Quality Assurance Aspects of Stereotactic Radiosurgery / Fractionated Stereotactic Radiation Therapy

Where to Start? Define Your Program Goals!

Cranial Only?
Benign?

Where to Start? Define Your Program Goals!

AVM?
Conformal Techniques - mMLC
Dynamic Arcs?
IMRT?

Where to Start? Define Your Program Goals!

AVM?
Conformal Techniques - mMLC
Dynamic Arcs?
IMRT?

Where to Start? Define Your Program Goals!

AVM?
Conformal Techniques - mMLC
RotationalAngio?
Dynamic Arcs?
IMRT?

Where to Start? Define Your Program Goals!

Trigeminal Neuralgia?
Circular Collimators
Detectors
Where to Start? Define Your Program Goals!

Frame-based

or Frameless (Image-Guided)

Where to Start? Get the Documentation

AAPM Efforts In Progress
Report 54 (TG 42) – Stereotactic Radiosurgery
TG 68 – Intracranial Stereotactic Positioning Systems
Report 101 (TG 101) – Stereotactic Body Radiotherapy
Report 104 (TG 104) – kV Localization in Therapy
Report 135 (TG 135) – QA for Robotic Radiosurgery

AAPM Efforts In Progress
TG 117 – Use of MRI in Treatment Planning and Stereotactic Procedures
TG 132 – Use of Image Registration and Data Fusion Algorithms and
Techniques in Radiotherapy Treatment Planning
TG 147 – QA for Non-Radiographic Radiotherapy Localization and
Positioning Systems
TG 155 – Small Fields / Non-Equilibrium Condition Photon Beam Dosimetry
TG 178 – Gamma Stereotactic Radiosurgery Dosimetry and QA
TG 179 – QA for Image-Guided Radiation Therapy Utilizing CT-Based
Technologies
TG 194 – Simulation Training for Medical Physicists and Impact on
Procedure Outcome

Where to Start? Get the Documentation

Technical Reference Guide
Revision 1.0

7 Monte Carlo: General Beam Data Measurement

7.1 General Information

7.1.1 Contents of This Chapter

Get the Resources

Other Efforts

Practical Guidelines for the Performance of Stereotactic Radiosurgery

Standards for Quality Control at
Canadian Radiation Treatment Centres
Stereotactic Radiosurgery/Radiotherapy

Quality Assurance for Radiation Therapy: The Challenges
of Advanced Technology Symposium (2007)

Quality Assurance for Radiation Therapy: The Challenges
of Advanced Technology Symposium (2007)

ASTROgram: Tell us what you think: safety considerations for SRT

Get the right equipment

So you will need more staff!!!
How well can you hit your target?
There are many aspects to localization

Align lasers based on W-L test
Everything else (e.g., image guidance) follows
Need to perform daily
Need to perform for cones and MLC
Need to perform after any service

Isocentric Accuracy:
The Winston-Lutz Test

Is the projection of the ball centered within the field?
Good results ≤ 0.5 mm

Can be performed in a variety of ways
But should be clinically relevant

Phantom Specifications:

<table>
<thead>
<tr>
<th>Phantom</th>
<th>AP</th>
<th>LAT</th>
<th>VERT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder</td>
<td>0.0</td>
<td>0.0</td>
<td>30.0</td>
</tr>
<tr>
<td>Cube</td>
<td>20.0</td>
<td>-17.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Cone</td>
<td>-35.0</td>
<td>-20.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Sphere</td>
<td>25.0</td>
<td>20.0</td>
<td>32.7</td>
</tr>
</tbody>
</table>
Assessment of Frame / Coordinate-based System

What About Image Guidance?

Identify target & plan
Image, fuse, and position phantom

Irradiate
Evaluate

Average 3D displacement
1.11 mm ± 0.42 mm

Image Guided End-to-End Assessment

Frame Case

3D error 1.2 ± 0.4 mm

Chang et al. Neurosurgery 2003

3D error 1.1 ± 0.3 mm
Results of Patient Data

<table>
<thead>
<tr>
<th></th>
<th>(mm)</th>
<th>Lat.</th>
<th>Long.</th>
<th>Vert.</th>
<th>3D vector</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single Fraction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>-0.09</td>
<td>0.13</td>
<td>0.23</td>
<td>1.02</td>
<td></td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.67</td>
<td>0.57</td>
<td>0.76</td>
<td>0.59</td>
<td></td>
</tr>
<tr>
<td><strong>Multiple Fraction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.17</td>
<td>0.47</td>
<td>0.17</td>
<td>2.36</td>
<td></td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>1.24</td>
<td>2.11</td>
<td>1.03</td>
<td>1.32</td>
<td></td>
</tr>
</tbody>
</table>

CBCT Localization – Titanium Ball

Hidden Target Evaluation: Titanium Ball – AP EPID Image

Daily QA of IGRT Systems is Essential

Align to Lasers

Assess Laser-kV coincidence
Daily QA of IGRT Systems is Essential

Assess kV-MV coincidence

Beam data acquisition for SRS / SBRT is challenging and time consuming

- Small fields
- Sharp gradients
- Lots of data to acquire

Cone-Direct Measurement
XLow Standard-Pencil Beam
XLow SRS-Pencil Beam
XHigh Standard-Pencil Beam
XLow Standard-Monte Carlo
XLow SRS-Monte Carlo
XHigh Standard-Monte Carlo

How should the data look?

How shouldn't the data look?
How shouldn’t the data look?

- Institution A
- Institution B

6.0% 10.3%

What can you do?

- Compare with Other Institutions / Machines

Off Axis Profiles – Cones

Compare with Other Institutions / Machines

- Novalis Tx

12A
12 UNMC

6X SRS Mode 4.0 mm Collimator

- Institution 1
- Institution 2

6X SRS Mode 6.0 mm Collimator

6X SRS Mode 7.5 mm Collimator

6X SRS Mode 10 mm Collimator

6X SRS Mode 12.5 mm Collimator

6X SRS Mode 15 mm Collimator

Observations of some treatment units: 15 mm collimator

Output Factors – difficult to measure, directly proportional to MU and dose
Are we having trouble? Yes!

U.S. Institution, July, 2010

<table>
<thead>
<tr>
<th>Cone size (mm)</th>
<th>Original Output Factor</th>
<th>Re-measured Output Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
<td>0.312</td>
<td>0.699</td>
</tr>
<tr>
<td>7.5</td>
<td>0.610</td>
<td>0.797</td>
</tr>
<tr>
<td>10.0</td>
<td>0.741</td>
<td>0.835</td>
</tr>
<tr>
<td>12.5</td>
<td>0.823</td>
<td>0.871</td>
</tr>
<tr>
<td>15.0</td>
<td>0.862</td>
<td>0.890</td>
</tr>
<tr>
<td>17.5</td>
<td>0.888</td>
<td>0.904</td>
</tr>
<tr>
<td>20.0</td>
<td>0.903</td>
<td>0.913</td>
</tr>
<tr>
<td>25.0</td>
<td>0.920</td>
<td>0.930</td>
</tr>
<tr>
<td>30.0</td>
<td>0.928</td>
<td>0.940</td>
</tr>
</tbody>
</table>

Million $$$ question: Are the output factors correct?
Compare with Other Institutions / Machines

<table>
<thead>
<tr>
<th>Cone size (mm)</th>
<th>Original Output Factor</th>
<th>Re-measured Output Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
<td>0.6562</td>
<td>0.6500</td>
</tr>
<tr>
<td>6.0</td>
<td>0.7681</td>
<td>0.7639</td>
</tr>
<tr>
<td>7.5</td>
<td>0.8184</td>
<td>0.8169</td>
</tr>
<tr>
<td>10.0</td>
<td>0.8724</td>
<td>0.8704</td>
</tr>
<tr>
<td>12.5</td>
<td>0.9022</td>
<td>0.9003</td>
</tr>
<tr>
<td>15.0</td>
<td>0.9266</td>
<td>0.9216</td>
</tr>
</tbody>
</table>

Circular Cones – Device A

Comparing with Other Institutions

Are the output factors correct?
Compare with Other Institutions / Machines

MLC Fields (XLow)

<table>
<thead>
<tr>
<th>Institution 1</th>
<th>Institution 2</th>
<th>Institution 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cone size (mm)</td>
<td>Original Output Factor</td>
<td>Re-measured Output Factor</td>
</tr>
<tr>
<td>----------------</td>
<td>------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>4.0</td>
<td>0.6562</td>
<td>0.6500</td>
</tr>
<tr>
<td>6.0</td>
<td>0.7681</td>
<td>0.7639</td>
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<tr>
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<td>0.8169</td>
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<tr>
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<tr>
<td>12.5</td>
<td>0.9022</td>
<td>0.9003</td>
</tr>
<tr>
<td>15.0</td>
<td>0.9266</td>
<td>0.9216</td>
</tr>
</tbody>
</table>

Would you have any trouble? Yes!

Circular Cones – Device B

Comparing with Other Institutions

Are the output factors correct?
Compare with Other Institutions / Machines

MLC Fields (XLow)

1 isocenter
2 isocenters
2 isocenters IMRT
4 field box
Dynamic Conformal Arcs

Million $$$ question: Are the output factors correct?
Compare with Other Institutions / Machines

Beam data is good? The job is ~ half complete. Dosimetric commissioning:
Do your calculations agree with measurement?

Start simple: can your TP system reproduce your measured beam data?

Dosimetric commissioning: Do your calculation agree with measurement?

Comprehensive range of energy, dose, technique, etc.
The beam data / treatment planning system look good (so far). What else should I look for?

End-to-End test incorporating both localization and dosimetry

Image-guided dosimetric assessment

Image guided dosimetric assessment
Image guided dosimetric assessment

Use ALL the RPC phantoms!!!

Percent Difference

Track your dosimetric results to look for systematic errors and trends

Are your electronic systems configured correctly?

Patient Specific QA – Dosimetry?????
Wrong site errors are common

Patient Specific QA – Checklists!

Errors in SRS / SBRT

Patient Specific QA – Checklists!
<table>
<thead>
<tr>
<th>Step</th>
<th>Isocenter Operations</th>
<th>Isocenter 1</th>
<th>Isocenter 2</th>
<th>Isocenter 3</th>
<th>Isocenter 4</th>
<th>Isocenter 5</th>
<th>Isocenter 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Arrange sheet and pad on couch.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2.</td>
<td>Set the couch to 0 &amp; coll to 90.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>3.</td>
<td>Take photos of patient (3).</td>
<td>/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4a</td>
<td>Set backup jaws to 4.0 x 4.0cm.</td>
<td>/</td>
<td>/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4b</td>
<td>Install the cone.</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>5.</td>
<td>Position isocenter templates on positioning box.</td>
<td>2 init.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>6.</td>
<td>Enable linac switches 1, 2, and 4.</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>7.</td>
<td>Unlock microadjusters/table locks.</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>8.</td>
<td>Fit ring onto patient head frame.</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Attach large bolts (2) onto ring.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Assist patient onto couch.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>Secure frame to couch mount.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.</td>
<td>Tighten large bolts.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.</td>
<td>Attach small bolts (2) onto ring.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>14.</td>
<td>Secure patient to couch w/ strap.</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.</td>
<td>Attach positioning box to the frame.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.</td>
<td>Position positioning box to the isocenter.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.</td>
<td>Tighten Lat &amp; Long table locks and disable linac switches 1,2,4.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.</td>
<td>Use microadjusters, reposition box to isocenter, lock microadjusters.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>