Conversion from LDR to HDR Intracavitary Brachytherapy for Cancer of the Cervix

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Learning Objectives

1. To understand the different variables in LDR and HDR intracavitary brachytherapy for cancer of the cervix.

2. To understand the procedures for HDR intracavitary brachytherapy for cancer of the cervix.

HDR Advantages for Cervical Ca Treatments

1. Shorter treatment times, resulting in:

a) Outpatient treatment.

b) Less patient discomfort since prolonged bed rest is eliminated

c) Treating patients intolerant of isolation or at risk for acute cardiopulmonary toxicity due to prolonged bed rest.

d) Reduced applicator movement during therapy.

e) Greater displacement of nearby normal tissues.

f) Possibility of treating larger number of patients.

HDR Advantages for Cervical Ca Treatments

2. Allows use of smaller diameter sources than are used in HDR:
   a) Resulting in less patient discomfort, thereby;
   b) Reducing the need for dilatation of the cervix and therefore reducing the need for heavy sedation or general anesthesia (allowing treatment for high-risk patients who are unable to tolerate general anesthesia).
   c) Making insertion of the tandem into the cervix easier.

HDR Advantages for Cervical Ca Treatments

3. Tailor dose distribution to target through optimization
4. Elimination of exposure to personnel

Disadvantages of HDR Brachytherapy Compared with LDR

- Labor intensive (requires large staff during procedure)
- Decreased therapeutic ratio (radiobiologically, normal tissue becomes relatively more sensitive than tumor)
- Increased probability of executing an error
- Must know target and desired doses

Dangers of HDR Brachytherapy

- Working fast
  - so patient doesn’t become uncomfortable and start to move
  - so patient doesn’t develop thromboses
  - so patient doesn’t stay under anesthesia
- Lots of input data required ($\approx$ 350 bits of information)
- complicated to check by hand

Steps in Converting from LDR to HDR Intracavitary Brachytherapy

1. Determine dose and fractionation
2. Determine applicator
3. Determine dwell positions
4. Determine optimization scheme
5. Establish quality management

Biological Equivalence: Dose per Fraction

LDR

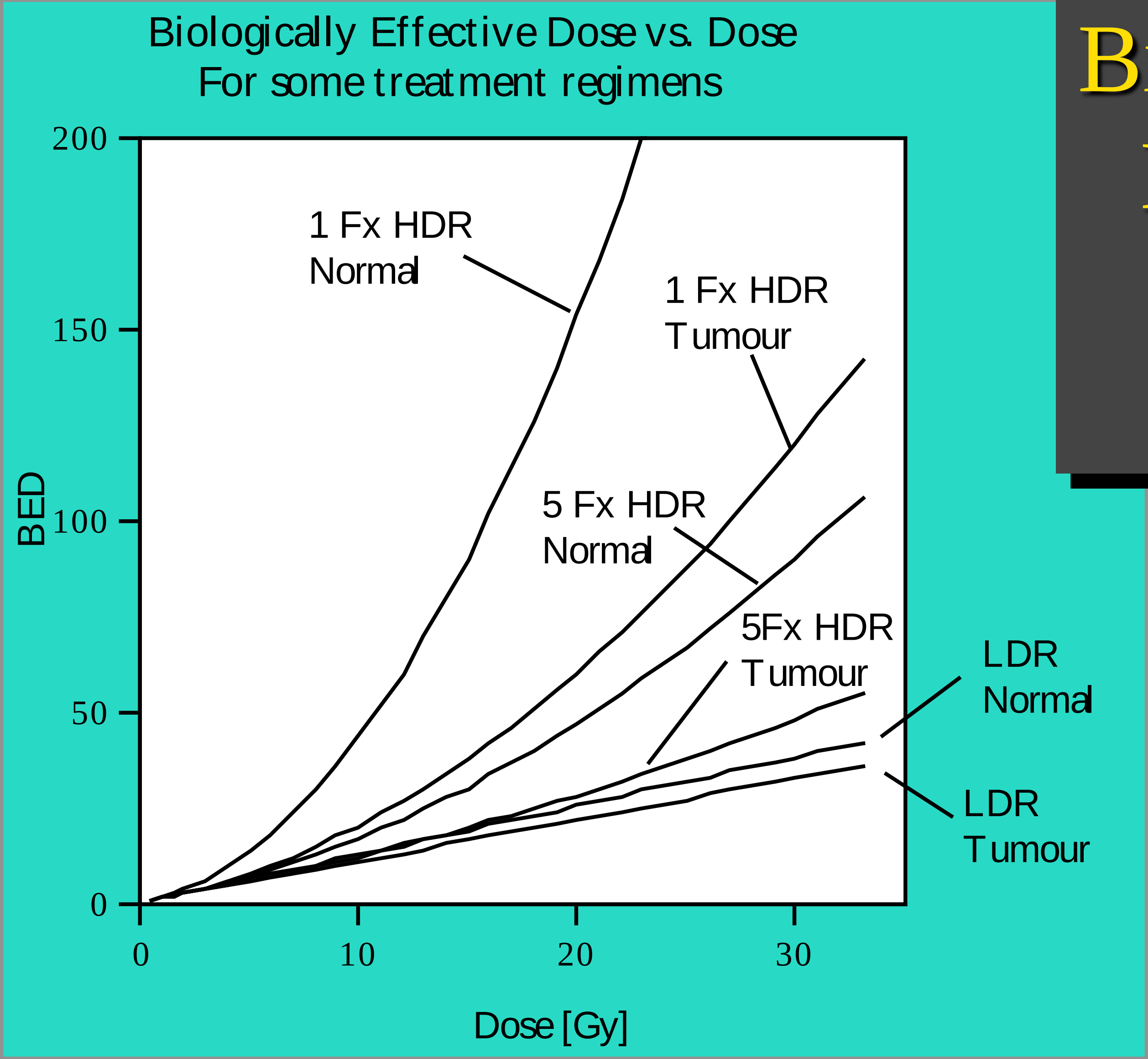
$$BED = D \{ 1 + [2\dot{D}(\beta/\alpha)/\mu] [1 - \langle 1- \exp(-\mu T)\rangle/(\mu T)]\} - 0.693T/(\alpha T_p)$$

HDR

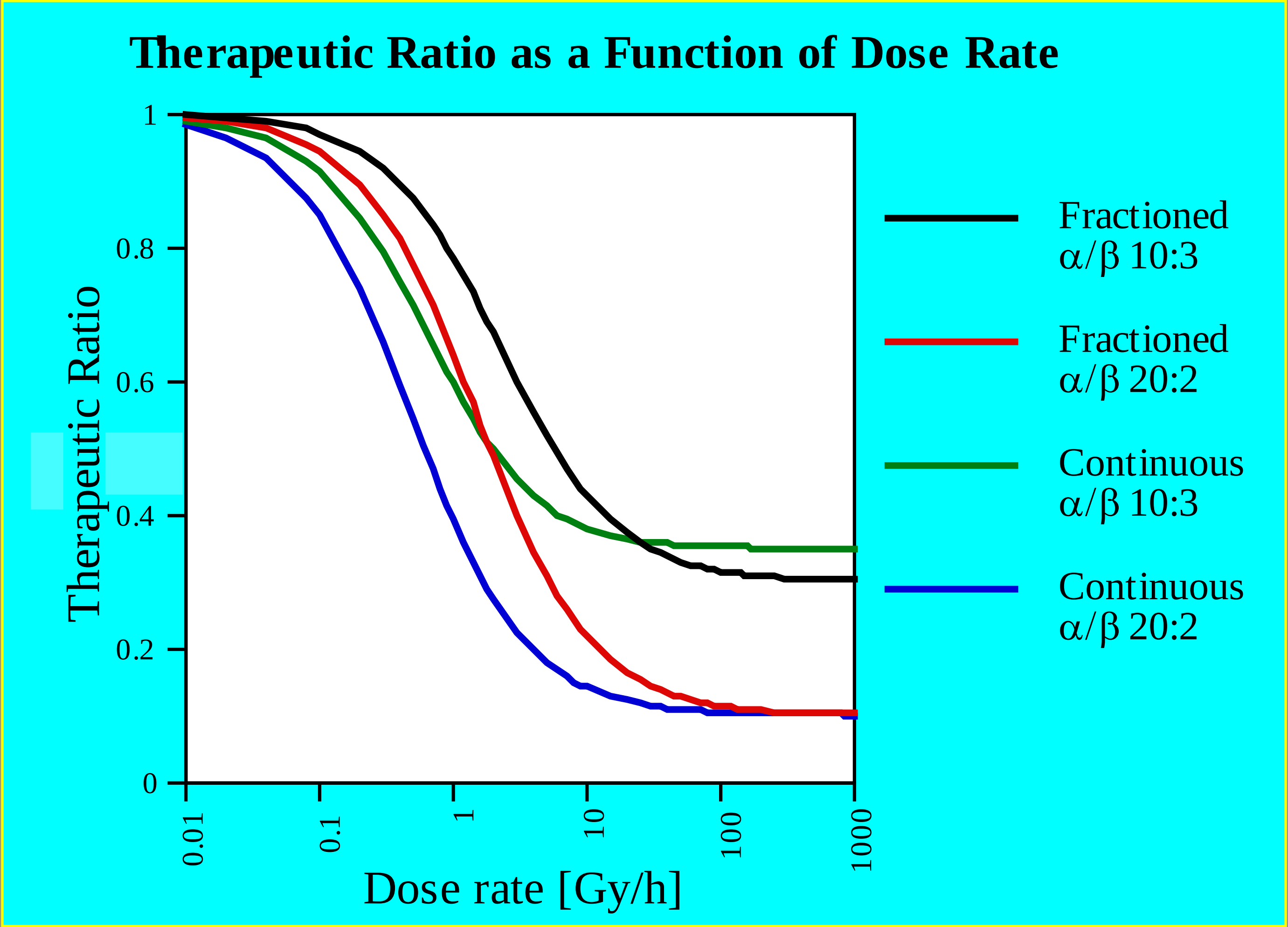
$$BED = n d [1 + d/(\alpha/\beta)] - 0.693T/(\alpha T_p)$$

$$d = \frac{-\left(\alpha/\beta\right) + \sqrt{\left(\alpha/\beta\right)^2 + \left(\frac{4D}{n}\right)\left(\alpha/\beta\right)\left\{1 + \left(\frac{2\dot{D}}{\mu}\right)\left(\frac{\beta}{\alpha}\right)\left[1 - \frac{1-e^{-\mu T}}{\mu T}\right]\right\}}}{2}$$

Biologically Effective Dose vs. Dose



Therapeutic Ratio vs. Dose Rate

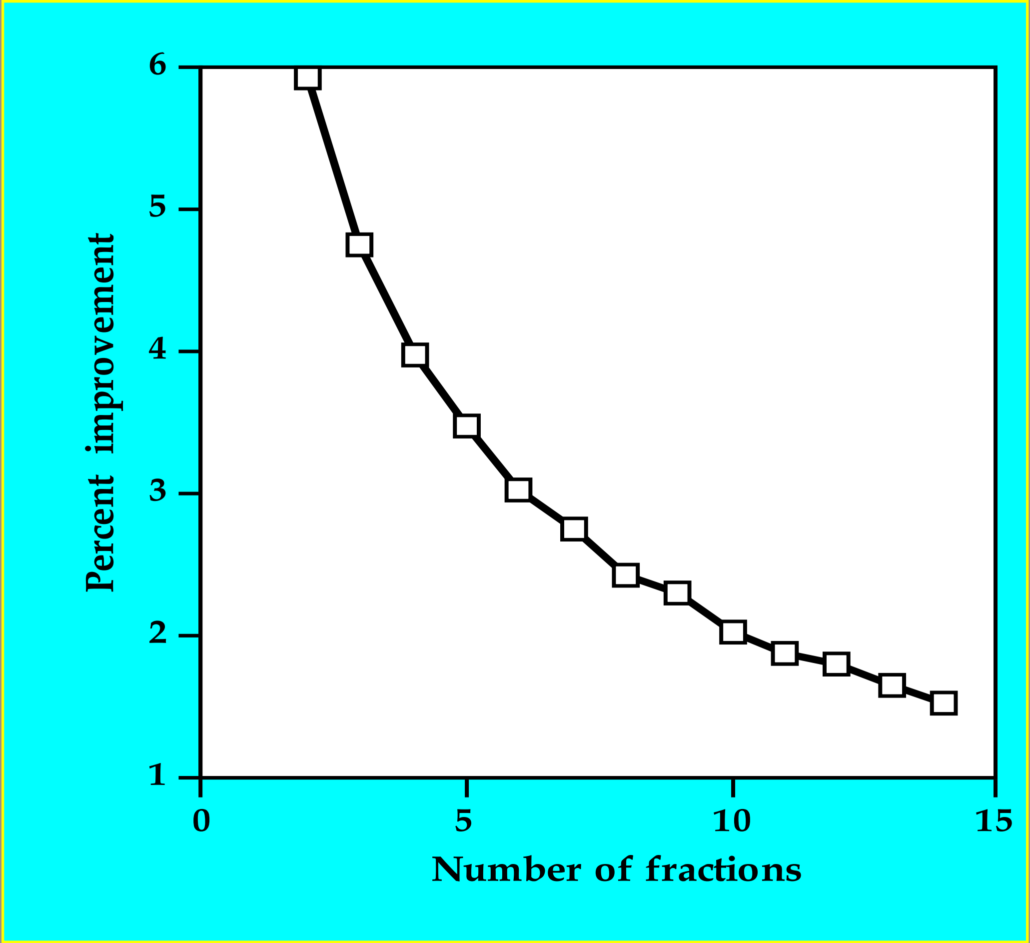


Living with Unfavorable Therapeutic Ratio

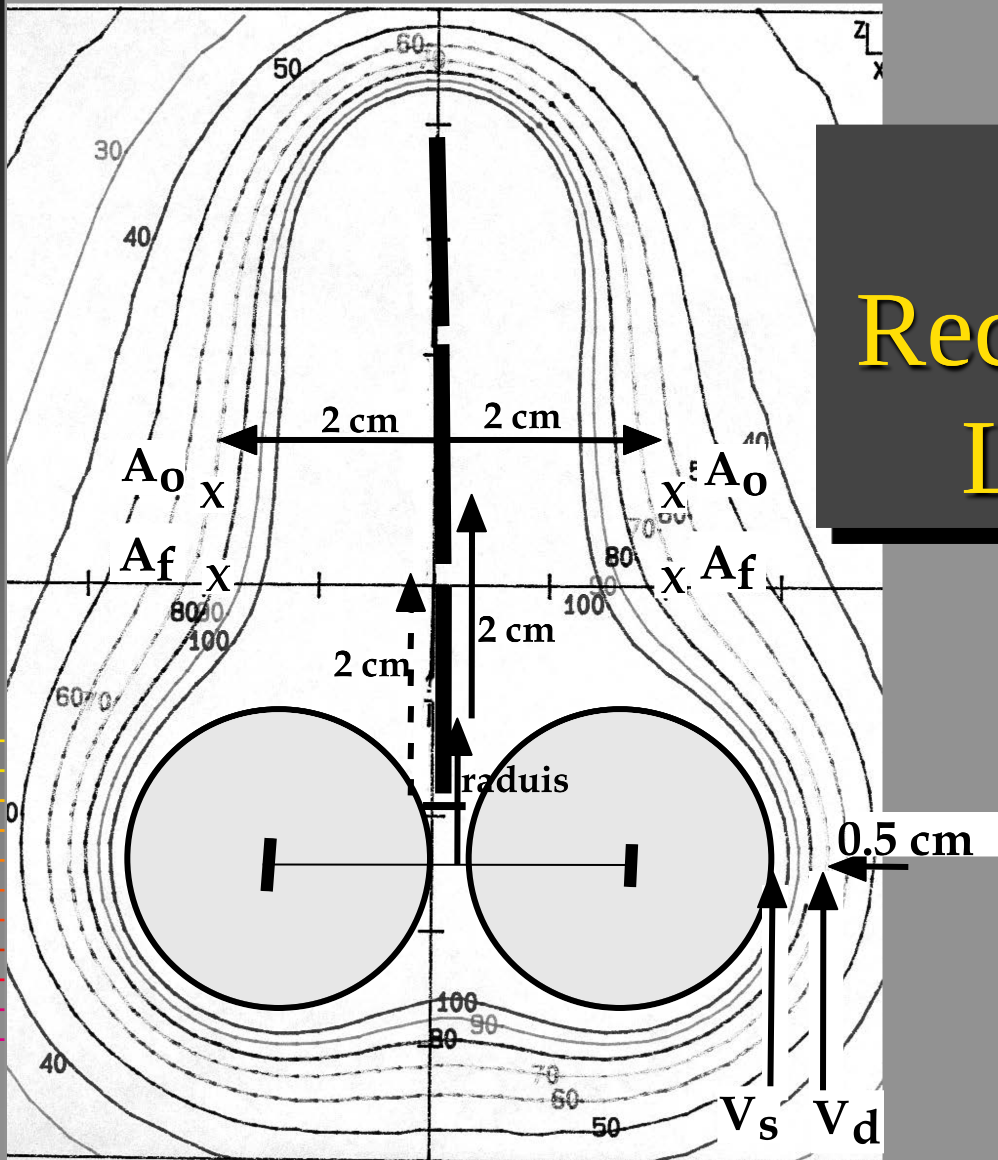
The save graces are:

- Geometric spacing - With HDR brachytherapy, normal structures can be held away during treatment; and
- Fractionation.

Improvement in Therapeutic Ratio with Increasing Number of Fractions



ABS Recommendations for Locating Point A



Absolute Dose

- The treatment usually has external beam treatments to about 44 - 50 Gy at 1.7 - 2.0 Gy/fraction.
- Total treatment to about 100 - 110 Gy_{10}.
- Typical HDR regimen is 5 fractions of 5.5 Gy.
- Chemotherapy strongly affects both normal tissue and tumor reaction.

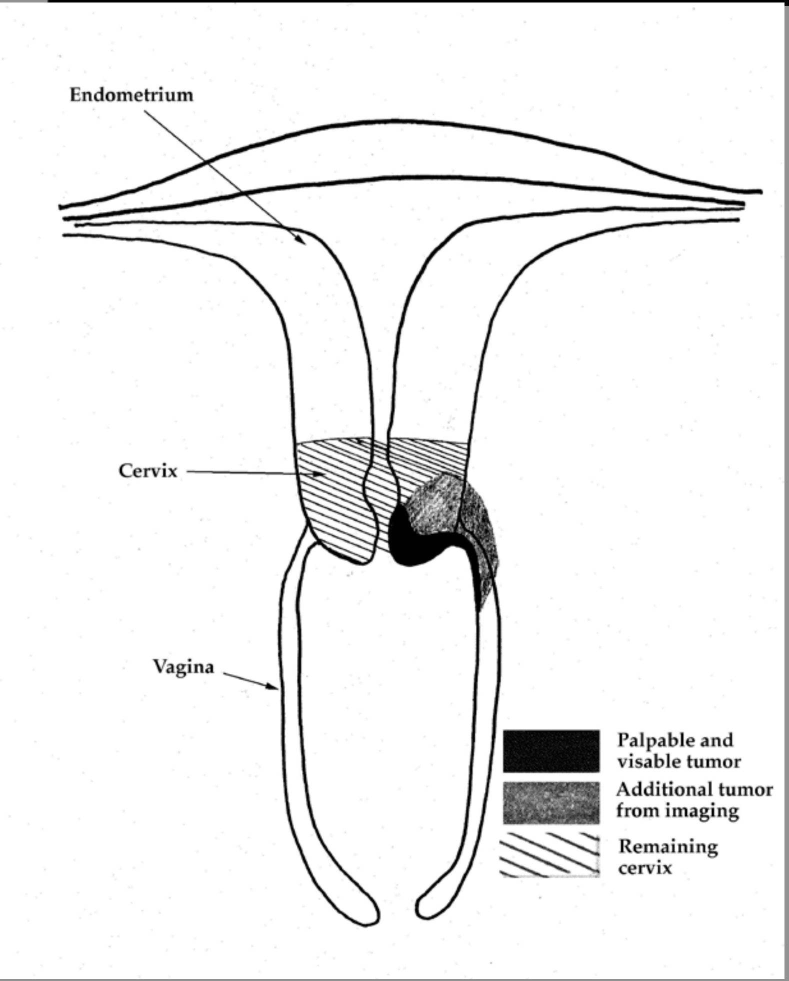
What if I used the M.D. Anderson Approach?

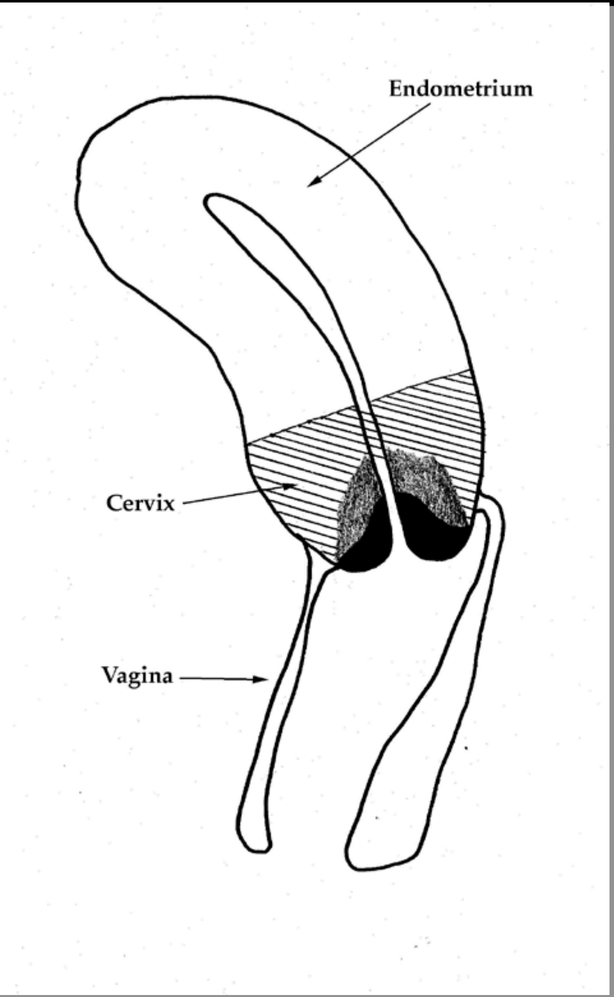
Review a selections of patients with a variety of applications and determine the doses to Points A.

What if I Didn't Use the M.D. Anderson Approach?

You should still review a set of your patients and look at the shape of the dose distribution. (Not that you want to duplicate that - it was what you could get, not what you wanted to get.)

Cervical Ca Targets





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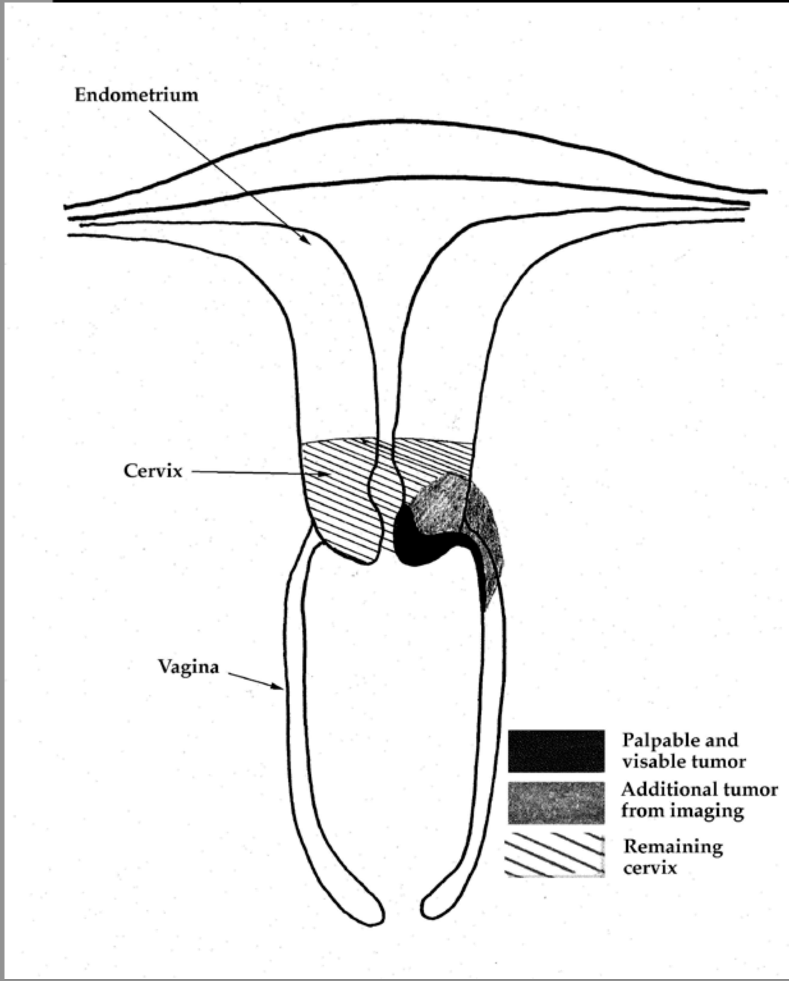
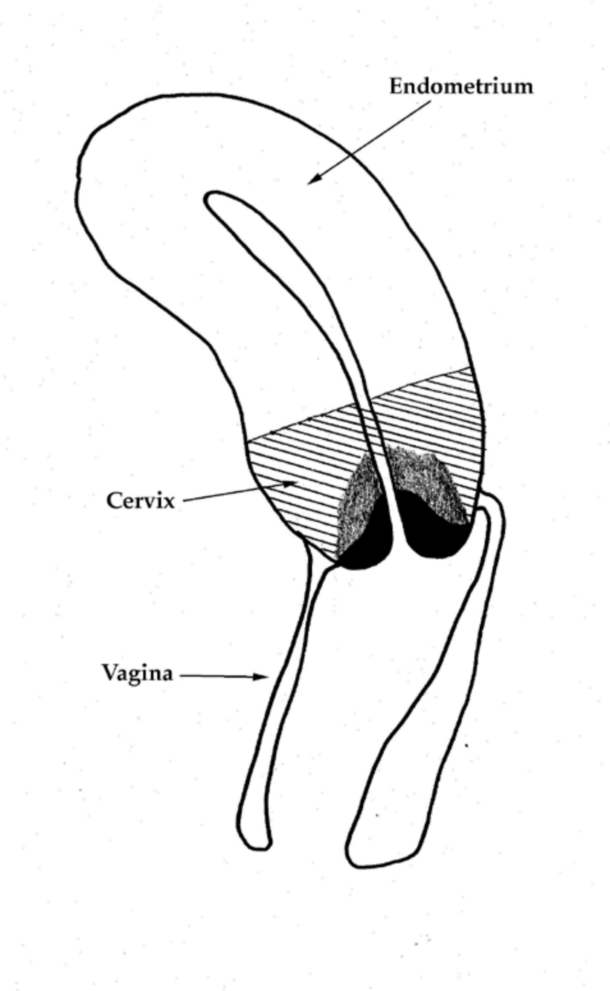
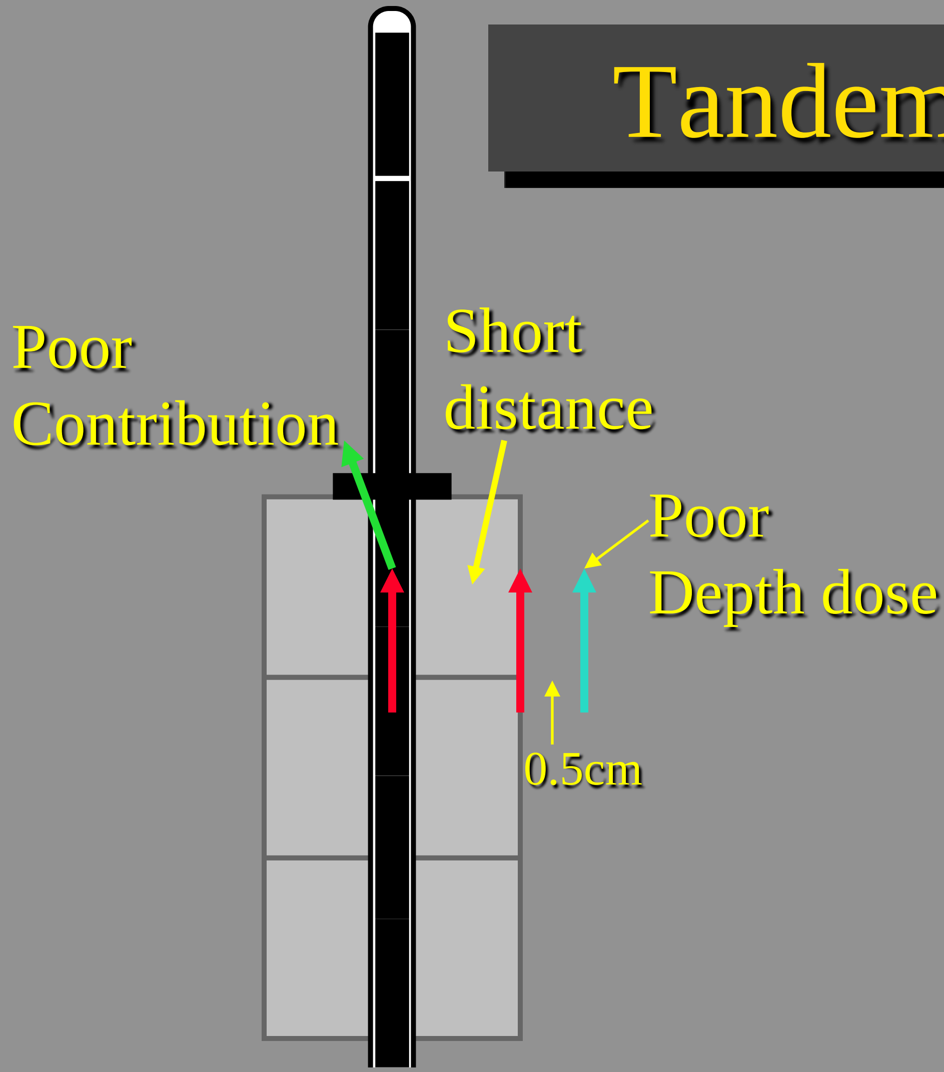
Cervical Ca Targets





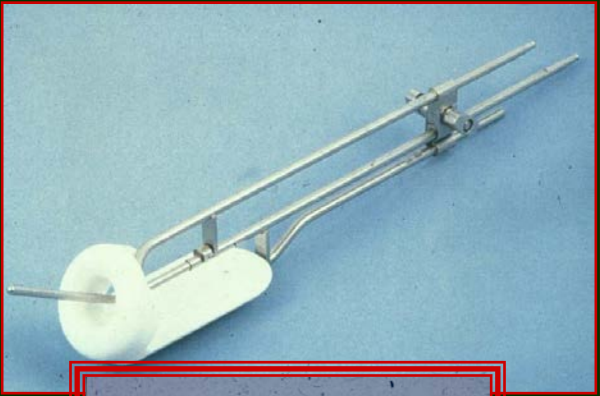
Tandem and Cylinders

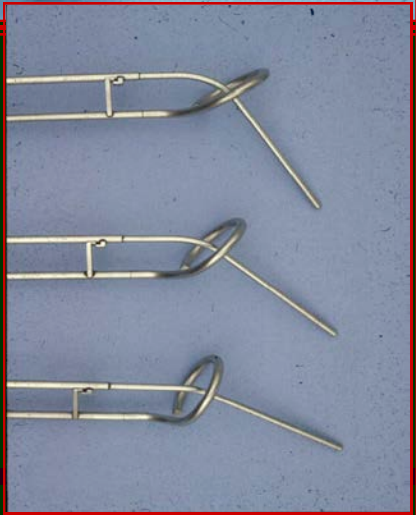


Because of the nature of the anisotropy, this maximizes the relative contribution to the bladder and rectum per dose to cervix, and usually prevents adding distance to those organs.

Tandem & Ring Geometry

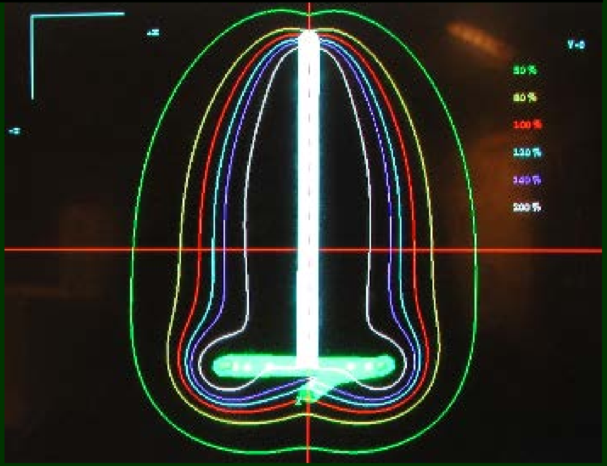
- Simple but complex geometry
- Ring diameter
  - Ring + Cap diameter
  - 36mm, 40mm, 44mm
  - constant 6mm source to surface
- Tandem Angle
  - 30°, 45°, 60°
  - 2cm, 4cm, 6cm, 8cm

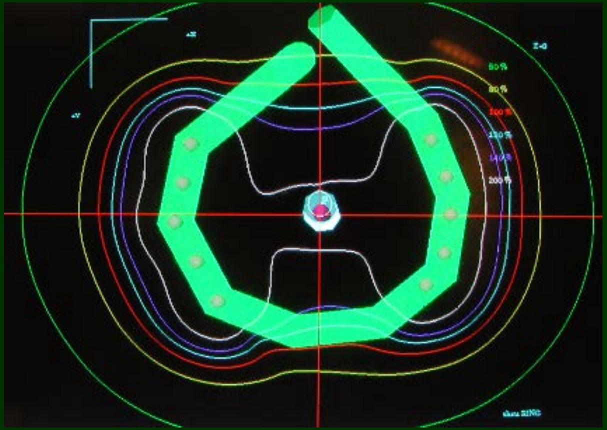




Tandem & Ring Geometry

- Fixed geometry - tandem fixed in center of ring
- Choose combination according to anatomy
- Dosimetry needed only for 1st fraction?
- Adapt fraction to fraction if needed





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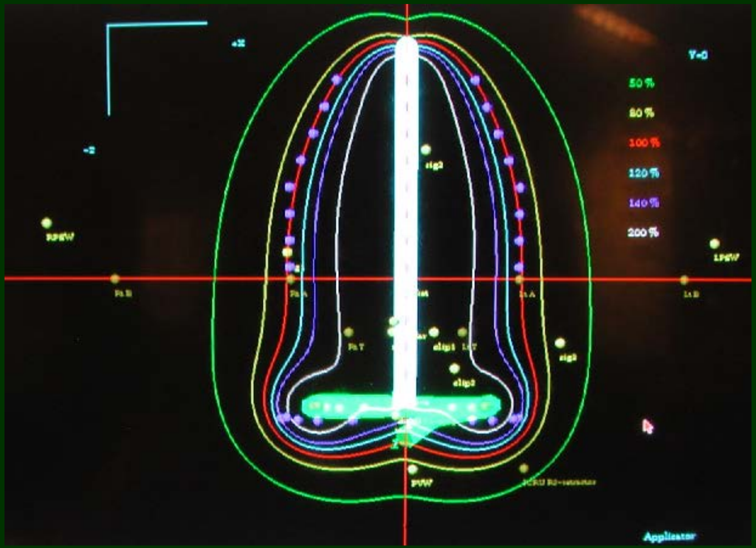
Dosimetry Methods-Tandem

- Dose optimization points are tapered along the tandem axis
- 12mm, 14mm, 16mm, 18mm,20mm down to level of Point A
- Dwell locations down to ring



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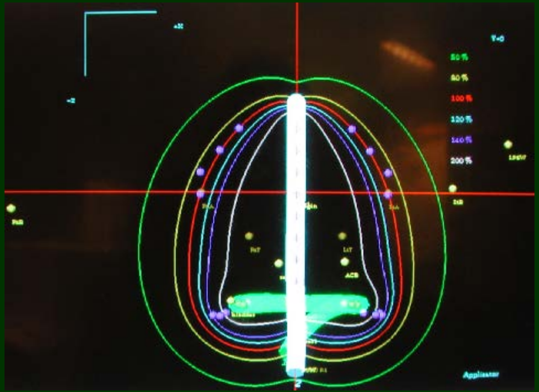
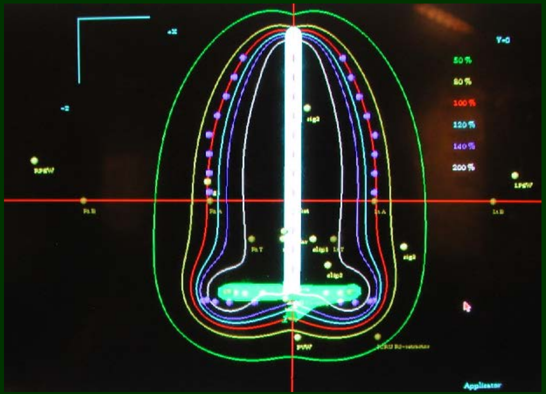
Dosimetry Methods-Tandem

- Tandem length will affect the dose around Point A
  - more tandem dwells, less relative contribution from ring dwells
  - goal percentage 100%, optimized 90-110%





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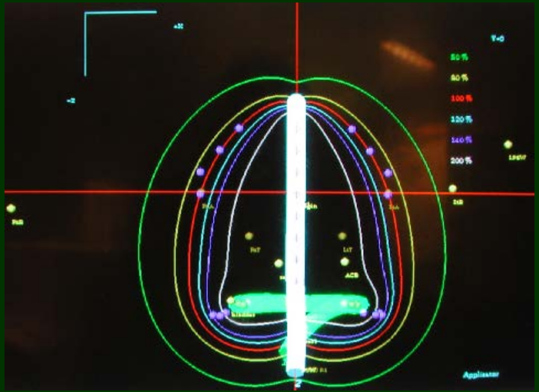

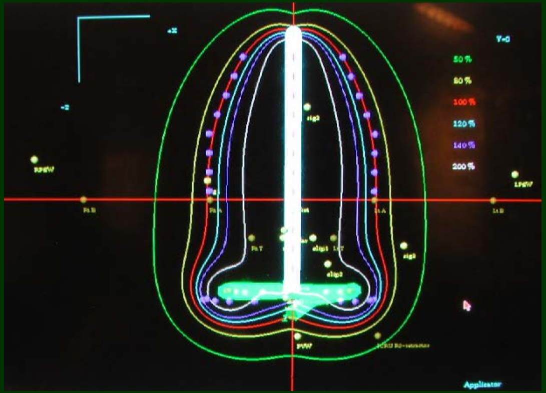

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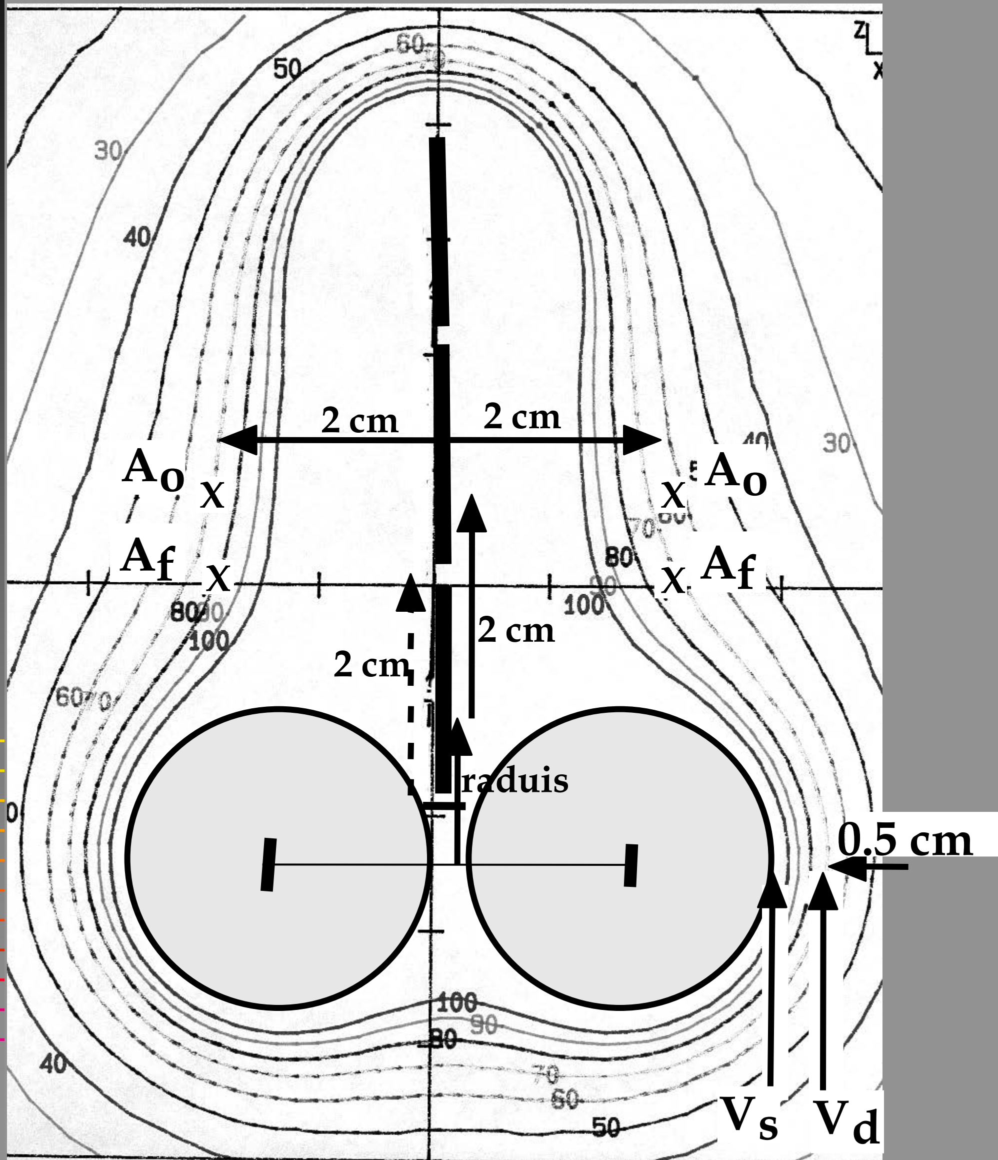
Dosimetry Methods-Ring

- Dwell locations are specified as part the prescription
  - 4, 5, or 6 dwells to a side
- Dose optimization points are placed radially at 6mm
  - non radial placement means different depths and not on ring surface



Tandem and Ovoids

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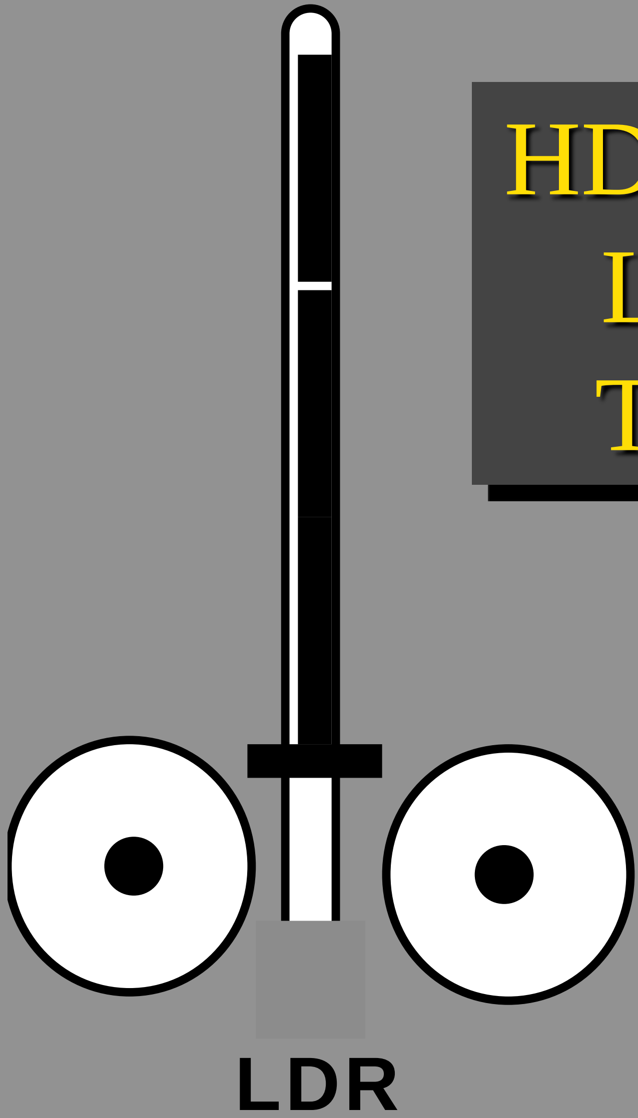
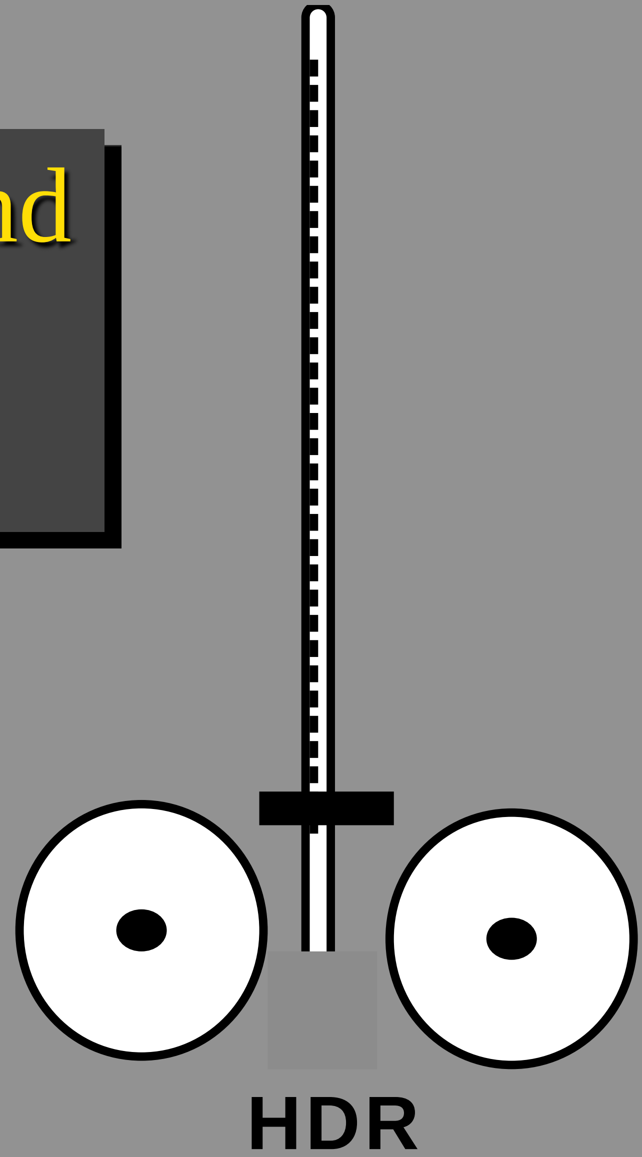
HDR and LDR T&O

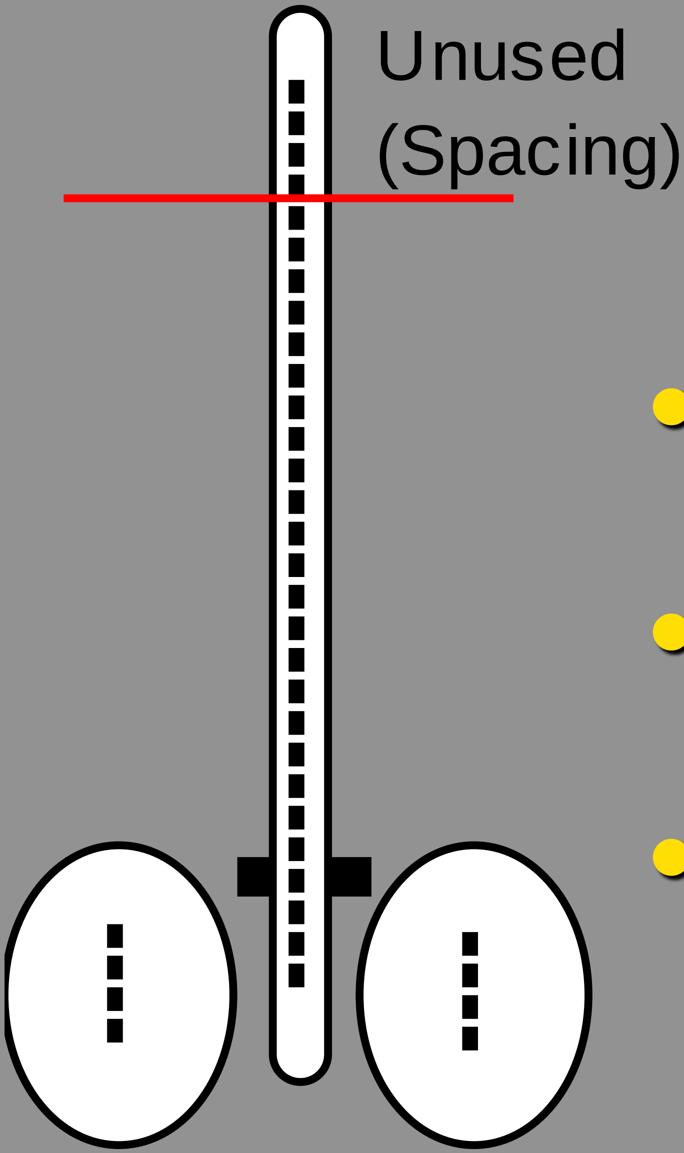




Duplicate the LDR Source Distribution with HDR Dwell Weights?

- Can we? Certainly, and a lot of work was done to do this well in the late 1980s.
- Should we? Absolutely not!
  - Duplicating the physical distribution does not duplicate the biological distribution because BED depends on dose/fraction.
  - Fails to give the patient the benefit of optimization.

Selecting Dwell Positions



- Add spacing in tip to protect bowel.
- Load tandem to about mid-ovoid.
- Ovoid use dwells 2-8.
  - Dwell 1 irradiates rectum.
  - Dwell 9 irradiates bladder.

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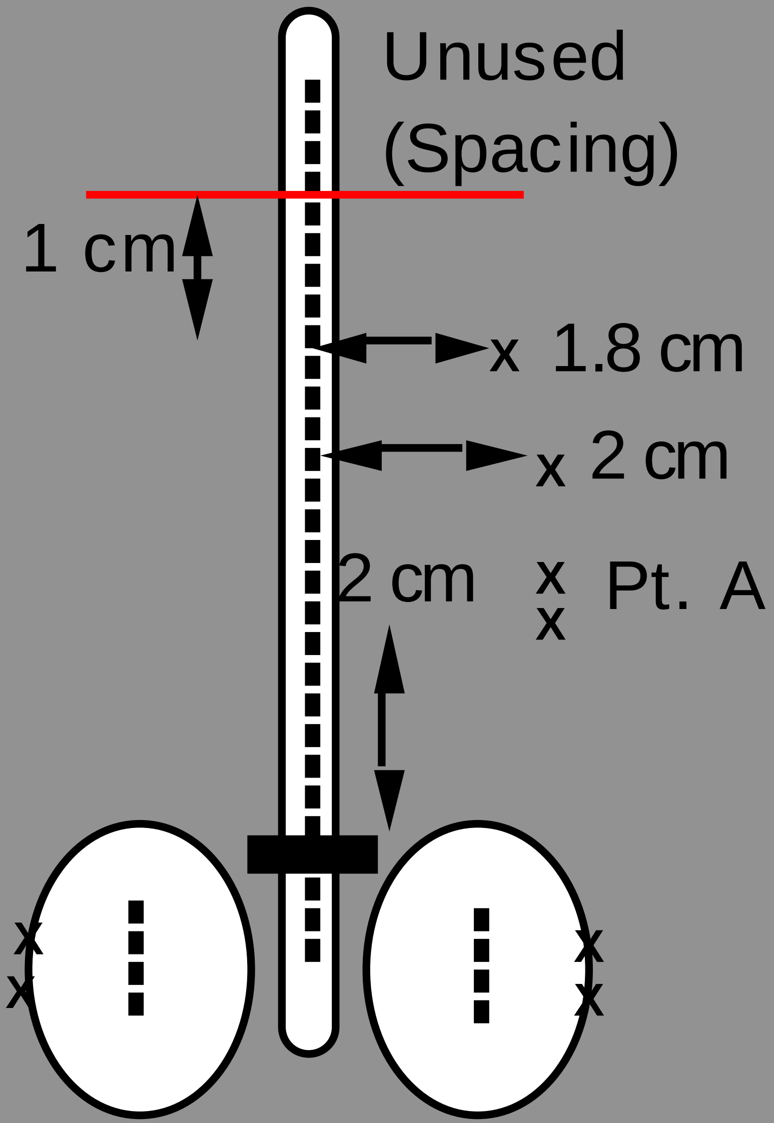
A Sample of Optimization



- Tip dwells to variable for optimization
- Tandem dwell inferior to Pt. A hard to specify
- Need to place points for ovoids

Optimization Scheme

- Specify relative doses to the optimization points (e.g., 100% tandem points, 125% ovoid points with chemo - depends on Pt A Dose)
- Use optimization on dose points,
- Distance optimization.
- Minimize the dwell gradient weighting factor.

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Quality Management

Things to check:

1. Dose specification (right dose - right point)
2. Applicator (right geometry)
3. Dose distribution (right doses - right places)
4. Normal Tissue doses (in tolerance)
5. Correct programming (right source movement - right catheter)
6. But I’ve talked about that before.

Physicist's Worksheet for Tandem and Ovoids

HDR DOSIMETRY CHECK
Treatments Using Tandem and Ovoids
Check in the box indicates parameter is correct.

Date:______________________________ MR#: _______________________________
Patient: ____ Fraction No. _____________ of __________
Disease & Stage: ____________________________________ Dose/Fraction from protocol:___________

1. Location and Dose Checks
____ a. Dose for this fraction on Rx __________ Gy Average dose to applicator points __________ Gy
____ b Difference between right and left A and prescribed dose is less than 5%
____ c Distance of Point A (Starting from midovoid line)
Distance cephalad as defined in Rx ________ mm Distance cephalad on films ________ mm
Distance lateral as defined in Rx ________ mm Distance lateral on printout _______ mm
Distance lateral on coronal plane _______ mm
____ d Ovoid cap sizes
Rt Visible marker ______ Rt size ________ mm Rt Distance to vaginal dose points ________ mm
Lt Visible marker ______ Lt size ________ mm Lt Distance to va ginal dose points ________ mm
____ e Dose percentile to vaginal surface ___________ % of Rx dose = __________ Gy and isodose lines on the plan fall on the vaginal surface
____ f Starting dwell for tandem on plan corresponds to start indicated on film Dwell #:____________
____ g Bladder ____________ Gy (____________%) Rectum _____________ Gy (____________%)
__________ Physician alerted if > 70%

2. Time Checks:
____ a Time index for dwell 1 cm from first dwell Index ________ Posted range ______ to ______
____ b Time index for total time Index ________ Posted range ______ to ______
____ c Total Time Index from previous treatmentIndex ________ Agree within 5%

3. Program Transfer Check
____ a Morning QA length ______________
Rt. ovoid programmed to channel 1 Length for this channel __________
Lt. ovoid programmed to channel 2 Length for this channel __________
Tandem programmed to c hannel 3 Length for this channel __________
____ b Step size ________ 2.5mm ________ 5.0mm
____ c Patient's file has been saved.

4. Programming of the HDR Unit
____ Dwell times, positions, length and step size on print out match that from the computer planning

All the appropriate checks above prove satisfactory

___________________________________ _____________________________ _________________________
Checking Physicist Time Date

Indices Formulae

$$\text{Index 1} = \frac{\text{Dwell time \#5} \times \text{Source strength}}{\text{Dose to Pts M}}$$

$$\text{Index 2} = \frac{\text{Total dwell time} \times \text{Source strength}}{\text{Dose to Pts M} \times \text{Number of dwells}}$$

$$\text{Index 2'} = \frac{\text{Total dwell time} \times \text{Source strength}}{\text{Dose to Pts M} \times \text{Total treatment length}} \times \frac{2.0\ \text{cm}}{\text{dist.}}$$

ABS Recommendations for HDR Cx Brachytherapy: 1

1. Brachytherapy must be included as a component of the definitive radiation therapy for cervical carcinoma.
2. Good applicator placement must be achieved to obtain improved local control, survival and lower morbidity.
3. HDR should be interdigitated with pelvic EBRT to keep the total treatment duration to less than 8 weeks.

ABS Recommendations for HDR Cx Brachytherapy: 2

4. The relative doses given by EBRT versus brachytherapy depend upon the initial volume of disease, the ability to displace the bladder and rectum, the degree of tumor regression during pelvic irradiation, and institutional preference.
5. Interstitial brachytherapy should be considered for patients with disease that cannot be optimally encompassed by intracavitary brachytherapy.