Technique For Plan Quality and Efficiency Using VMAT Radiosurgery For Patients with Multiple Brain Metastases

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The University of Alabama at Birmingham
Disclosures

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• Kimberly Dempsey, CMD
• Ivan Brezovich, Ph.D.
• ...and countless others.
Outline

• UAB History and program overview

• Future of the program

• Treatment Planning Techniques
UAB History

- April 1992-1st patient in Alabama treated with radiosurgery was at UAB
  - Treated for a primary brain tumor
  - Linear-Accelerator based with modifications done by the medical physics team
  - Instruments and devices were designed and manufactured in a laboratory

1995
- # of patients had increased so rapidly that it was realized that a machine dedicated to CNS treatments was necessary
- Began treating on a Model B Gamma Knife

1999
- By 1999, GK had grown and treated approximately 1000 patients
- By 2004, we had upgraded to the Model C
UAB History

• 2001, RPM
  • 1st center in Alabama to offer the Real-time Position Management (RPM) System

• 2004-Tomotherapy
  • 14th Tomotherapy unit installed in the world
  • 1st installed in Alabama

• 2005
  • 1st in Alabama to treat with stereotactic body radiation therapy (SBRT)
UAB History

• May, 2008-VMAT
  • UAB became 1st institution in US to treat patients with the newly developed Volumetric Arc Therapy (VMAT)
  • UAB physicists were instrumental in the final research stages of development and testing of RapidArc before FDA approval.

• 2010-TruBeam
  • 1 of the 1st in the world, 3rd in the US
  • Flattening Filter Free Beams
  • Highest dose rate available on any linear accelerator
  • Began institutional SBRT protocols
Information

• Outcomes Booklet – Since 2009
  • Designed for a healthcare provider audience
  • Google uabradonc

• “As an institution, we have chosen to develop a multidisciplinary approach to the treatment of patients with complicated tumors requiring stereotactic radiation therapy. Additionally, tumors that were untreatable just a few years ago, can now be treated successfully with SRS and SBRT.”
  - James Bonner, Chairman of UAB Radiation Oncology, 2009.

• Radiation Oncologists, Surgeons, Medical Physicists and Dosimetrists
Gamma Knife vs. Linac-Based Radiosurgery
Gamma Knife

- Noninvasive
- Length of procedure and set up
- Helmet
- Length of treatment

![Gamma Knife Diagram](image_url)
Gamma Knife

Cobalt-60

FDA Regulations
Linac-Based Radiosurgery

- Noninvasive
- Length of procedure and set up
- Face mask
- Length of treatment
SRS/SBRT Simulation

Isocenter

Center of PTV

23.4 cm
Linac SRS Growth

Radiosurgery Cases Radiation Oncology

<table>
<thead>
<tr>
<th>Year</th>
<th>HSROC - SBRT</th>
<th>HSROC - SRS</th>
<th>Highlands - Gamma Knife</th>
<th>Total Radio Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY 2013</td>
<td>124</td>
<td>35</td>
<td>174</td>
<td>333</td>
</tr>
<tr>
<td>FY 2014</td>
<td>150</td>
<td>39</td>
<td>173</td>
<td>362</td>
</tr>
<tr>
<td>Ann FY 2015</td>
<td>152</td>
<td>102</td>
<td>102</td>
<td>356</td>
</tr>
</tbody>
</table>
Linac-Based Radiosurgery

• Specialized Dosimetrist for Treatment Planning

When I grow up, I want to be a Medical Dosimetrist!

• Specialized Physicists When Implementing New Procedures
The Future

2016

Edge Radiosurgery System, Varian Medical Systems
Edge
“Treatment as sharp as a scalpel”

• Speed, precision and streamlined treatment planning.
• SRS is progressing to include targets never thought possible just a few years ago.
• Accurate delivery and motion management are the two of the top reasons why Radiosurgery numbers continue to increase.
• According to information on Varian.com, over the next 10 years:
  • SRS utilization for brain cancer treatments is predicted to increase 108%
  • SRS treatment volume is expected to grow 93%
  • SBRT volume is expected to grow 144%
Edge

- 6- Degree of Freedom (6dof) Couch
- 2400MU/min Dose Rate
- Motion Management
- Sub-Millimeter Accuracy
  - Calibrated to perform accuracy checks every 10 milliseconds
  - Extra-fine 2.5mm MLC leaves
- Decrease in Procedure Time
  - Standard treatment time slot
Technology has come a long way!
TrueBeam SRS - evolution of number of treated targets

15 mets, Rx = 18 Gy, GTVtotal = 2cc

Rationale for changing

• Brain Radiation: The Treatment is Worse Than the Illness, Study Finds - NBC News
Planning Techniques
Goals

• Provide instruction for producing a high quality single isocenter VMAT radiosurgery plan for patients with multiple brain metastases

• Demonstrate how to use plan information to evaluate plan quality
Technical Aspects
TrueBeam STx

- TrueBeam allows for the ability to use a 10MV flattening filter free (FFF) beam that has a dose rate of 2400 monitor units per minute.
- Varian HD-120 multileaf collimator (MLC)
- 6 Degrees Of Freedom Couch
- Jaw Tracking
Flattening filters were originally incorporated into the beam of linear accelerators in order to increase dose homogeneity. Achieving a homogeneous plan is not the goal in stereotactic planning.

Benefits of FFF

- Decreased treatment time due to 2400 MU/min dose rate
  - Increase efficiency and decrease the length patient time slots
  - Reduce the probability of intrafraction motion

- Decreased Scatter
  - The flattening filter is a major source of scatter, so removing it from the beam can greatly reduce the dose outside of the field.
10X FFF COMPARED TO 10X FLATTENED BEAM
Planning

- Planning CT scan with slice spacing of 1mm
- Thermoplastic mask for immobilization
- T1-weighted, post-contrast MR imaging
What is the goal of the plan?

Conformity

VS.

Organ Avoidance
What is the goal of the plan?

Conformity
What is the goal of the plan?

Organ Avoidance
Plan quality and treatment planning technique for single isocenter cranial radiosurgery with volumetric modulated arc therapy

Grant M. Clark MD, Richard A. Popple PhD, Brendan M. Prendergast MD, Sharon A. Spencer MD, Evan M. Thomas MS, John G. Stewart MD, Barton L. Guthrie MD, James M. Markert MD, John B. Fiveash MD.

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Conclusions

The results of this report show that the single isocenter VMAT radiosurgery technique for the treatment of 1 or more brain metastases produces plans of high clinical quality, including favorable values for both conformity and dose gradient indices. We have outlined a practical, systematic approach that treatment planners may utilize when creating plans using this treatment platform. Given the high plan quality and extreme clinical efficiency, single isocenter VMAT approaches will continue to become more prevalent for linac-based radiosurgical treatment of 1 or more intracranial targets.
Steps for Treatment Planning
Evaluate Planning Targets

- Measure Volume for Each Target
Evaluate Planning Targets

Are any of the targets smaller than 3cm³? If so, set the calculation grid size to 0.1CM
Create GTV_total

Using the Boolean Operator function, combine all of the targets into one structure. This will help in determining collimator angle and field size.
Conformity

The UAB “recipe” calls for concentric rings around each target in order to achieve conformity.

• Inner Control---edge of GTV_total; outer surface = 5 mm from GTV-total
• Middle Control---inner surface = 5 mm from GTV_total; outer surface = 10 mm from GTV_total
• Outer Control---inner surface = 10 mm from GTV_total; outer surface = 30 mm from GTV_total

***Control structure size may have to be adjusted when treating smaller targets.
Control Structures

• Using the add margin tool in contouring, add 3 new structures-
  • _INNER CONTROL
  • _MIDDLE CONTROL
  • _OUTER CONTROL
From INNER CONTROL
+10mm
MIDDLE CONTROL

From MIDDLE CONTROL
+30mm
OUTER CONTROL

GTV
GTV+5mm
INNER CONTROL

GTV
Thoughts to Consider........

• Targets of varying size

Small Targets (ex. 2cm³)
  • 0.4cm for Inner Control
  • 0.8cm for Middle Control
  • 2.5cm for Outer Control

• Different prescription dose levels
ISOCENTER LOCATION

• A single isocenter is visually placed at the geometric center of the targets.
• Easily determined by looking at an orthogonal view
TREATMENT BEAM ARRANGEMENT

- The beam arrangement should include two arcs, one axial and one vertex or non-coplanar arc.
- As the number of targets increases, additional beams may need to be added.
Once the treatment beams have been added, right click on each field and add a New MLC. This will help to set the appropriate field size for treatment.
• Using the Fit to Structure tool, fit the MLC to the “GTV_TOTAL” structure that was created.

• Use a margin of 0.3cm around each target.

• Check the optimize collimator jaws box. This will choose the correct field size that is needed for treatment.
COLLIMATOR ANGLE SELECTION

Island Blocking

- This is a frequent occurrence for single isocenter treatments, but may not always have dosimetric or clinical consequences.

- In some cases, the collimator can be rotated in order to avoid island blocking.

- For more difficult cases where targets are spaced closely together, or where organs-at-risk are located between targets, optimizing the collimator angle to eliminate or minimize island blocking could improve the quality of the plan.

- For more details, see:
  - Kang (Hopkins); Med Physics; 37: 4146-4154
Optimization Objectives

- Each target=lower objective with 102% of the RX dose at 100% priority
- Inner Control=upper objective with 98% of the RX dose at 150% priority
- Middle Control=upper objective with 50% of the RX dose at 100% priority
- Outer Control=upper objective with 40% of the RX dose at 100% priority
- Include the BRAIN-GTV in the cost function.

Do not check NTO
Observe Optimization process.
Evaluate DVH

Normalize the plan according to the GTV that is the least covered so that 100% of the dose covers 99% of the target volume.
The plan will be HOT!
Plan Quality
Evaluating Plan Quality

- Conformity Index
- Gradient Index
- Dose Bridging
- Mean Dose for Normal Brain
Conformity Index <1.5

Conformity index is calculated as follows:

Volume of Body at 100% of RX dose
Volume of GTV_TOTAL at 100% RX dose

Example calculation:

\[
\frac{12.54\text{cc}}{11.43\text{cc}} = \text{CI of 1.097}
\]

A perfectly conformal plan would have a CI of 1. Also, you can calculate conformity for individual targets.
Gradient Index

Range for Gradient Index is 3-5

Gradient index is defined as follows:

**Volume of Body at 50% RX dose**

**Volume of target at 50% RX dose**

50% line

Same Conformity Index
Different Gradient Index
Dose Bridging

- Try to avoid dose bridging between targets at the 50% line
- Sometimes can be avoided by adding an avoidance structure and penalizing that structure in the optimization objectives
Normal Brain Dose

• Single fraction is 2Gy-3Gy
• Hypofractionated is 6Gy
• As the number of targets and target size increases, achieving this goal may become difficult.
### Single Fraction (radiosurgery)

<table>
<thead>
<tr>
<th>Organ</th>
<th>Constraint</th>
<th>Priority*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td>V12 Gy &lt; 5 cc or V10 Gy &lt; 10cc¹⁴⁴</td>
<td>I</td>
</tr>
<tr>
<td>Brain stem</td>
<td>Max dose 12.5 Gy¹</td>
<td>I</td>
</tr>
<tr>
<td>Chiasm/optic nerve</td>
<td>Max dose 10 Gy (point dose: 12 Gy)¹</td>
<td>I</td>
</tr>
<tr>
<td>Cochlea</td>
<td>Max dose 14 Gy¹</td>
<td>II</td>
</tr>
<tr>
<td>Lens</td>
<td>Max dose 3 Gy²</td>
<td>II</td>
</tr>
<tr>
<td>Retina</td>
<td>Max dose 5 Gy (Dr. Fivash: 8 Gy?)²</td>
<td>II</td>
</tr>
<tr>
<td>Spinal cord</td>
<td>Max dose 13 Gy¹</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>V10 Gy &lt; 0.5 cc³ (RTOG 0631: V10 &lt; 0.35 cc)⁴</td>
<td>I</td>
</tr>
<tr>
<td>Cauda equine</td>
<td>Max dose 16 Gy***</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>V14 Gy &lt; 5 cc⁴</td>
<td>I</td>
</tr>
<tr>
<td>Sacral plexus</td>
<td>Max dose 18 Gy***</td>
<td>II</td>
</tr>
<tr>
<td></td>
<td>V14.4 Gy &lt; 5 cc⁴</td>
<td>II</td>
</tr>
</tbody>
</table>

* I = Do not violate. Achieving constraint is more important than target coverage.
** II = Planning goal, but less important than target coverage.
### Hypofractionated CNS Radiosurgery

<table>
<thead>
<tr>
<th>Organ</th>
<th>Constraint</th>
<th>Priority*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Brain</strong></td>
<td>5 fractions: Max dose 20 Gy&lt;sup&gt;1&lt;/sup&gt;</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>3 fractions: Max dose 23 Gy, V18 Gy &lt; 1 cc&lt;sup&gt;2&lt;/sup&gt;</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>5 fractions: Max dose 31 Gy, V26 Gy &lt; 1 cc&lt;sup&gt;2&lt;/sup&gt;</td>
<td>I</td>
</tr>
<tr>
<td><strong>Brain stem</strong></td>
<td>3 fractions: Max dose 19.5 Gy, V15 Gy &lt; 0.2 cc&lt;sup&gt;2&lt;/sup&gt;</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>5 fractions: Max dose 25 Gy, V20 Gy &lt; 0.2 cc&lt;sup&gt;2&lt;/sup&gt;</td>
<td>I</td>
</tr>
<tr>
<td><strong>Chiasm/optic nerve</strong></td>
<td>3 fractions: Max dose 20 Gy&lt;sup&gt;2&lt;/sup&gt;</td>
<td>II</td>
</tr>
<tr>
<td></td>
<td>5 fractions: Max dose 27.5 Gy&lt;sup&gt;2&lt;/sup&gt;</td>
<td>II</td>
</tr>
<tr>
<td><strong>Cochlea</strong></td>
<td>Max dose 3-7 Gy (no solid data)</td>
<td>II</td>
</tr>
<tr>
<td><strong>Lens</strong></td>
<td>Max dose 5-15 Gy (no solid data)</td>
<td>II</td>
</tr>
<tr>
<td><strong>Retina</strong></td>
<td>Max dose 5-15 Gy (no solid data)</td>
<td>II</td>
</tr>
<tr>
<td><strong>Spinal cord</strong></td>
<td>3 fractions: Max dose 18-20 Gy&lt;sup&gt;2&lt;/sup&gt;</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>4 fractions: Max dose 26 Gy, V20.8 &lt; 0.35 cc&lt;sup&gt;2&lt;/sup&gt;</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>5 fractions: Max dose 30 Gy, V22.5 &lt; 0.25 cc&lt;sup&gt;2&lt;/sup&gt;</td>
<td>I</td>
</tr>
<tr>
<td><strong>Cauda equina</strong></td>
<td>3 fractions: Max dose 24 Gy, V21.9 &lt; 5 cc&lt;sup&gt;2&lt;/sup&gt;</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>5 fractions: Max dose 34 Gy, V30 &lt; 5 cc&lt;sup&gt;2&lt;/sup&gt;</td>
<td>I</td>
</tr>
</tbody>
</table>

* I = Do not violate. Achieving constraint is more important than target coverage.
* II = Planning goal, but less important than target coverage.
Physics QA

Graph 1: Dose (%) vs. y (mm)
- Blue line: Film
- Red line: Calculation

Graph 2: Heat map (x vs. y)
- Color scale: 0 to 150
- Heat patterns indicate dose distribution
Case Study

- 75 year old male
- Cystoprostatectomy in 2011 after presenting with hematuria and urgency
- Followed without recurrence until seizure
- 30Gy in 5 fractions
- Conformity index of 1.1
- Gradient index of 3.3
- Mean normal brain dose is 2.8Gy
Case Study

- 72 year old female
- History of metastatic melanoma
- Presented to oncology with headache
- 30Gy in 5 fractions
- Conformity Index of 1.1
- Gradient Index of 4.4
- Mean normal brain dose of 3.2Gy
A modified version of the UAB recipe can be used to treat additional sites within the body.

SBRT for Liver
SBRT for Lung
SBRT for Spine

We are currently beginning protocols through RTOG for prostate SBRT.
Thank You!

The UAB Department of Radiation Oncology has partnered with Varian to develop a three day conference that discusses and demonstrates stereotactic radiation (SRS) and stereotactic body radiation (SBRT) delivery with Eclipse™ and TrueBeam™. For more information regarding attending this course, please visit: uab.edu/radonc
Questions?