Basic Fundamentals & Tricks of the Trade for Intracavitary Radiotherapy for Cervix Cancer

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Conflicts of Interest

- None to disclose
- Equipment
  - Philips Healthcare, USA
  - Nucletron / Elekta
My Background

• Practicing medical dosimetry for over 28 years.
• Past 21 years have been practicing solely as a brachytherapy dosimetrist.
• Last year our office did 747 brachytherapy procedures.

• My duties include:
  – Source assay
  – Source preparation
  – Treatment planning
  – OR participation
  – Treatment initiation
  – QA
  – Teaching
  – “On call”
  – Other duties as assigned
My Background

- Our group participates in the following brachytherapy implants:
  - GYN (LDR, PDR, HDR)
    - Intracavitary
    - Interstitial
  - Prostate (LDR)
  - H&N (LDR, PDR)
  - Recurrent colorectal (LDR)
  - Ocular Melanoma (LDR)
  - Sarcoma (LDR, PDR, HDR)

- Treatment Planning Systems we use:
  - Oncentra
  - Brachyvision
  - Variseed
  - MIM
Learning Objectives

- Cervix cancer basics.
- Basic concepts of what defines good applicator placement for intracavitary radiotherapy (ICRT) of the cervix.
- Applicator selection.
- Prescription Preference:
  - What about Point A?
- Basic treatment planning.
- Tricks of the Trade
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Cervix Cancer Basics

- Cervix is the lower, narrow end of the uterus.
- Occurs most often in women over 30.
- NCI data for 2013 has 12,340 new cases diagnosed with 4030 deaths in the US.
- Squamous cell carcinoma, which accounts for 80% - 90% of cervix cancer, is caused by HPV (human papilloma virus).
- Adenocarcinoma, second most prevalent cervical cancer, has a lower survival rate than squamous cell carcinoma of the cervix.
Cervix Cancer Basics
Treatment of Cervix Cancer

• Surgery – Stage IA1 – IA2
• Radiation Therapy
  – Brachytherapy alone - Stage IA – IB1
  – EBRT + Brachytherapy – Stage IB2 - IVA
• Chemoradiation – RTOG 90-01
  – Overall survival rate of patients was significantly greater than patients treated with radiation alone (73% v 52% at 5 years)
Cervix Cancer Basics

Treatment of Cervix Cancer with Radiation

• Control of cervical tumors is based on successful integration of EBRT & ICRT

• Uterus & vagina are well suited for placement of applicators & sources centered in the tumor
Cervix Cancer Basics
Treatment of Cervix Cancer
Role of EBRT

- Shrink tumor to improve geometry of ICRT
  - Endocervical tumors to bring them within range of the high-dose portion of the ICRT dose distribution
  - Exophytic tumors distort anatomy & prevent optimal geometry

- Sterilize disease beyond high-dose region of ICRT
  - Paracervical
  - Nodal

Cervix Cancer Basics

Treatment of Cervix Cancer

Role of ICRT

- Integral component of the definitive treatment of cervix cancer.
- Has the ability to selectively deliver high doses to the tumor while minimizing delivered dose to critical pelvic organs – inverse square law.
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Achieving the Best from ICRT

• Source Geometry
  – Dose distribution is relatively even
  – Cervix is covered
  – No areas of overdose or underdose

• Adequate dose
  – Delivered to the most distant point of the tumor – paracervical areas

• Mucosal tolerances
  – Must be respected
Achieving the Best from ICRT Optimized System Geometry

• Requires
  – Optimal applicator placement
  – Yields optimal placement of radioactive material

• Pear-shaped dose distribution
  – ↑ dose to the cervical & paracervical tissues
  – ↓ dose to the bladder & rectum
AP View
Optimized Applicator Placement

✓ Adequacy of placement on film
✓ Ovoids fill vaginal fornices
✓ Ovoids separated just enough to admit tandem
✓ No packing above the ovoids
Lateral View
Optimized Applicator Placement

- Adequacy of placement on film
- Placement in the pelvis
  - Tandem 1/3 between SP & S1 – S2
  - Tandem midway between bladder & S1 – S2
- Ovoids flush with the cervix
- Flange flush with the cervix
- Tandem bisects ovoids
- Adequacy of packing
ICRT for Cervix Cancer
Painful Mistakes

Imaging Trends

Survey of the American Brachytherapy Society 2008

- 55% CT
- 43% Plain Film
- 2% MRI

Three-Dimensional Imaging in Gynecologic Brachytherapy

Applicator Placement

Akila N. Viswanathan, M.D., M.P.H. and Beth A. Erickson, M.D.
Applicator Placement
Patient A
Applicator Placement
Patient B
Applicator Placement
Patient B
Applicator Placement
Patient C
Applicator Placement
Patient D
Three-Dimensional Imaging in Gynecologic Brachytherapy

- If you are using CT / MR imaging, you MUST LOOK
- Where is the tandem?
- Do not place
  - Sources
  - Dwell times
  - Weights
  in a perforating tandem
Applicator Placement

Time Out

- Before you begin planning
- Follow the tandem from cervix through out the entire length of the uterus
Optimized Applicator Placement

Tandem is in the uterus / not perforated
Tandem well placed in uterus
Top of ovoids are at marker seeds in cervix
Optimized Applicator Placement

Tandem fairly bisects ovoids, activity in tandem & ovoids will be centered on the cervix
Optimized Applicator Placement

Critical structures are pushed away from the applicators with packing. The cervix has not been packed away from the applicators.
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• Tricks of the Trade
Basics of Applicator Selection

- **Tandem**
  - Uterine length
  - Distribution of disease in cervix/uterus
  - Uterine position/flexion

- **Vaginal applicators**
  - Size of cervical tumor
  - Vaginal involvement
  - Vaginal capacity
Basics of Applicator Selection

- **Tandem**
  - 3 curvatures or angles
  - $45^\circ$ tandem is most commonly used for uterus 5.5 cm or longer
  - Shorter the uterus the less curvature tandem is used

Fletcher Williamson PDR/HDR Applicators
Basics of Applicator Selection

**Long Uterus**
- 10+ cms in length
- If disease is cervical and not endometrial
- Flange can be set at 7.0 – 7.5 cms
- 45° tandem can be selected

**Short Uterus**
- Cervical stump
- 15° tandem is appropriate

Fletcher Williamson PDR/HDR Applicators
Basics of Applicator Selection

- **Vaginal Applicators**
- Ovoids
- Shielded
- Unshielded
- Selection should be based on size / capacity of vagina

Fletcher Williamson PDR/HDR Applicators
Ovoid Shielding

- ↑ depth dose to the paracervical & parametrial areas
- Does not ↓ dose in the direction of the uterosacral & broad ligaments.
Ovoid Shielding

- Shielding is in the direction of the anterior rectal wall & the bladder trigone.
- ↓ dose to the bladder & rectum.

*Surface dose on Critical Structures
Fletcher-Williamson Ovoids

*Mourtada, et. al., AAPM 2004, Dose calc by Attila
Does Ovoid Shielding Matter?

TG43 (no shields)  TG186 (shields modeled)

Fletcher CT/MR Shielded Applicator, Castle, Mourtada, et al., ABS 2014
Dose Distribution
Does Ovoid Shielding Matter?

- **Rectum**: Mean (Range)
  - D2cc 15% (5-22)
  - D1cc 15% (4-22)
  - D0.1cc 13% (3-22)

- **Bladder**
  - D2cc 6% (3-12)
  - D1cc 6% (3-11)
  - D0.1cc 6% (1-11)

- **Sigmoid**
  - D2cc 2% (1-14)
  - D1cc 2% (1-13)
  - D0.1cc 2% (1-12)

*Fletcher CT/MR Shielded Applicator, Castle, Mourtada, et. al., ABS 2014*
Basics of Applicator Selection

• **Vaginal Cylinders**
  • Use if the vagina is too narrow to accommodate ovoids.
  • Use if there is vaginal disease or vaginal extension of the disease.

Fletcher Williamson PDR/HDR Applicators
Tandem & Rings

- Tandems have fixed lengths
  - 2 cm, 4 cm, 6 cm
- Most uterus measure
  - 6.5 – 7.5 cm
- Fixed geometry can distort anatomy
Tandem & Rings

• Ring
  – Have no shields
  – Similar to mini ovoid
  – Limits amount of activity / time / weight

• Sources are closer to mucosa than in mini ovoids
  – ↑ vaginal surface dose
  – ↓ depth dose
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• Basic treatment planning.
• Tricks of the Trade
Basic Treatment Specification
Prescription Preference

Three-Dimensional Imaging in Gynecologic Brachytherapy

- Despite the high use of CT, Point A remains the most frequent prescription method.

Survey of the American Brachytherapy Society 2008

- 76% Pt A
- 14% CTV
- 7% Pt A & CTV
- 3% Pt A & mg-hrs

Akila N. Viswanathan, M.D., M.P.H. and Beth A. Erickson, M.D.
Prescription Preference

• What about Point A?
The Manchester System
Origin of Point A - 1938

- Definitions / locations based upon detailed studies of the nature & course of Radiation Therapy necrosis.
- In 1938 hypothesis that necrosis was 2nd to damage to the paracervical vessels.
- Led to the definition of the paracervical triangle.
- Definition of Point A as a point of dose limiting tolerance.

Tod and Meredith BJR 11:809, 1938
The Manchester System
1953 modifications

- 1938 definition of Point A was a point 2 cm lateral to the center of the uterine canal & 2 cm from the mucous membrane of the lateral fornix in the axis of the uterus.
- 1953 revision placed vertical origin at the external os instead of the vaginal mucosa.

*Treatment of Cancer of the Cervix Uteri – A Revised Manchester Method; Tod & Meredith, 1953*
### Table 3
A Practical Loading System
(Using standard British G-type radium tubes)

<table>
<thead>
<tr>
<th>Intra-uterine Applicators</th>
<th>Long</th>
<th>Medium</th>
<th>Short (Non-standard)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading mg.</td>
<td>10, 10, 15</td>
<td>10, 15</td>
<td>20</td>
</tr>
<tr>
<td>Type</td>
<td>G2, G2, G3</td>
<td>G2, G3</td>
<td>G4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vaginal Ovoids</th>
<th>Large</th>
<th>Medium</th>
<th>Small</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading mg.</td>
<td>One 5 mg. + Two 10 mg.</td>
<td>One 20 mg.</td>
<td>One 10 mg. + Two 5 mg.</td>
</tr>
<tr>
<td>Type</td>
<td>$1 \times G1 + 2 \times G2$</td>
<td>$G4$</td>
<td>$1 \times G2 + 2 \times G1$</td>
</tr>
<tr>
<td>Equiv. mg.</td>
<td>22.5</td>
<td>20</td>
<td>18</td>
</tr>
</tbody>
</table>

or alternatively:
- Large: One insertion, one 20 mg. (G4) and One insertion, one 25 mg. (G5)
- Small: One insertion, one 20 mg. (G4) and One insertion, one 15 mg. (G3)

Time for 8,000 R at Point A = 140 hours

NOTES:—
1. Range of dose-rate at Point A for standard insertions: 57 R per hr. ± 1.5%.
2. Dose at Point A in 140 hrs. with short intra-uterine applicator and standard ovoids: 7,000 R.
3. Dose at Point A in 140 hrs. if ovoids are in “tandem”: 7,500 R.
Prescription Preference
What About Point A?

• Point A is specifically prohibited by ICRU 38.
• Contemporary use of Point A is not consistent.
• Definition is often based on ease of visualization on imaging.
• Bears no constant relationship to anatomy or applicators.
• Should not be regarded as a target – it was originally considered to represent tolerance.
• Treatment techniques that provide identical doses at Point A can provide drastically different dose distributions.
Treatment should always be prescribed after careful consideration of the following:

- Placement of applicators / source geometry
- Type of applicators used
- Initial tumor extent
- Residual tumor
- Dose to tumor
- Dose to OAR
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Basic Treatment Planning

• Regardless of simulation method employed & dose rate used for treatment you need:
  – Optimized system geometry – applicators correctly placed
  – Adequate packing
  – Weighting / dwell time that produces an optimal dose rate
  – Respect for normal tissue tolerances
Basic Treatment Planning
Distribution of Activity

LDR Loadings – $^{137}$Cs Tubes

- **Tandem**
  - 35 - 40 mgRaeq in 6.0 - 7.5 cms

- **Ovoids**
  - Small 10 – 15 mgRaeq
  - Medium 15 – 20 mgRaeq
  - Mini 5 – 10 mgRaeq

*Eifel*
Basic Treatment Planning Distribution of Activity

PDR – $^{137}$Ir Stepping Source
- Take LDR loading & convert mgRaeq to dwell positions & absolute time.
- Tandem
  - 35 - 40 mgRaeq in 6.0 - 7.5 cms
- Ovoids
  - Small  10 – 15 mgRaeq
  - Medium 15 – 20 mgRaeq
  - Mini    5 – 10 mgRaeq
  - Activate dwells 1-4
Basic Treatment Planning
Distribution of Activity

HDR – $^{137}$Ir Stepping Source

- Based on weights
- Tandem
  - Greatest weights usually in first 2 cm of tandem.
  - Remaining weights in tandem are proportional to greatest weight.
- Ovoids
  - Activate dwells 1-4
Basic Treatment Planning
Distribution of Activity

• Tandem
  – Entire length of the tandem, from the tip to about 0.25 – 0.50 cm above the ovoid caps, is usually activated.
  – Tip of the tandem is often loaded with slightly
    • Higher activity (LDR)
    • Longer dwell times (PDR/ HDR)
    • Greater dwell weight (HDR)
  than the inferior portion of the tandem, where the ovoids contribute to the cervical dose.
Basic Treatment Planning
Distribution of Activity

• Ovoids
  – Activate positions between the shields, usually dwell positions 1 through 4.
  – If no shielding, activate dwell positions 1 through 4.
  – If the tandem is not bisecting the ovoids in the lateral aspect, you can still center the activity in the ovoids, unless it will compromise covering the tumor.
Basic Treatment Planning Optimization

- Optimization of brachytherapy during the treatment planning process will not compensate for poor applicator placement.
- Optimization refers to the sophisticated process of achieving certain dose values at points or volumes within the implant; it is not the simple generation of a standard dose distribution by using fixed dose points located around the applicators.

American Brachytherapy Society consensus guidelines for locally advanced carcinoma of the cervix. Part II: High-dose-rate brachytherapy
Basic Treatment Planning
Volumetric Planning

• Optimization
  – Begin with a customary loading of the full length of the tandem & the vaginal applicator(s)
  – Modify dwell positions & dwell times to reduce the dose to the OAR & ensure maximum tumor coverage
  – An optimal compromise is then reached between the tumor & the OAR goals
Basic Treatment Planning
Volumetric Planning

- Optimization should be performed with caution by observing changes in
  - Dose distribution
  - Dose / volume parameters
  - Spatial dose distribution

- Dose Volume Histograms (DVH)
  - Their exclusive use is not recommended due to potential undesirable changes in spatial dose distribution
Basic Treatment Planning Optimization

Manual

Graphical
Basic Treatment Planning Optimization

Manual

Graphical

<table>
<thead>
<tr>
<th>ROI</th>
<th>Dose [%]</th>
<th>Dose [cGy]</th>
<th>Volume [%]</th>
<th>Volume [ccm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bladder</td>
<td>60.27</td>
<td>27.12</td>
<td>2.65</td>
<td>2.00</td>
</tr>
<tr>
<td>HRCTV</td>
<td>63.18</td>
<td>28.43</td>
<td>90.00</td>
<td>82.43</td>
</tr>
<tr>
<td>Rectum</td>
<td>23.57</td>
<td>10.60</td>
<td>3.64</td>
<td>2.00</td>
</tr>
<tr>
<td>Sigmoid</td>
<td>66.97</td>
<td>30.14</td>
<td>8.71</td>
<td>2.00</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>ROI</th>
<th>Dose [%]</th>
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<th>Volume [%]</th>
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<tr>
<td>Bladder</td>
<td>77.29</td>
<td>34.78</td>
<td>2.65</td>
<td>2.00</td>
</tr>
<tr>
<td>HRCTV</td>
<td>86.20</td>
<td>38.79</td>
<td>90.00</td>
<td>82.43</td>
</tr>
<tr>
<td>Rectum</td>
<td>27.87</td>
<td>12.54</td>
<td>3.64</td>
<td>2.00</td>
</tr>
<tr>
<td>Sigmoid</td>
<td>92.67</td>
<td>41.70</td>
<td>8.71</td>
<td>2.00</td>
</tr>
</tbody>
</table>
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• Tricks of the Trade
Tricks of the Trade

• Rectal Retractor
• Applicator selection
  – Retroverted Uterus
  – Retroflexed Uterus
• Packing
• CT Planning with shielded ovoids
  – O-MAR Filter
  – Finding first dwell position in ovoids
  – Ovoids with moving shields
Tricks of the Trade
Loose the Rectal Retractor

With Rectal Retractor

With Packing
Tricks of the Trade
Applicator Selection

Normal Positioned Uterus

Retroverted Uterus

Retroflexed Uterus
Tricks of the Trade
Applicator Selection

Retroverted Uterus Tandem Selection

- Goal is to bring the uterus into a more anterior position without going through the back of the uterine wall
- A less curved tandem will aid with this task.
Retroflexed Uterus

Tandem Selection

- The uterus will need to be flipped / turned.
- Will lose some of the length of the tandem when uterus is flipped/ turned.
- Set flange a bit “shorter” than uterus measures.
- A less curved tandem may lay more posterior, against the sacrum.
- Use a more curved tandem.
Tricks of the Trade

Packing

Do not pack cephalad
A suture placed in the lip of the cervix can be used to provide counter traction when packing.
A suture placed in the lip of the cervix can be used to provide counter traction when packing.
Tricks of the Trade
CT Planning & Shielded Ovoids

Where is the first dwell position?
CT/Sim therapists
• Decided to employ the O-MAR filter on the GYN intracavitary patients scans

Brachy dosimetrist
• Another approach to locating the first dwell position in shielded ovoids on CT scan
CT/Sim therapists decided to employ the O-MAR filter on our T&O CT scans
O-MAR is short for Metal Artifact Reduction for Orthopedic Implants.

Implements a robust & efficient algorithm to mitigate artifacts caused by metal objects in CT images.

The algorithm works on the raw CT data to reduce streaking & shadowing that occurs in the vicinity of metal objects.

O-MAR is a commercial product available from Philips Healthcare.

_Metal Artifact Reduction for Orthopedic Implants (O-MAR), White Paper, Philips CT Clinical Science, Philips Healthcare, USA_
Tricks of the Trade

1st Dwell Position in Ovoids

- QA image of Fletcher-Williamson mini (unshielded) ovoid
- Mag factor for image was 1.0
- Distance from mini ovoid cap screw to center of 1st dwell position is 16 mm.
Fletcher-Williamson Mini (Unshielded) Ovoids
Tip of Ovoid Cap Screw
Fletcher-Williamson Mini (Unshielded) Ovoids
Ovoid Stem

↓ ovoid cap screw into ovoid tube
First dwell position in mini ovoid is 1.6 cm in posterior direction from ovoid cap screw.
Tricks of the Trade
1st Dwell Position in Ovoids

- QA image of Fletcher-Williamson small (shielded) ovoid.
- Mag factor for image is 1.0
- Distance from small ovoid cap screw to center of 1st dwell position is 16.5 mm.
Fletcher-Williamson Small (Shielded) Ovoids
First Dwell Position

Ovoid Cap Screw

Ovoid Shield
Fletcher-Williamson Small (Shielded) Ovoids
First Dwell Position

Tip of ovoid cap screw
Fletcher-Williamson Small (Shielded) Ovoids
First Dwell Position

↓ ovoid cap screw into ovoid tube
First dwell position in small ovoid is 1.65 cm in posterior direction from ovoid cap screw.
Fletcher-Williamson Small (Shielded) Ovoids
First Dwell Position

Reconstructed patient right ovoid
Fletcher CT/MR Shielded Applicator
Fletcher CT/MR Shielded Applicator

Radiographs

Shields in Anterior (Bladder) Position

Shields in Posterior (Rectal) Position

Shields in Treatment Position
Fletcher CT/MR Shielded Applicator
CT Acquisition

Anterior (Bladder) Position

Poster (Rectal) Position

Treatment Position
Fletcher CT/MR Shielded Applicator
Plain Film Images
Fletcher CT/MR Shielded Applicator
CT Images
Fletcher CT/MR Shielded Applicator
CT Images
Fletcher CT/MR Shielded Applicator
MR T2 cubed
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