IGRT Protocol Design and Informed Margins

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Conflict of Interest

- I have no conflict of interest to disclose

Outline

- Overview and definitions
- Quantification of motion
- Influences on margin selection
- Protocol design
- Marginless planning
Definitions

- ICRU 50 – GTV

The GTV is the gross palpable or visible/demonstrable extent and location of malignant growth.

Definitions

- ICRU 50 – GTV – CTV

The CTV is a tissue volume that contains a demonstrable GTV and/or subclinical microscopic malignant disease, which has to be eliminated. This volume thus has to be treated adequately in order to achieve the aim of therapy, cure or palliation.

Definitions

- ICRU 50 – GTV – CTV – PTV

The PTV is a geometrical concept, defined to select appropriate beam sizes and beam arrangements, taking into consideration the net effect of all the possible geometrical variations, in order to ensure that the prescribed dose is actually absorbed in the CTV.
Definitions

• ICRU 50
  – GTV
  – CTV
  – PTV
• ICRT 62
  – Concepts of GTV, CTV, PTV stayed the same
  – PTV components better defined (internal margin, setup margin, etc.)

What Makes Up A Margin?

• Internal margin compensates for physiologic movements and variations in size, shape, and position of CTV
• Setup margin accounts for uncertainties in patient positioning and alignment
  – Includes positioning, mechanical, and dosimetric uncertainties
Types of Tissue Motion

• When is the motion happening?
  • Interfractional – day to day variations
    – Difference from time of simulation

Types of Tissue Motion

• When is the motion happening?
  • Interfractional – day to day variations
  • Intrafractional – variations during treatment
    – Gradual, sudden, periodic

Quantification of Motion

• Systematic error – an error that will influence all fractions equally
  – An error having non-zero mean
  – Manifests as a shift the cumulative dose distribution relative to the target
• Random error – error caused by factors that vary from one measurement to another
  – Manifests as a blurring of the dose distribution
Systematic and Random Errors

Position

Fraction

Systematic and Random Errors

Position

Mean

Fraction

Systematic and Random Errors

Position

Mean

Standard deviation (SD)

Fraction

**Systematic/Random Errors for a Population**

<table>
<thead>
<tr>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Target 1</th>
<th>Target 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 3</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Trial 4</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Mean</td>
<td>3.2</td>
<td>2.8</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Fig. 1. Estimation of the SD of random and systematic errors based on measurements in a population of patients. The numbers in the table could represent, for example, a shift of the patient in millimeters in the field, the effect determined using the target and measurement, etc. Different combinations of these values give an estimate of the errors for a population of patients.

**Margin Recipes**

**Influences on Margin**

- Systematic/random error quantification paired with established margin recipes can give a good estimate of appropriate margin
- Errors dependent on many factors
Disease Site

- Most obvious and arguably most important
- Different disease sites move differently
- Lung – large, semi-regular cyclical tumor motion\(^1\)
- Prostate – bladder/rectal filling and large, sudden intrafractional motion\(^2\)
- Spine SBRT – mostly rigid, close proximity to critical structures

Immobilization/Motion Management

- Closely linked to disease site
- Motion can be reduced by
  - compression\(^1\), breath hold, gating\(^2\), etc.

Type of Treatment/Dose Distribution

- “Geometrical miss” can be mitigated by a forgiving dose falloff
- Dosimetric effects of dose falloff not as severe for 3D conformal vs. IMRT/SBRT
- Some margin formulas take this into account with beam penumbra parameter


Length of Treatment

- In general, the longer the treatment, the greater chance of something going wrong
- Prostate provides a good example

Correction Strategies

- What is being used and how often?
- Image Guidance
  - Portal imaging, orthogonal kV, CBCT
  - Each imaging modality has inherent accuracy
  - Imaging of surrogate vs. target
- Couch – translational vs. full 6D rotational strategies

Correction Strategies – Prostate Example

<table>
<thead>
<tr>
<th></th>
<th>LR (mm)</th>
<th>AP (mm)</th>
<th>SI (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setup to skin marks</td>
<td>8.2</td>
<td>10.2</td>
<td>12.5</td>
</tr>
<tr>
<td>Initial setup to prostate transponders</td>
<td>1.8</td>
<td>5.8</td>
<td>7.1</td>
</tr>
<tr>
<td>Interbeam adjustments to transponders</td>
<td>1.4</td>
<td>2.3</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Protocol Design

- Each treatment has become increasingly individualized
- Each clinic has own treatment protocols
- Cannot give a prescriptive “one size fits all” recommendation
- Start by setting standards for most common treatments
  - Make this a collaborative effort – involve the Docs!

Protocol Design - Example

- Spine SBRT
  - Generally high dose (18 Gy x 1 fx)
  - High dose falloff
  - Proximity to cord
  - Intent of treatment
  - Well defined/visualized

Protocol Design - Example

- CBCT – correct for rotational errors
  - Resolution alone yields uncertainty of ~1.5mm
- Isocentric alignment ~1mm
- Interfractional motion
  - Mitigate with repeat imaging
  - ~1mm
- Total uncertainty ~2mm
  - Good candidate for asymmetric margin
  - Match to cord

Marginless Planning

- It is possible to do away with PTV margins altogether
- Optimize on the CTV directly
  - Maximize the probability of CTV coverage in the face of various uncertainties

Coverage optimized planning

Coverage optimized planning is based on percentile DVHs (PDVHs):

- \[ \Pr(CTV \text{ D}_{98} > TD) \geq 95\% \]
- \[ \Pr(OAR \text{ D}_{20} < OD) \geq 95\% \]


Conclusions

- Margins are complicated
- Set protocols for your most common procedures
  - Then don’t treat them as absolutes
- Must be catered to individual treatment at hand
Thank You!