Radiosurgery of multiple targets using single isocenter VMAT

Richard Popple
Disclosures

• Research support from Varian Medical Systems
• Intellectual property licensed to Varian Medical Systems through UAB
• Product evaluation agreements with Standard Imaging and Sun Nuclear
Outline

• Plan quality
  • Conformality
  • Gradient index
  • Low dose spill to normal brain

• Treatment planning
  • Planning techniques
  • Semi-automated planning
  • Comparison to multiple isocenters

• Rotational uncertainty

• QA
  • Mechanical
  • Patient specific

• Treatment delivery efficiency

• Clinical Outcomes
FEASIBILITY OF SINGLE-ISOCENTER VOLUMETRIC MODULATED ARC RADIOSURGERY FOR TREATMENT OF MULTIPLE BRAIN METASTASES

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Purpose: To evaluate the relative plan quality of single-isocenter vs. multi-isocenter volumetric modulated arc therapy (VMAT) for radiosurgical treatment of multiple central nervous system metastases.

Methods and Materials: VMAT plans were created using RapidArc technology for treatment of simulated patients with three brain metastases. The plans consisted of single-arc/single-isocenter, triple-arc (noncoplanar)/single-isocenter, and triple-arc (coplanar)/triple-isocenter configurations. All VMAT plans were normalized to deliver 100% of the 20-Gy prescription dose to all lesions. The plans were evaluated by calculation of Paddock and Radiation Therapy Oncology Group conformity index scores, Paddock gradient index scores, and 12-Gy isodose volumes.

Results: All plans were judged clinically acceptable, but differences were observed in the dosimetric parameters, with the use of multiple noncoplanar arcs showing small improvements in the conformity indexes compared with the single-arc/single-isocenter and triple-arc (coplanar)/triple-isocenter plans. Multiple arc plans (triple-arc [non-coplanar]/single-isocenter and triple-arc [coplanar]/triple-isocenter) showed smaller 12-Gy isodose volumes in scenarios involving three metastases spaced closely together, with only small differences noted among all plans involving lesions spaced further apart.

Conclusion: Our initial results suggest that single-isocenter VMAT plans can be used to deliver conformity equivalent to that of multiple isocenter VMAT techniques. For targets that are closely spaced, multiple noncoplanar single-isocenter arcs might be required. VMAT radiosurgery for multiple targets using a single isocenter can be efficiently delivered, requiring less than one-half the beam time required for multiple isocenter set ups. VMAT radiosurgery will likely replace multi-isocenter techniques for linear accelerator-based treatment of multiple targets. © 2010 Elsevier Inc.

Brain, metastases, volumetric modulated arc therapy, VMAT, radiosurgery, RapidArc.
INITIAL EXPERIENCE WITH VOLUMETRIC IMRT (RAPIDARC) FOR INTRACRANIAL STEREOTACTIC RADIOSURGERY

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Purpose: Initial experience with delivering frameless stereotactic radiotherapy (SRT) using volumetric intensity-modulated radiation therapy (IMRT) delivered with RapidArc is presented.
Methods and Materials: Treatment details for 12 patients (14 targets) with a mean clinical target volume (CTV) of 12.8 ± 4.0 cm³ were examined. Dosimetric indices for conformity, homogeneity, and dose gradient were calculated and compared with published results for other frameless, intracranial SRT techniques, including CyberKnife, TomoTherapy, and static-beam IMRT. Statistics on setup and treatment times and per patient dose validations were examined.
Results: Dose indices compared favorably with other techniques. Mean conformity, gradient, and homogeneity index values were 1.10 ± 0.11, 64.9 ± 14.1, 1.083 ± 0.026, respectively. Median treatment times were 4.8 ± 1.7 min.
Conclusion: SRT using volumetric IMRT is a viable alternative to other techniques and enables short treatment times. This is anticipated to have a positive impact on radiobiological effect and for facilitating wider use of SRT. © 2010 Elsevier Inc.

RapidArc, Radiosurgery, Treatment time.
Intensity-modulated radiosurgery with rapidarc for multiple brain metastases and comparison with static approach

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ABSTRACT

Rotational RapidArc (RA) and static intensity-modulated radiosurgery (IMRS) have been used for brain radiosurgery. This study compares the 2 techniques from beam delivery parameters and dosimetry aspects for multiple brain metastases. Twelve patients with 2–12 brain lesions treated with IMRS were replanned using RA. For each patient, an optimal 2-arc RA plan from several trials was chosen for comparison with IMRS. Homogeneity, conformity, and gradient indexes have been calculated. The mean dose to normal brain and maximal dose to other critical organs were evaluated. It was found that monitor unit (MU) reduction by RA is more pronounced for cases with larger number of brain lesions. The MU-ratio of RA and IMRS is reduced from 104% to 39% when lesions increase from 2 to 12. The dose homogeneities are comparable in both techniques and the conformity and gradient indexes and critical organ doses are higher in RA. Treatment time is greatly reduced by RA in intracranial radiosurgery, because RA uses fewer MUs, fewer beams, and fewer couch angles.

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Efficiency vs Static Beams
Plan evaluation – multiple targets
Plan evaluation – multiple targets
Plan evaluation – multiple targets
Plan evaluation

- TV = target volume
- PIV = prescription isodose volume
- V50% = volume receiving at least 50% of the prescription dose
Plan evaluation – multiple targets

- Composite RTOG conformity index = PIV / ΣTV
  - 1.1 for case shown
Plan evaluation – multiple targets

- Composite Paddick gradient index = V50% / PIV
  - 18.5 for case shown
- Composite indices do not account for different prescriptions
Plan evaluation – multiple targets

• Individual conformity and gradient indices requires constructing a shell around each target

• Shell must enclose the “local” 50% isodose volume
  • Targets in close proximity might be enclosed by a common 50% isodose volume – “bridging”
Plan evaluation – multiple targets

• Target shown
  • RTOG conformity index 1.9
  • Paddick gradient index 13.2
Plan evaluation – multiple targets

- Computing individual indices is tedious
- Use composite indices
- Review individual target DVHs
- Inspect 50% isodose volume
Plan evaluation – multiple targets

- Some planning systems provide target specific metrics

<table>
<thead>
<tr>
<th>Show DVH</th>
<th>Structure</th>
<th>Dose Level [cGy]</th>
<th>RTOG CI</th>
<th>Paddick CI</th>
<th>GI</th>
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</table>
Plan evaluation – V12Gy

• V12Gy has been found to correlate with radionecrosis
Plan evaluation – V12

• V12-based models of toxicity are based on single target treatments.

• Radiation necrosis estimates from V12 for multiple lesions should not be extrapolated from single target models.
Plan evaluation – Mean brain dose
Plan quality and treatment planning technique for single isocenter cranial radiosurgery with volumetric modulated arc therapy

Island blocking

- Collimator angle and table angle optimization (Kang (Hopkins); Med Physics; 37: 4146-4154)
- Include dose to normal brain in objective function
- Multiple arcs limiting MLCs to individual tumors
“To reduce low dose spill into normal brain for single isocenter VMAT radiosurgery of multiple targets, it is important to incorporate a limit on low dose spill into the objective function.”

Semi-automated planning - HyperArc

• No ring structures → SRS specific normal tissue objective
• Simplified planning workflow
• Field geometry template designed to meet planning goals for nearly all cases
• Reduction in SRS treatment planning time
• Systematic SRS treatment planning results
Multimets Element (MME) Plan: Pre-templated arc geometry

Courtesy Haisong Liu, Ph.D., Thomas Jefferson University
“Conformity was more favorable in multiarc VMAT plans than GK.”


**FIGURE 3.** Distributions of V4.5, V9, V12, and V18 levels for Gamma Knife and multiarc VMAT. VMAT, volumetric modulated arc therapy.

**FIGURE 4.** Distribution of mean brain doses for Gamma Knife and multiarc VMAT. VMAT, volumetric modulated arc therapy.
Managing rotational error

Roper et al, IJROBP 2015;93(3):540-6
Managing rotational error

- Single isocenter treatment requires rotational error correction
### Table VI. Imaging.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Application-type tolerance</th>
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<tr>
<td></td>
<td>non-SRS/SBRT</td>
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<tr>
<td></td>
<td>Functional</td>
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<tr>
<td>Daily&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td><strong>Planar kV and MV (EPID) imaging</strong></td>
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<tr>
<td>Positioning/repositioning</td>
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<td>Imaging and treatment coordinate coincidence (single gantry angle)</td>
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<tr>
<td>Positioning/repositioning</td>
<td>(\leq 1 \text{ mm})</td>
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Patient-specific QA – Radiochromic film

![Histogram showing film-to-plan ratio distribution with a mean of 1.011 (n=487).]
Patient-specific QA – Radiochromic film

Mean = 0.31 mm
Median = 0.28 mm
95% < 0.64 mm
Patient-specific QA

• More commercial tools are becoming available
• Plastic scintillator detector
• 2D diode array
• Others...
Treatment time

First image to beam-off

Median = 10.8 min

Beam-on to beam-off

Median = 3.2 min
Fast Treatment Decreases Intrafraction Motion


Carminucci et al, J Neurosurg (Suppl) 129:133–139, 2018
Local Tumor Control is Independent of Distance from Isocenter

- 532 tumors single fraction SRS
- Frameless
- No margins
- Single Isocenter

Marcrom et al, ASTRO 2018, abstract MO_8_267
Thanks

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