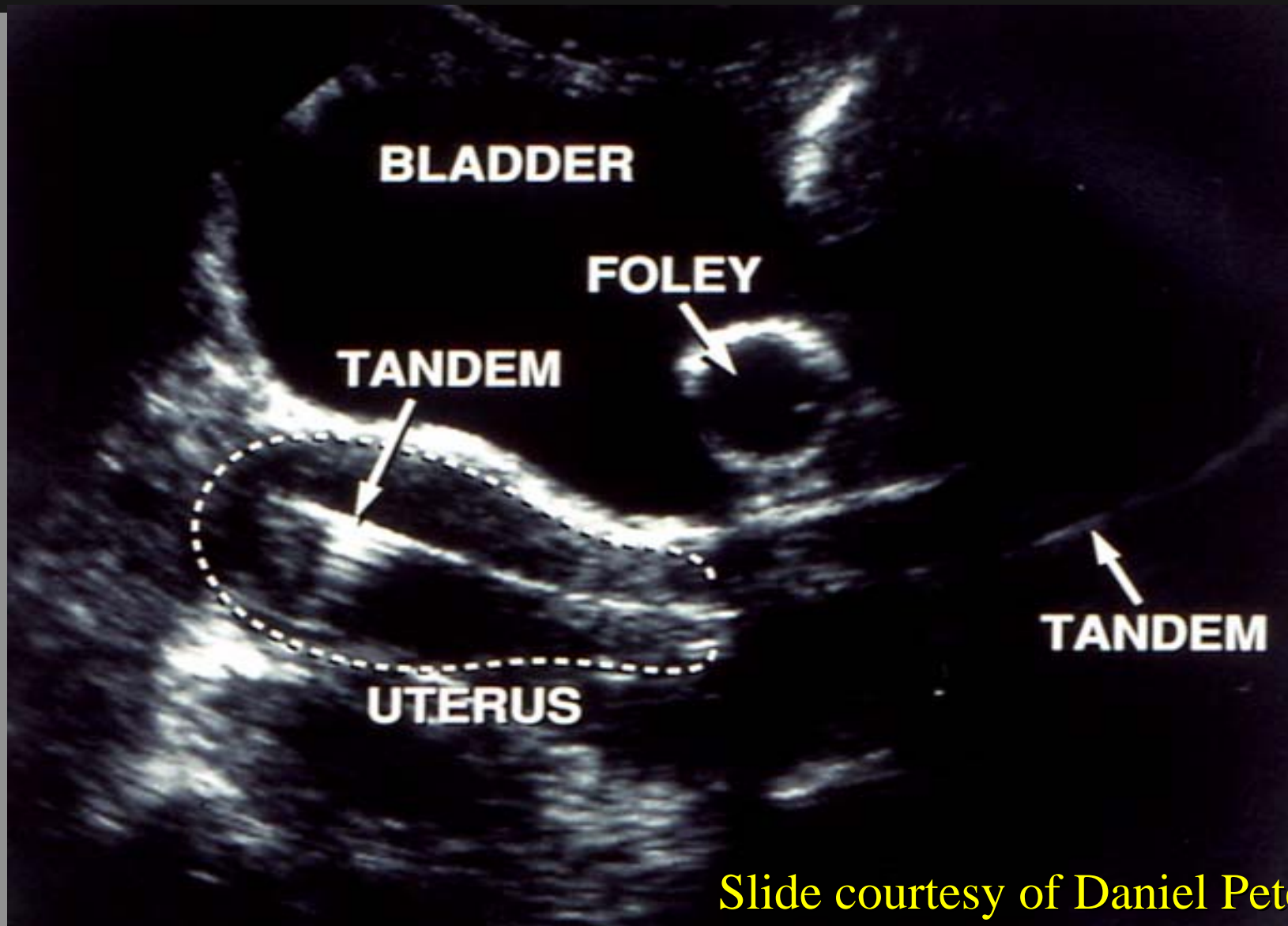
- ^{18}F labeled FDG PET images has been shown to be useful for accessing
 - metastases to pelvic and para-aortic lymph nodes
metastases from cervical carcinoma (Rose et al, 1999; Grigsby, Siegel and Dehdashti2001), and
 - tumor volume assessment, particularly before and after radiation (Narayan et al, 2001; Miller and Grigsby, 2002)
- For treatment planning, Mutic has shown it is possible

PET-2

- One problem with PET images is the lack of anatomical information.
- Can combine with CT, but then one is really planning with CT (we'll get to that).
- Does require positron-emitting dummy sources.
- Not a lot of interest in that.

Ultrasound

- Can be very useful during tandem insertion
 - Localizing the cervical canal when obscured by tumor,
 - detecting a retroverted uterus before tandem insertion.
- Also very helpful in assessing the uterine wall thickness for placement of optimization points for endometrial cancer (but this is a different, although equally interesting topic).



Slide courtesy of Daniel Peterreit

US Treatment Planning

- US systems can create volume images by
 - Sequential cuts, such as in prostate brachytherapy, but this requires stepping the probe in a rigid holder, of
 - Sweeping the beam through a volume.
- Treatment planning is routinely performed using US, however, the US used in cervical localization normally is freehand, so does not produce a volume image.

US Treatment Planning - 2

- US would also have a very difficult time imaging source-simulating markers in an applicator. US compatible applicators would have to be developed.

Computed Tomography

- CT is the obvious candidate for volume-imaged based treatment planning for cervical intracavitary brachytherapy.
 - Long experience in treatment planning for external beam.
 - Fairly good soft-tissue contrast, visualizing bladder and rectum.
 - The images are radiological quantities used in dose calculations.
 - Often readily available in radiotherapy departments or nearby.

CT Treatment Planning - 2

Problems with CT treatment planning for Cx TP:

1. Requires special applicators.

- » Either very thin metal (may not be strong enough), or
- » Plastic/graphite (may need to be thick, big and clunky).
- » Some on market not designed well (for instance, having the ovoid sources 1 cm from the later surface regardless of the diameter).
- » Currently *very expensive*.

CT treatment Planning - 3

Problems with CT treatment planning for Cx TP:

2. Requires moving the patient after localization to the treatment room:

- » Unless there is a CT in the treatment room or a treatment unit in the CT room).
- » Can produce motion that nullifies the increased accuracy of volume-image treatment planning (even with a transfer board).
- » Must image and treat in the same position.

CT Treatment Planning - 4

Problems with CT treatment planning for Cx TP:

3. More to the point, CT fails to provide differentiation between the uterus, pariuterine tissues and tumor.

Cervical CT with Ring Applicator

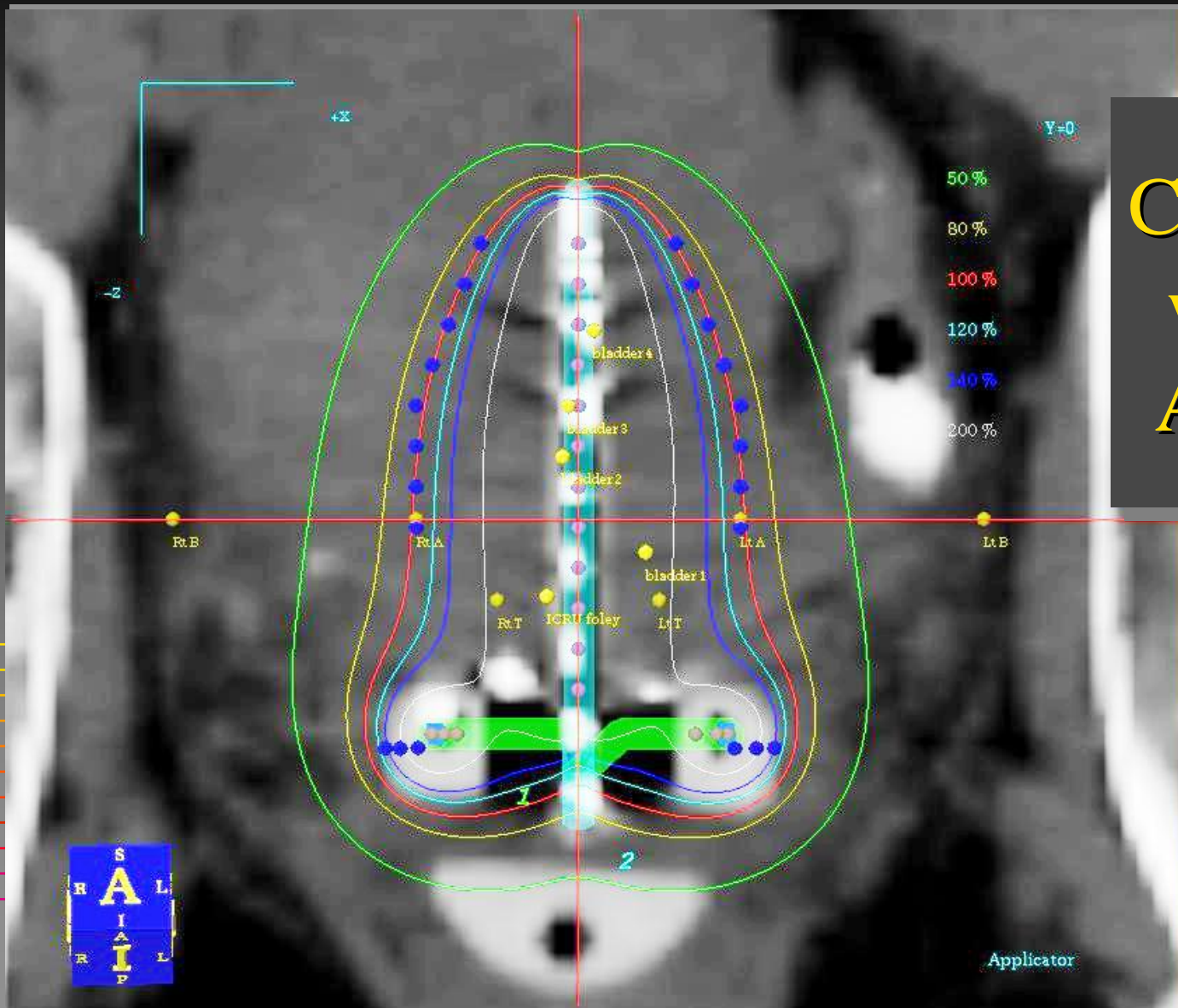


Image courtesy of Jason Rownd, Medical College of Wisconsin

Showing Urethra and Rectum

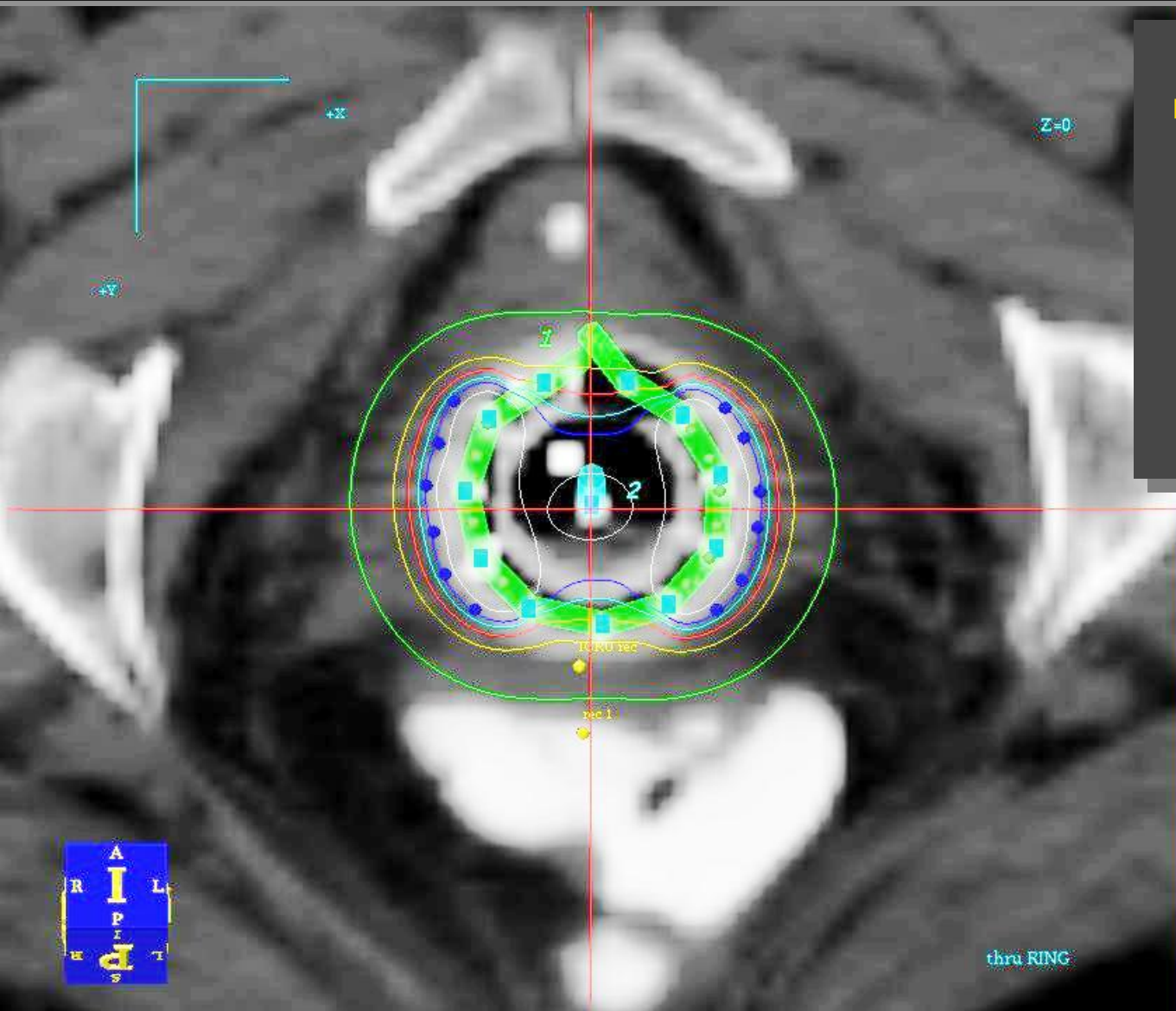


Image courtesy of Jason Rownd, Medical College of Wisconsin

CT Treatment Planning - 5

Problems with CT treatment planning for Cx TP:

4. Localizing the sources

- » In plane localization is pretty good, of course, but the limiting factor is slice thickness/spacing.
- » Recall, this is where radiographs excelled.

CT Treatment Planning - Summary

CT treatment planning for cervical intracavitary brachytherapy has been done (since Schoeppe et al, 1989), and it is a way of determining the doses delivered to organs at risk, but not for tumor dose distribution.

Magnetic Resonance

- MR can differentiate between uterus, uterine tumors, and other pelvic tissues, as well as showing the regional organs at risk.
- MR does produce a true volume image.

MR Treatment Planning - 2

Problems with MR treatment planning for Cx TP:

1. Requires special applicators.

- » Non-ferromagnetic, metal or plastic/graphite (again, may need to be thick, big and clunky).
- » Often the same as the CT compatible applicator.
- » Currently *very expensive*.

MR treatment Planning - 3

Problems with MR treatment planning for Cx TP:

2. Requires moving the patient after localization to the treatment room:

- » Can produce motion that nullifies the increased accuracy of volume-image treatment planning (even with a transfer board).
- » Must image and treat in the same position.
- » Unless there is a MR in the treatment room.

Unless there is an MR in Department

- Pötter et al. in Vienna have an open-field MR in department.
- Can do the procedure under MR guidance.
- The patient stays in the same position throughout.

MR Treatment Planning - 4

Problems with MR treatment planning for Cx TP:

3. Localizing the sources

- » In plane localization is pretty good, of course, but the limiting factor is slice thickness/spacing.
- » Recall, this is where radiographs excelled but CT also fell down.

RECALL:

CT Treatment Planning - 4

Problems with CT treatment planning for Cx TP:

3. More to the point, CT fails to provide differentiation between the uterus, pariuterine tissues and tumor.

This is *NOT* a problem with MR, but its great strength!

slice : 17 of 34
Z (CT) : -69.8

MR of Tandem in the Uterus

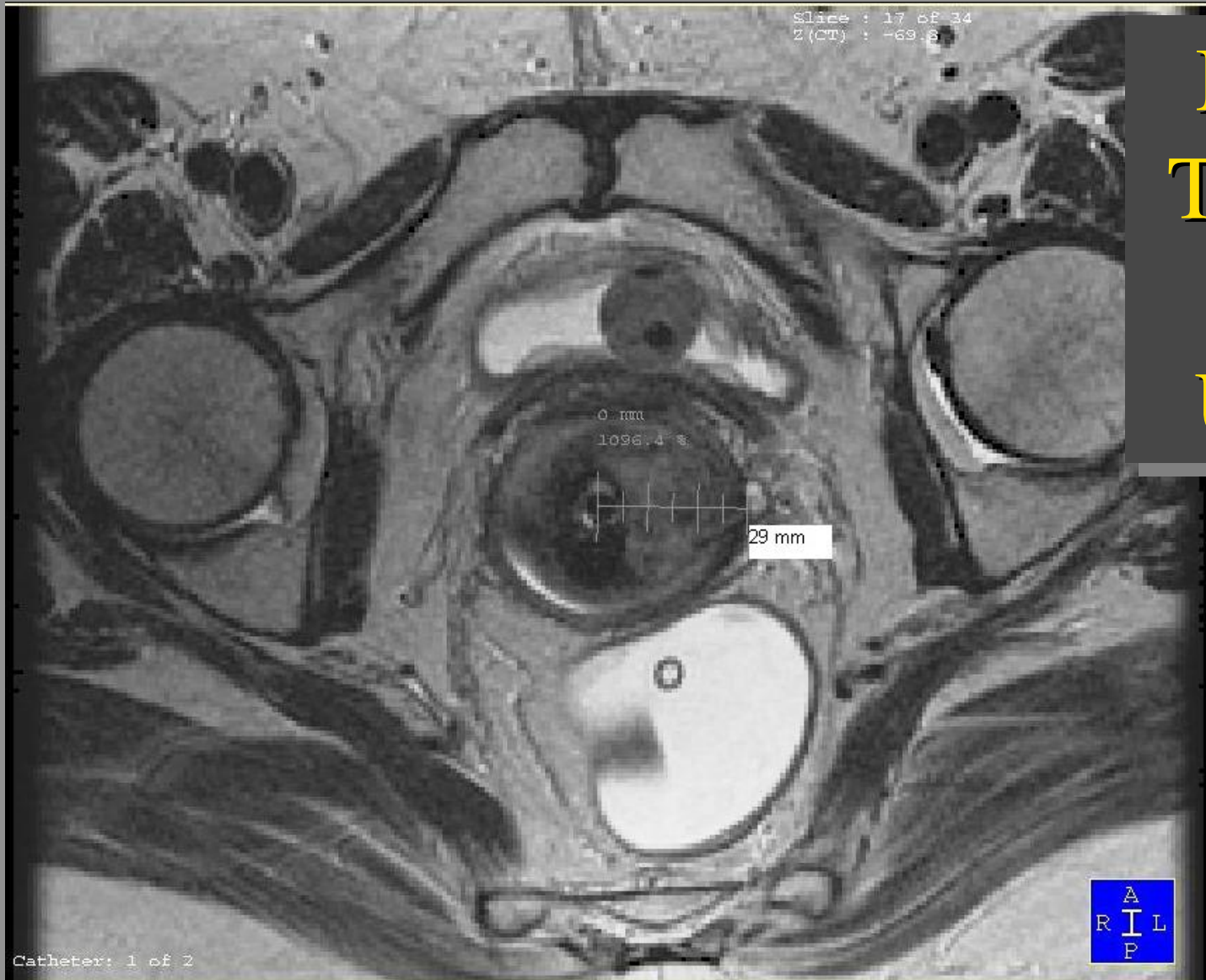


Image courtesy of Jason Rownd, Medical College of Wisconsin

Recommendations of a Somewhat Intersociety Committee on Volume-image guided Treatment Planning for Cervical Intracavitary Brachytherapy (Led by the Gynecological Oncology Group)

- Oops, ran out of space.

Recommendations

Published in IJROBP 60:1160-1172 (2004).

S Nag, H Cardenes, S Chang, I Das, B Erickson,
G Ibbott, J Lowenstein, J Roll, B Thomadsen,
M Varia

Proposed guidelines for image-based intracavitary
brachytherapy for cervical carcinoma: Report
from Image-Guided Brachytherapy Working
Group

The Situation

- We can now delineate target tissues as well as organs at risk.
- The inclination is to treat intracavitary brachytherapy in a manner similar to external-beam radiotherapy, i.e., define a target and prescribe a dose to that target.

The Problem

After a century of intracavitary brachytherapy

- We do not know the target.
- We do not know what dose to give it (?)

The Problem

- We do not know the target.
 - Doses have been prescribed to points A defined with respect to the appliance.
 - We do not know where the target was in any case.
 - It could be that the very high dose near the applicator is what makes this treatment so effective.
 - It may be that the long tail of dose beyond Pt A is important to success.
 - These may be more warning to trying to replace Bx with IMRT.

The Problem

- We do not know what dose to give it (?)
 - Since we don't know what the target was.
 - It is premature to assume that if we gave Point A 45 Gy beyond 40 Gy of external-beam that we should give a visible tumor that same dose.
 - Some tumors may have received less, if they extended beyond Point A, and some more if they were small.

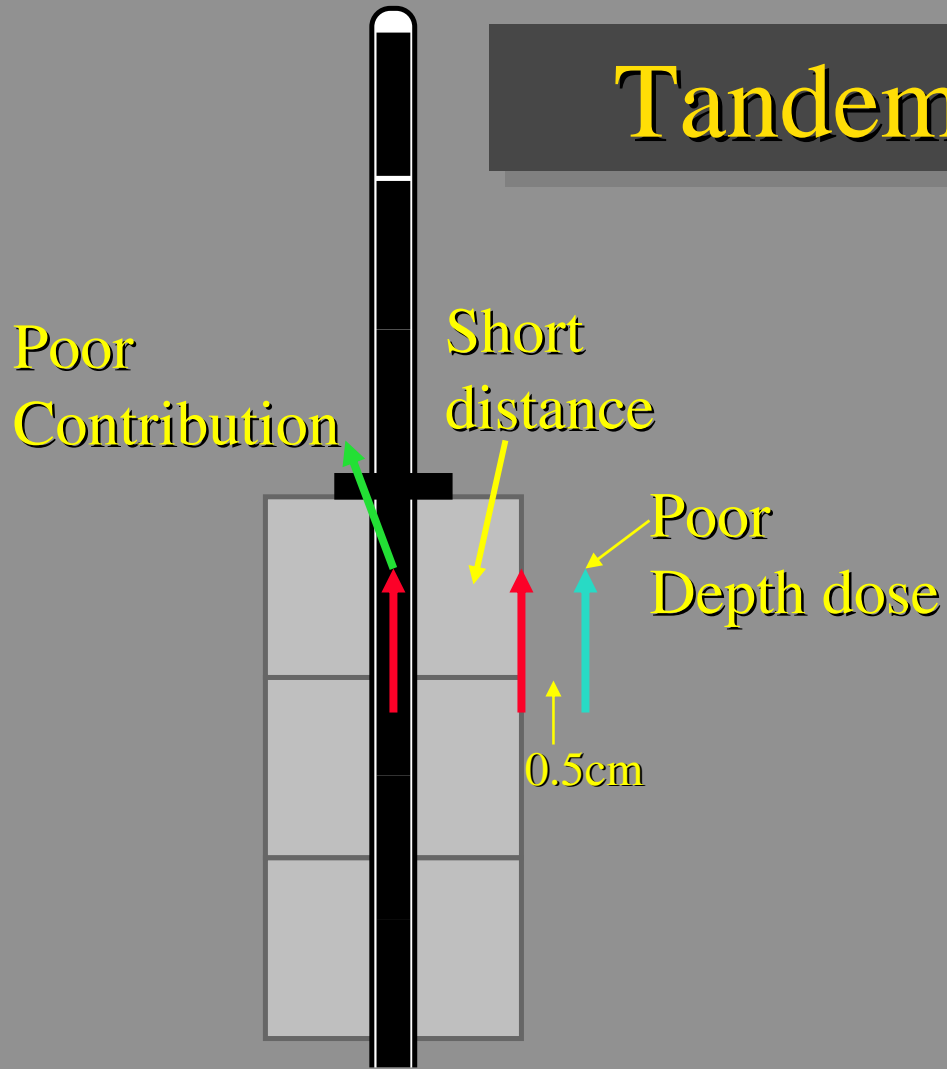
Recommendations (Continued)

Targeted at Researchers and Cooperative groups to report data, so after some years of reporting on image-guided intracavitary brachytherapy we *will* have the information necessary to answer those two questions.

Recommendations

1. Treatments should be prescribe as in the current practice, and the integrated reference air kerma and the dose to Point A as defined by the ABS [Nag et al, 2000; Nag et al, 2002] should be reported.

Tandem and Cylinders



Because of the nature of the anisotropy, this maximizes the relative contribution to the bladder and rectum per dose to cervix, and usually prevents adding distance to those organs.

Recommendations (Cont.)

2. Cooperative Groups collect the data listed below and correlate the information with patient outcomes.

Recommendations (Cont.)

3. MRI is to be used for image-based cervical brachytherapy. T2-weighted (with fat suppression) MRI imaging using a pelvic surface coil should be performed with the patient in the treatment position with brachytherapy applicators in place for intracavitary implants. PET/CT fusion should be investigated for treatment planning.

(CT is not allowed)

Recommendations (Cont.)

4. The following information should be gathered on each patient:

a. Target Dosimetry:

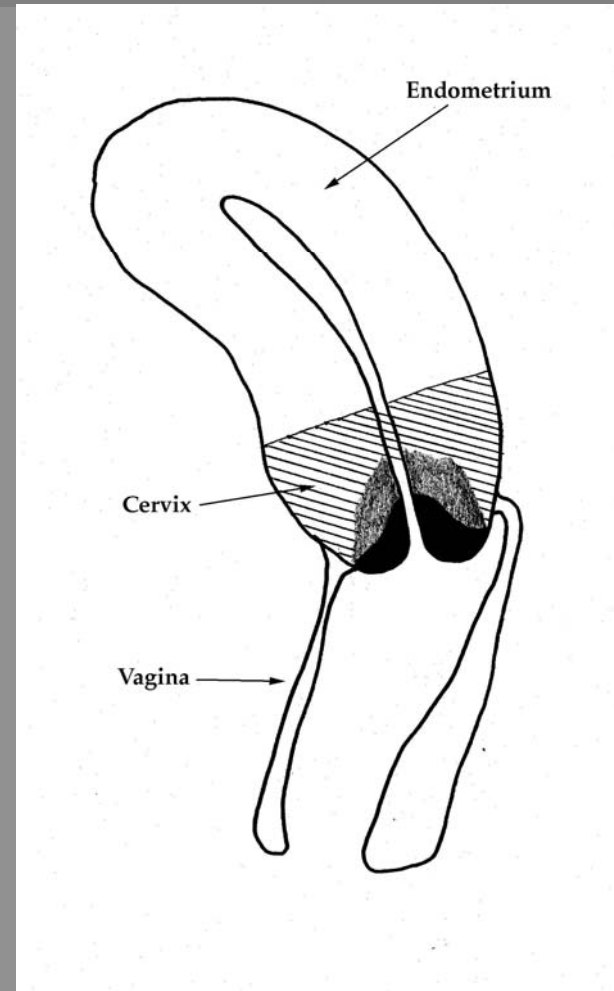
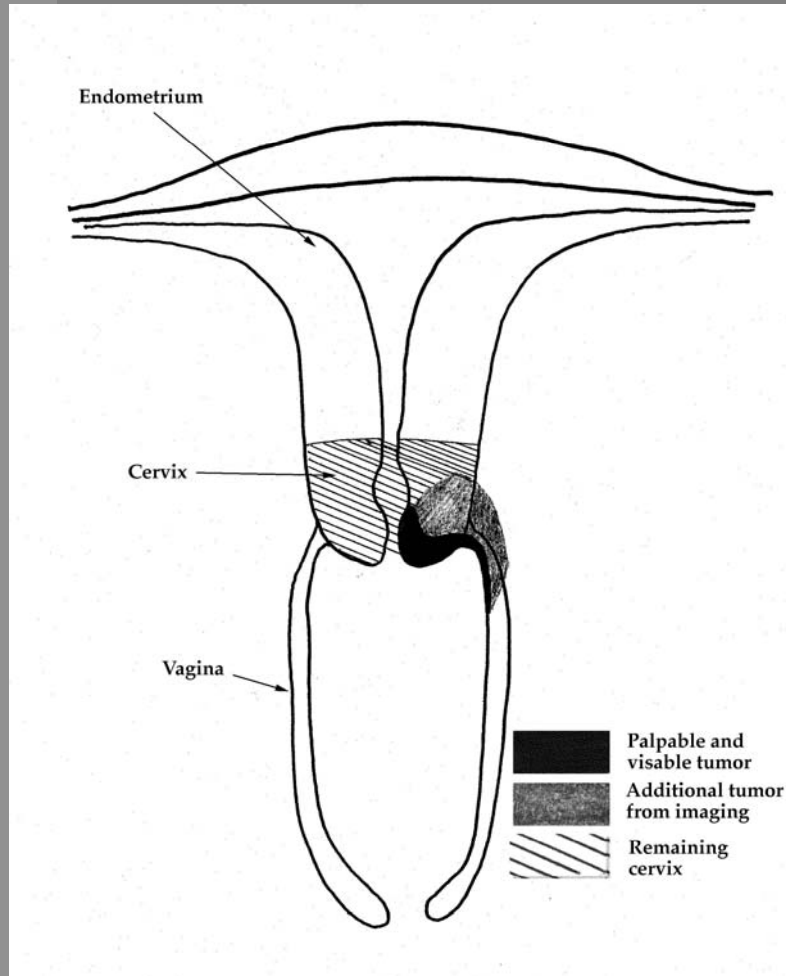
- DVH of GTV_I and GTV,
- D_{100} , D_{95} , D_{90} (for the various GTV and CTV),
- V_{100} (% of GTV covered by Point A dose) ,

using the following definitions:

Recommendations (Cont.)

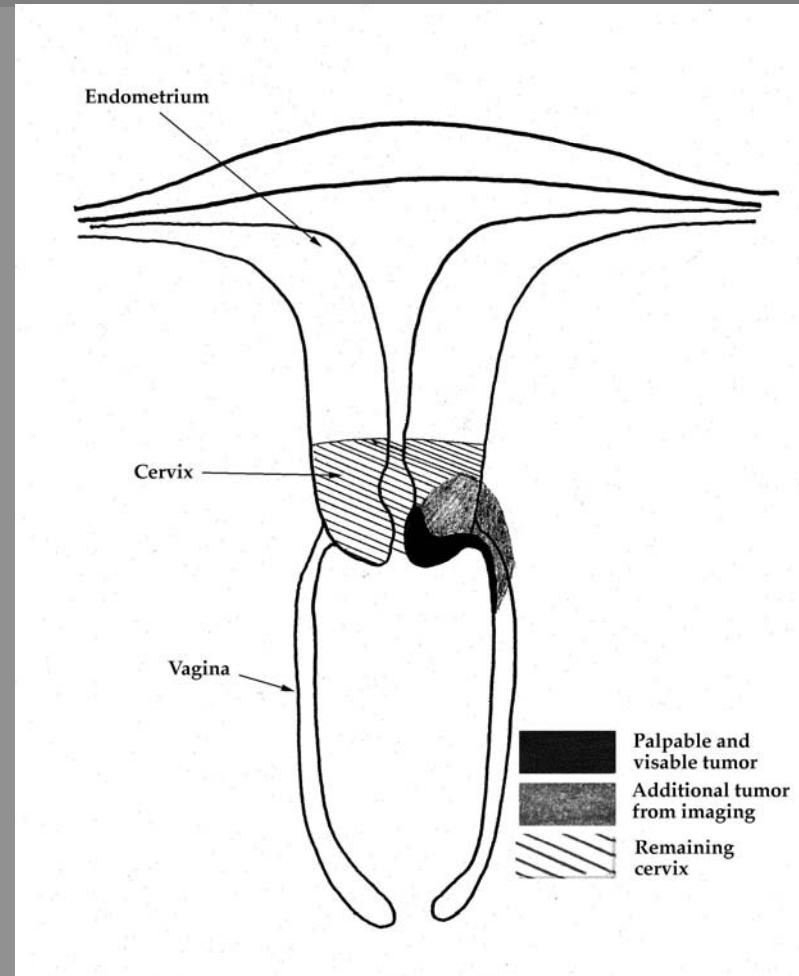
- i. GTV_I : gross tumor volume as defined through imaging plus any palpable or visual tumor.
- ii. GTV: the GTV_I plus the entire cervix.
- iii. pCTV: the primary tumor clinical target volume, which equals the GTV plus a 2 cm margin.
- iv. rCTV: the pCTV plus a 1.5 cm margin around regional lymph nodes.
- v. CTV: the pCTV and the rCTV, all of which are to be included in the external beam radiotherapy field.

Cervical Ca Targets



Recommendations (Cont.)

- i. GTV_I : gross tumor volume as defined through imaging plus any palpable or visual tumor.
- ii. GTV: the GTV_I plus the entire cervix.
- iii. pCTV: the primary CTV, which equals the GTV plus a 2 cm margin.



Recommendations (Cont.)

b. Normal Structure Dosimetry:

- i. absolute DVH of the organ wall alone, which requires contouring of the inner and outer wall of the bladder and rectum.
- ii. for bladder doses: the ICRU bladder point dose, the maximum bladder dose, and the maximum doses to contiguous 1 cc and 5 cc volumes of bladder (Bladder_{V1cc} , Bladder_{V5cc}).
- iii. for rectal doses: the ICRU rectal point dose, maximum rectal dose, and the maximum doses to contiguous 1 cc and 5 cc volumes of rectum (Rectum_{V1cc} , Rectum_{V5cc}) are to be reported.
- iv. for small bowel doses: the maximum doses to contiguous 1 cc and 5 cc volumes of small bowel ($\text{Small Bowel}_{V1cc}$, $\text{Small Bowel}_{V5cc}$) are to be reported.

Some Problems

An attempt to harmonize with the GEC-ESTRO recommendations in the proof stage of the article led to an inconsistency in the recommendations in the text and the summary of the recommendations at the end.

- pCTV – primary tumor clinical target volume
 - Text: $pCTV = GTV + \text{entire uterus} + \text{parametria to sidewall} + 2\text{cm normal vagina}$.
 - Summary: $pCTV = GTV + \text{cervix} + 1\text{-cm margin}$.

GEC-ESTRO Critique

(Other than the pCTV)

1. MR details missing. [There are many details and what is needed.]
2. Is GTV at diagnosis or at brachytherapy, and if fractionated, at the first or each fraction?
3. Object to Organ-at-risk wall contouring: takes too long (only for retrospect) and is uncertain. [Is only for reporting and is what is relevant. Uncertainty may be inherent in procedure.]

GEC-ESTRO Critique (Cont.)

4. Dose-Volume Parameters:
 - a. Problematic since the time of assessment for the target volumes not given.
 - b. V_{100} related to Point A – an applicator not patient point. Should be the prescribed point. [See earlier comments on prescriptions.]
 - c. OAR - regardless of the volume, the maximum dose is the same. Should be the minimum dose in the volume. [Agreed]

Conclusions

1. Volume-imaged guidance is likely to enhance cervical intracavitary brachytherapy.
2. MRI is probably the only volume-imaging modality that allows target-based prescriptions.
3. Until we analyze what doses have been given to what locations and structures we do not know what doses to prescribe nor to what targets.
4. Until we gather enough data, we do not know the tolerance doses or significant volumes for normal structures.
5. US and European groups need to harmonize protocols.