A Dosimetric Study Using Split X-Jaw Planning Technique for Treatment of Endometrial Carcinoma

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Disclaimer

• This presentation is not sponsored by any vendor.
Learning Objectives

- Describe the split x-jaw planning technique.
- Develop an understanding of when to apply the split x-jaw technique.
- Identify treatment areas that may benefit from the split x-jaw technique.
- Discuss limitations.

WHAT I LEARNED TODAY

Public Speaking does not necessarily result in hurling, anxiety attacks and death!
Introduction

- The goal of radiation therapy is to deliver the prescribed amount of radiation to a tumor while sparing the normal tissue as much as possible.
- Endometrial cancer can create a huge challenge because of the large planning target volume (PTV) and proximity of organs at risk (OAR)
- IMRT allows for very conformal dose distribution
- VMAT increases the efficiency of radiation delivery
  -- Many field arrangement options with full arcs.

VMAT or RapidArc®

- Advanced form of IMRT that delivers a precisely sculpted 3D dose distribution with a 360 degree rotation of the gantry in a single or multi-arc treatment.
- RapidArc ensures treatment precision which helps to spare surrounding healthy tissue.
- RapidArc consists of two components:
  -- treatment planning
  -- treatment delivery
X-Jaw Limitations

- Mechanical limitation
  - Maximum leaf span of MLC is 15cm.
- Field size ≤ 15cm
  - Anywhere inside the field can be modulated by both sides of the MLC
  - Higher degree of freedom for modulation = better optimization results
- Field size > 15cm
  - Some areas within the field not reached by MLC
  - Prohibits achieving optimal modulation
- Dosimetric effect of different X-jaw widths needs to be investigated further.

In this case, the maximum distance from most retracted to the most extended leaf is 15cm.

Leaves from either carriage can be used to block any portion of the field.
• Leaves will not be able to move completely across the field when the size is larger than 15cm in the X direction.

• Leaf movement is limited and modulation capabilities are severely decreased.

• The larger the field size is increased above 15cm, the less modulation capabilities are possible.

Field Arrangement Definitions

• Limited X-Jaw
• Open X-Jaw
• Split Beam X-Jaw
**Limited X-Jaw**

Field size = 15cm (-7.5cm,7.5cm)

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**Open X-Jaw**

Field size > 15cm
Split Beam X-Jaw

Field size = 15cm

HOW TO SET UP
SPLIT BEAM

Eclipse TPS – Arc
Geometry Tool
Arc Geometry Tool - Eclipse

- Choose the PTV
- Select 1 isocenter with 2 full rotations.
- Enter collimator angle and hit apply.

Arc Geometry Tool - Eclipse

- Highlight fields and enter target margin.
- Check “adjust isocenter while fitting in”
- Click “Fit Collimator to Target”
Arc Geometry Tool - Eclipse

• After adjusting X, Y, and Z values, come back to Arc Geometry Tool
• Uncheck “Adjust isocenter while fitting in”
• Click “Fit Collimator to Target”

Open X-jaw

Field 1
Field 2

• What we see after using Arc Geometry Tool
• X-jaw > 15cm (21cm)
Duplicate Each Field

Field 1

Field 1A

Close X-Jaws

Field 1

Field 1A

- Close the X-jaw on each field in one direction so that the maximum width is 15cm.
Duplicate Each Field

Field 2  Field 2A

Close X-Jaws

Field 2  Field 2A

- Close the X-jaw on each field in one direction so that the maximum width is 15cm.
Retrospective Study

- What is the problem we are trying to research?
  - To improve conformality of plans with PTVs larger than the mechanical limitation of the MLC width (>15 cm) using the split x-jaw technique.

- What would be the purpose of the research?
  - To compare and contrast the conformality of plans using open x-jaw, limited x-jaw, and split x-jaw techniques.
  - Taking into account dose to organs at risk.

- What questions are we trying to answer?
  - Is the split x-jaw technique better than open x-jaw and limited x-jaw in conforming to the PTV?
  - Does the split x-jaw technique limit dose to the organs at risk in comparison to the open x-jaw and limited x-jaw?
  - What are limitations to the split x-jaw technique?

Retrospective Study - Methods

- 20 patients – Endometrial carcinoma
  - PTV requiring x-jaw greater than 19cm
  - Arc Geometry tool
- Target structures – RTOG 0921 protocol
  - Boost plans not included in study
- Immobilization
  - Per department protocol
- Contouring
  - Bladder, rectum, sigmoid, bowel, and right and left femoral heads per RTOG 0921 guidelines.
  - Prior to planning, image datasets were evaluated, and contours were modified on an as needed basis by the planning medical dosimetrist for consistency and correctness.
Treatment Planning

- Eclipse 13.5 TPS
- Prescription - 45Gy in 25 fractions
- 3 VMAT plans for each patient
  - Open, limited, and split x-jaw
- Open and limited techniques – 2 full arcs
  - CW 180° – 179°, CCW 179° –180°, Couch 0°
  - Collimators 15° and 345° respectively – minimize width of x-jaw
- Split x-jaw technique - 4 full arcs
  - (2) CW 180° – 179°, (2) CCW 179° –180°, Couch 0°
  - Collimators 15° and 345° respectively

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Treatment Planning

- Reduce Variability
  - Single dosimetrist completed all 60 plans
  - Equivalent optimization objectives and normalization
    - RTOG 0921 constraints
    - Normalization
      - 100% dose covering 95% PTV
- First Optimization – Base Plan
  - Open x-jaw plan
    - Selected because it has least opportunity for modulation.
  - Optimization objectives applied to limited and split x-jaw plans with no modifications.

<table>
<thead>
<tr>
<th>OAR</th>
<th>LIMIT</th>
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</thead>
<tbody>
<tr>
<td>Bowel $V_{40}$</td>
<td>&lt; 30%</td>
</tr>
<tr>
<td>Rectum $V_{40}$</td>
<td>&lt; 60%</td>
</tr>
<tr>
<td>Bladder $V_{45}$</td>
<td>&lt; 35%</td>
</tr>
<tr>
<td>Femoral heads $V_{35}$</td>
<td>&lt; 15%</td>
</tr>
</tbody>
</table>
Plan Comparison

• Primary evaluation based on conformality and OAR sparing.
  – Conformality determined using Eclipse TPS CI in dose statistics.
    • Defined as the volume encompassed by the prescription isodose region divided by the target volume.
• Secondary evaluation – various parameters
  – Maximum dose
  – Volume of 50%, and 105% isodose regions in cm³
    • Used as measure of plan conformality.

CASE STUDY

Field Arrangement and Isodose Distribution
Plan 1 – Open X-Jaw

Open X-jaw field arrangement. Field X = 19.9cm
Field 1 (X1=-9.8cm, X2=10.1cm), Field 2 (X1=-10.1cm, X2=9.8cm)

Plan 2 – Limited X-Jaw

Limited X-jaw field arrangement. Field X = 15.0cm
Field 1 (X1=-7.5cm, X2=7.5cm), Field 2 (X1=-7.5cm, X2=7.5cm)
Plan 3 – Split Beam X-Jaw

Split X-jaw field arrangement. Field X = 15.0cm
Field 1 (X1=−9.8cm, X2=5.2cm), Field 1A (X1=−4.9cm, X2=10.1cm)

Plan 3 – Split Beam X-Jaw

Split X-jaw field arrangement. Field X = 15.0cm
Field 2 (X1=−10.1cm, X2=4.9cm), Field 2A (X1=−5.2cm, X2=9.8cm)
Plan 1 – Open X-Jaw

Isodose Plan. 100% isodose covers 95% PTV 4500. Max dose = 109.7%.

Plan 2 – Limited X-Jaw

Isodose Plan. 100% isodose covers 95% PTV 4500. Max dose = 110%.
Plan 3 – Split Beam X-Jaw

Isodose Plan. 100% isodose covers 95% PTV 4500. Max dose = 108.3%.

Isodose Comparison
Results - Conformality

- Split x-jaw technique
  - PTV conformality (0.98 ± 0.02)
- Open x-jaw technique
  - PTV conformality (1.01 ± 0.03)
- Limited x-jaw technique
  - PTV conformality (1.04 ± 0.05)

Results – Average Max Dose

Plan Maximum Dose

- Split
- Open
- Limited
The Average max dose to the OAR was the least using the split x-jaw planning method compared to the open and limited techniques.
Results

### Average Volume – 50% Isodose

<table>
<thead>
<tr>
<th>Volume (cm³)</th>
<th>Split</th>
<th>Open</th>
<th>Limited</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,600</td>
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<td></td>
<td></td>
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<tr>
<td>5,650</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5,700</td>
<td></td>
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<td></td>
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<td>5,750</td>
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<tr>
<td>5,950</td>
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<tr>
<td>6,000</td>
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Conclusion

- The Split x-jaw Method
  - reduced the 50% and 105% isodose regions
  - improved plan conformality
  - superior target dose distributions
  - spared OAR more effectively than other techniques
Future Research

- More research comparing three types of X-Jaw arrangements.
  - Larger sample size.
  - Using limited x-jaw or split x-jaw as “base plan.”
  - Large PTVs in abdomen, head & neck, VMAT breast planning, etc.

Filed Arrangement and Isodose Distribution

**BONUS CASE STUDY**

**SIB HEAD AND NECK**
Volumes

Coronal View of PTVs

Volumes

Axial View of PTVs
Volumes

Sagittal View of PTVs

Open X-Jaw

Open X-jaw field arrangement. Field X = 24.6cm
Field 1 (X1=-13.6cm, X2=11.0cm), Field 2 (X1=-11.0cm, X2=13.6cm)
Limited X-Jaw

Field arrangement. Field X = 15.0 cm
Field 1 (X1=-7.5 cm, X2=7.5 cm), Field 2 (X1=-7.5 cm, X2=7.5 cm)

Split Beam X-Jaw

Field arrangement. Field X = 15.0 cm
Field 1 (X1=-4.0 cm, X2=11.0 cm), Field 1A (X1=-13.6 cm, X2=1.4 cm)
**Split Beam X-Jaw**

Split X-jaw field arrangement. Field X = 15.0cm
Field 2 (X1=-11.0cm, X2=4.0cm), Field 2A (X1=-1.4cm, X2=13.6cm)

**Open X-Jaw**

Isodose Plan. 100% isodose covers 95% PTV 7000. Max dose = 111.5%.
Limited X-Jaw

Isodose Plan. 100% isodose covers 95% PTV 7000. Max dose = 111.5%.

Split Beam X-Jaw

Isodose Plan. 100% isodose covers 95% PTV 7000. Max dose = 111.8%.
H&N Case Study

Organs at Risk

- Spinal Cord + 5mm
- Spinal Cord (max)
- Brainstem (max)
- Oral Cav-PTV (mean)
- Oral Cav-PTV (max)

- Rt Parotid (mean)
- Rt Parotid (50%)
- Lt Parotid (mean)
- Lt Parotid (50%)
- Lips (mean)
- Rt Lens (max)
- Lt Lens (max)

Open, Limited, Split

H&N Case Study

Organs at Risk

- Rt Parotid (mean)
- Rt Parotid (50%)
- Lt Parotid (mean)
- Lt Parotid (50%)
- Lips (mean)
- Rt Lens (max)
- Lt Lens (max)

Open, Limited, Split
## Open X Jaw

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less treatment time</td>
<td>More low dose spread</td>
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<tr>
<td></td>
<td>Generally lower OAR sparing</td>
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<tr>
<td></td>
<td>Dose less conformal than other techniques</td>
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<td></td>
<td>Prohibits achieving optimal modulation</td>
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## Limited X-Jaw

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
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</thead>
<tbody>
<tr>
<td>Less treatment time</td>
<td>Lower dose conformality for large target volumes</td>
</tr>
<tr>
<td>Higher degree of freedom for modulation</td>
<td>Difficult to achieve optimal OAR sparing for large target volumes</td>
</tr>
<tr>
<td>Better optimization results</td>
<td></td>
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</tbody>
</table>
Split Beam X-Jaw

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Better dose conformity for large target volumes</td>
<td>Longer treatment times because of more arcs</td>
</tr>
<tr>
<td>Higher degree of freedom for modulation for large target volumes</td>
<td></td>
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<tr>
<td>Better optimization results</td>
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</table>

Things to Consider

- Split beam X-jaw technique has shown to be very effective in treating large target volumes but should be used on a case to case basis.
  - Patient can not tolerate longer treatment times.
- Limited X-jaw technique provides a great alternative when split beam can not be used for large target volumes.
  - Produces clinically treatable plans
- Open X-jaw technique
  - Should be avoided if possible because of lower OAR sparing and inability to achieve optimal modulation.
References


Thank You!

And a special thanks to:

Jade Reihart, CMD
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Marjorie Seidel, CMD
Questions?