RapidArc and Novalis Tx Radiotherapy Technology: Clinical Implications for SRS/SBRT and IGRT

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Phoenix, Arizona
>3000 SRS and >2500 SBRT treatments

- 1997 Peacock/Varian/Corvus IMRT program
  - 1997 Gamma Knife program
  - 2003 CyberKnife program
  - 2003 Novalis BrainLab program
  - 2006 Tomotherapy program
  - 2006 Varian Trilogy program
  - 2009 Elekta Axesse program
  - 2009 Novalis Tx with RapidArc program
RapidArc & Novalis-Tx SRS/SBRT: Agenda

1. Definition and requirements of Radiosurgery (SRS and SBRT) compared to conventional fractionated radiotherapy (XRT)
2. Introduction of Novalis-Tx® Robotic Radiosurgery System with RapidArc
3. Literature overview: SRS/SBRT & RapidArc SRS/SBRT
4. Clinical applications:
   1. Lung SBRT as a Model
   2. Spine/paraspinal IGRT
   3. Liver SBRT
   4. Brain SRS
   5. Skull base and H&N SBRT
5. Summary and Conclusions
Conventional Radiotherapy (XRT)

- Treat tumor and margin of normal tissue in order to:
  - Encompass microscopic invasion
  - Account for tumor, organ, and patient movement.
  - Treat draining lymphatics at highest risk for harboring micro-metastatic disease.

- Radiobiological differences between tumor and normal tissue are exploited to maximize therapeutic ratio.

- Fractionation spares normal tissues.
Conventional Radiotherapy (XRT)

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- Radiobiological differences between tumor and normal tissue are exploited to maximize therapeutic ratio.

- Fractionation spares normal tissues.
Limitations of Fractionated XRT

The curative and palliative abilities of standard fractionated XRT are limited for many tumors due to:

- Dose-limiting early, but fully repairable, toxicity
  - Mucositis, pneumonitis, dermatitis, enteritis, etc.
- Insufficient therapeutic ratio for late effects in some tissues.
- Inconvenience & expense of protracted treatment courses.
Radiosurgery (SRS/SBRT)

Large Doses / Few Fractions = Radiation Ablation

• Use 1-5 large fractions to get more tumor cell kill (ablation) and potentially induce apoptosis of tumor neovasculature.

• Use equipment & physics (not biology) to get a therapeutic advantage by excluding normal tissue from high-dose region.
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- Use equipment & physics (not biology) to get a therapeutic advantage by excluding normal tissue from high-dose region.
## Conventional XRT vs SBRT: Summary

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Conventional XRT</th>
<th>SBRT / SRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose / Fraction</td>
<td>1.8 – 3 Gy</td>
<td>5 – 45 Gy*</td>
</tr>
<tr>
<td># Fractions</td>
<td>10 – 40+</td>
<td>1 – 5</td>
</tr>
<tr>
<td>Target Definition</td>
<td>CTV / PTV</td>
<td>GTV</td>
</tr>
<tr>
<td>Margin</td>
<td>Centimeters</td>
<td>Millimeters</td>
</tr>
<tr>
<td>Physics-Dosimetry Check</td>
<td>Indirect</td>
<td>Direct</td>
</tr>
<tr>
<td>Required Setup Accuracy</td>
<td>TG40 – conventional</td>
<td>TG40 – SRS</td>
</tr>
<tr>
<td>Treatment Accuracy &amp; Tracking</td>
<td>3-point laser positioning Port films</td>
<td>Intrafraction stereo imaging Optical arrays / head frames</td>
</tr>
</tbody>
</table>

Not all combinations are valid – e.g. 30 Gy x 5 is not a recognized treatment. Extracranial may be in the high range of 60 Gy (20 Gy x 3) range, for NSCLC for example. Certain specialized intracranial functional treatments, trigeminal neuralgia for example, are treated in the 100 Gy range.
SBRT for Primary Tumors: Patient Selection

• Curative-intent treatment of primary malignancies
  – Small (<3-5cm)
  – Low probability of regional or distant spread at diagnosis
  – Located in or near relatively radiation-tolerant organs

• Current Indications:
  – Medically inoperable non-small cell lung cancer

• Potential Future Indications:
  – Medically operable non-small cell lung cancer
  – Medically inoperable renal cell cancer
  – Early-stage prostate cancer
  – Unresectable hepatoma
SBRT for metastatic disease should follow same general guidelines as indications for surgical metastasectomy:

- Controlled primary
- Limited metastatic disease either at presentation (synchronous or metachronous)
- Radiation + chemo-resistant histologies:
  - colorectal, sarcoma, RCC, melanoma
- Good performance status
- If intent is to improve survival, all gross metastatic disease should be treatable
Requirements for SBRT

• Ablation so small margins required to minimize normal tissue damage

• Accurate identification of tumor target necessary
  – Integration of treatment planning with advanced diagnostic radiology techniques, (MRI, PET/CT, gated CT, etc.)
  – If the tumor can’t be well defined with imaging, treat with fractionated XRT

• Conformation of the radiation dose to the contoured target

• Confirmation of accurate targeting of tumor on radiosurgery machine needed before treatment
  – Stereotaxis with orthogonal kV imaging
  – On-Board Image Guidance (CT, fluoroscopy of implanted fiducials)

• Strict control of patient and organ motion required during SBRT delivery
  – Immobilization system, compression
  – Respiratory movement compensation, tracking, breath-hold or gating
IMRT vs RapidArc Technique

• Many tightly shaped beams converge on tumor
• Spreads out low dose
• Overlap regions get high dose
• Usually 5-10+ beams
• +/- modulate fluence of beams to improve dose-distribution

• “RapidArc = 360 beams”
IMRT vs RapidArc Technique

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• +/- modulate fluence of beams to improve dose-distribution

• “RapidArc = 360 beams”
RapidArc – a review

- Time Optimized Rotational IMRT
- Modulate:
  - Gantry Speed
  - Dose Rate,
  - MLC
- Patented Progressive Sampling

<table>
<thead>
<tr>
<th>Qualitative Benefits of Treatment Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feature</td>
</tr>
<tr>
<td>Conformality</td>
</tr>
<tr>
<td>Speed</td>
</tr>
<tr>
<td>Reduced Pat Mot</td>
</tr>
<tr>
<td>Patient Comfort</td>
</tr>
<tr>
<td>Dose Avoidance</td>
</tr>
</tbody>
</table>
Varian Novalis Tx™ at Banner Good Sam
## SBRT Studies Reported to Date

<table>
<thead>
<tr>
<th>Cancer type</th>
<th>Smallest (n)</th>
<th>Largest (n)</th>
<th>Non-randomized comparison</th>
<th>Prospective single group</th>
<th>Retrospective</th>
</tr>
</thead>
<tbody>
<tr>
<td>GI (Colon, Liver, Pancreas)</td>
<td>n = 4</td>
<td>n = 79</td>
<td>0</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>Head and Neck</td>
<td>n = 8</td>
<td>n = 112</td>
<td>4</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>Kidney</td>
<td>n = 3</td>
<td>n = 48</td>
<td>0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Lung/Thorax</td>
<td>n = 9</td>
<td>n = 141</td>
<td>1</td>
<td>24</td>
<td>11</td>
</tr>
<tr>
<td>Multiple Sites</td>
<td>n = 14</td>
<td>n = 108</td>
<td>0</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Eye/Orbit</td>
<td>n = 5</td>
<td>n = 211</td>
<td>4</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Pelvis, Sacrum, and Uterus</td>
<td>n = 3</td>
<td>n = 23</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Prostate</td>
<td>n = 10</td>
<td>n = 41</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Spine</td>
<td>n = 3</td>
<td>n = 486</td>
<td>1</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total number of studies</strong></td>
<td></td>
<td></td>
<td><strong>10</strong></td>
<td><strong>59</strong></td>
<td><strong>49</strong></td>
</tr>
</tbody>
</table>
RapidArc: Clinical Evidence Growing

- 40 Papers Published or In-Press
- 27 Abstracts at AAPM09
- 26 Abstracts at ASTRO
  - 23 Clinical
  - 3 Technical
  - 8 of 23 on SBRT/SRS
Thoracic SBRT
-- a Model for SBRT development --

Selected Literature review

SBRT RapidArc clinical example
Early Stage NSCLC Management

XRT

Five Year Survival Rates: 15-30%
Dose escalation improves LC & OS
Radiation pneumonitis (grade 3+) and lung fibrosis
Early Stage NSCLC Management

Dose-Distributions

Conventional 3D-RT
(60-66Gy in 30fxs/6wks)
BED = 72 Gy\textsubscript{10}

Intensity Modulated RT (IMRT)
(80Gy in 40fxs/8wks)
BED = 95 Gy\textsubscript{10}

Stereotactic Body RT (SBRT)
(48-60Gy in 3-5fxs/1wk)
BED = 168 Gy\textsubscript{10}
## Local Control Early Stage NSCLC

<table>
<thead>
<tr>
<th>Total Dose</th>
<th>Reference</th>
<th>BED</th>
<th>LC%</th>
</tr>
</thead>
<tbody>
<tr>
<td>60G, 30Fx</td>
<td>RTOG</td>
<td>72</td>
<td>15%</td>
</tr>
<tr>
<td>70G, 35Fx</td>
<td>RTOG</td>
<td>84</td>
<td>24%</td>
</tr>
<tr>
<td>45G, 3Fx</td>
<td>Blomgren</td>
<td>113</td>
<td>&gt;80%</td>
</tr>
<tr>
<td>48G, 3Fx</td>
<td>Blomgren</td>
<td>125</td>
<td>&gt;90%</td>
</tr>
<tr>
<td>60G, 3Fx</td>
<td>Timmerman</td>
<td>180</td>
<td>&gt;80%</td>
</tr>
<tr>
<td>69G, 3Fx</td>
<td>Emami</td>
<td>228</td>
<td>&gt;90%</td>
</tr>
</tbody>
</table>
## SBRT for Stage-I NSCLC: Literature Review

### Published studies of > 40 patients

<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>Median FU (mo)</th>
<th>Actuarial LC</th>
<th>Late Complications &gt; Grade 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pneumonitis</td>
</tr>
<tr>
<td>Baumann</td>
<td>138</td>
<td>33</td>
<td>95% (2-yr) 85% (3-yr)</td>
<td>1%</td>
</tr>
<tr>
<td>Lagerwaard</td>
<td>197</td>
<td>12</td>
<td>94% (2-yr)</td>
<td>3%</td>
</tr>
<tr>
<td>Nagata</td>
<td>45</td>
<td>30</td>
<td>98% (2-yr)</td>
<td>0%</td>
</tr>
<tr>
<td>Nymann</td>
<td>45</td>
<td>43</td>
<td>--</td>
<td>0%</td>
</tr>
<tr>
<td>Onishi</td>
<td>257</td>
<td>38</td>
<td>98% (2-yr) 84% (5-yr)</td>
<td>5%</td>
</tr>
<tr>
<td>Timmerman</td>
<td>70</td>
<td>18</td>
<td>96% (2-yr)</td>
<td>0%</td>
</tr>
<tr>
<td>Uematsu</td>
<td>50</td>
<td>36</td>
<td>94% (2-yr)</td>
<td>0%</td>
</tr>
<tr>
<td>Xia</td>
<td>43</td>
<td>27</td>
<td>99% (2-yr) 95% (3-yr)</td>
<td>2%</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td>845</td>
<td>30</td>
<td>96% (2-yr)</td>
<td>1.4%</td>
</tr>
</tbody>
</table>

Japanese SBRT studies for NSCLC

Overall survival of operable NSCLC patients irradiated with BED >100 Gy according to T stage

Onishi, et al., ASCO 2006
Japanese SBRT studies for NSCLC

Comparison of 5-year overall survival between Surgery & SBRT

<table>
<thead>
<tr>
<th>Stage</th>
<th>Surgery</th>
<th>Stereotactic Body Radiation Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mountain</td>
<td>JCOG</td>
</tr>
<tr>
<td>IA</td>
<td>67%</td>
<td>80%</td>
</tr>
<tr>
<td>IB</td>
<td>57%</td>
<td>63%</td>
</tr>
</tbody>
</table>

Onishi, et al., ASCO 2006
LUNG SBRT 0236: Predictor of the future?

SBRT Lung Trial Update


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SBRT Phase II NSCLC Trial: RTOG 0236

Results Are In – ASTRO09 paper #5:
Room W181: Monday, 11:10 am

- 20 Gy x 3 (54 Gy w homogeneity correction)
- Medically In-Operable; biopsy proven NSCLC
- Peripheral tumors: 2 cm from central bronchus
- 55 evaluable patients: 44-T1, 11-T2

Results:
High local control: 2 yr LC 94%
Moderate Morbidity: 24%&4%; Gr 3&4
Encouraging 2 yr DFS and OS
Disease Free Survival: 66%
Overall Survival: 72%
|------------------------|-------------------------------------|

**Lung RapidArc SBRT: ASTRO09**


**RapidArc compared to IMRT for Lung SBRT**

- **Study details:** Pair of 2-358º arcs vs 10 field IMRT; SBRT tmt 18Gyx3, 11Gyx5 & 7.5Gyx8
- **Times 40% faster** at 600 MU/min [11 min @ 18 Gy to 4.5 min @ 7.5 Gy]
- Conformality better for high dose regions: $\text{CI}_{80}$: 1.09 vs 1.22; $\text{CI}_{60}$: 2.19 vs 2.41
- Chest wall doses reduced with RapidArc
- 18 Gy RapidArc will fall to 6 minutes with Novalis Tx @ 1000 MU/min
Medically Inoperable Early Stage NSCLC

DEMOGRAPHICS:
• 56 year old female
• Histology: broncho-alveolar carcinoma and adenocarcinoma NSCLC

CLINICAL HISTORY / SBRT Treatment Rationale:
• Referred by: Thoracic Surgeon
• Presenting History: Abnormal, asymptomatic surveillance PET/CT
• Previous Treatment: LLL lobectomy 2003 for T2 BAC followed by Carbo+Taxol on clinical protocol; 2007 LUL solitary BAC relapse s/p completion pneumonectomy
• Diagnosis: Bx+ BAC/ACA 1.3cm RLL lung lesion
• Treatment Rationale: No other reasonable options
Medically Inoperable Early Stage NSCLC

Axial 5 mm CT scans with surgically absent L lung
Development of a solitary 1.5 cm lung nodule is seen on (bottom) image

Axial & coronal PET scan shows a 1.5 cm nodule of metabolic activity in R lung.
Consistent with the clinical and biopsy proven finding of T1 NSCLC
Medically Inoperable Early Stage NSCLC

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Development of a solitary 1.5 cm lung nodule is seen on (bottom) image

Axial & coronal PET scan shows a 1.5 cm nodule of metabolic activity in R lung.
Consistent with the clinical and biopsy proven finding of T1 NSCLC
Medically Inoperable Early Stage NSCLC

Treatment Planning:
- RapidArc SBRT; obliqued RA
- One 360° arc delivered at 10° to minimize dose to healthy lung
- 54 Gy to 89% IDL: 18Gy x 3 fx
- ITV = 34.2 cc; CTV = 24.5 cc
- Plan was superior to IMRT plan
- CI = 1.076; HI = 1.123

Treatment Delivered:
- CBCT and ExacTrac for guidance
- Snap for Intrafraction review
- Beam on time = 9 min / fx
- Total tmt time = 21 min / fx
RapidArc: NonAxial MultiArc

**12Gy Fx; Beam-on Time < 4 min**
Two 360° arcs; Yaw ±10°; Collimator ±30°
Medically Inoperable Early Stage NSCLC

12 Field IMRT SBRT
- 12 field coplanar beam arrangement
- approx 21° separation between fields
- 6x energy
- Beam arrangement predominantly from left non functioning side of thorax as to spare right functioning lung
- Dose of 18 Gy in 3 fractions for 54 Gy Total
- Normalization Value of 82% chosen as to achieve 96% coverage of PTV with prescription dose of 54 Gy

Rapid Arc SBRT
- Single coplanar rotation arc; variably modulated dose rate, gantry speed & dynamic MLC
- 6x energy
- 10° couch rotation towards lung apex decreases lung volume irradiation
- Optimization parameters set with objectives to decrease irradiation of trachea, esophagus, spinal cord, heart, right lung
- Dose of 18 Gy in 3 fractions for 54 Gy Total
- Normalization Value of 89% chosen as to achieve 96% coverage of PTV with prescription dose of 54 Gy
RapidArc vs IMRT SBRT for Stage-I NSCLC

<table>
<thead>
<tr>
<th>Calculation</th>
<th>IMRT</th>
<th>RA</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI 54 Gy</td>
<td>1.18</td>
<td>1.076</td>
</tr>
<tr>
<td>CI 27 Gy (50%)</td>
<td>4.79</td>
<td>4.22</td>
</tr>
<tr>
<td>V20 Lung</td>
<td>9.25%</td>
<td>8.29%</td>
</tr>
<tr>
<td>V10 Lung</td>
<td>24.58%</td>
<td>23.08%</td>
</tr>
<tr>
<td>V5 Lung</td>
<td>37.82%</td>
<td>35.08%</td>
</tr>
</tbody>
</table>

![Graph showing comparison between 12 Field IMRT SBRT and Single Arc SBRT](image)

- Total Lung
- Trachea-Bronch
- Esophagus
- Spinal Cord

Calculation:
- CI: (Relative Biological Effectiveness) Ratio
- V20, V10, V5: Percentage of volume receiving 20, 10, 5 Gy, respectively.
Medically Inoperable Early Stage NSCLC

Treatment Response:

- 2, 4 and 6 week CXR stable; 3 month CT with >25% tumor reduction, minimal fibrosis
- No post-SRS decline in pulmonary function status
Spine SRS/IGRT
Selected Literature Review
IGRT Spine Avoidance Case Example
Radiosurgery for Metastatic Spine


**Nelson, et al**
- 32 patients / 33 lesions; 21 patients alive at 1 yr
- PTV 6 axially, 3mm radially; 3 x 7 Gy average dose
- At 1-mo: 30 patients complete or partial pain relief (13 patients complete relief)
- SBRT effective in the palliative/re-treatment setting

**Chang, et al**
- 63 patients / 74 lesions
- Median FU 21.3 mo; no neuropathy or myelopathy
- 1 yr. progression free survival was 84%
- No subacute or late grade 3 or 4 toxicity
- SBRT for spinal metastases is safe and effective
## Spine: RapidArc SBRT

### RapidArc SBRT for Spine


### Spine RapidArc: ASTRO09


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**Wu, et, al**

- 10 patients evaluated retrospectively
- 1 or 2 arcs vs IMRT; 2 arcs better
- 2 arc RA had better CI than IMRT
- RapidArc substantially improved efficiency
- Mean tmt time 7.88 v 15.86 min: RapidArc v IMRT
### DEMOGRAPHICS:

- 58 year old male
- Histology: Non-small cell, Adenocarcinoma, strongly TTF-1 positive

### CLINICAL HISTORY / SBRT Treatment Rationale:

- Referred by: Medical Oncologist and Pulmonologist
- Presenting History: 2 month history of progressive right shoulder/SC pain associated with RUE anhidrosis and weakness
- Previous Treatment: None
- Diagnosis: T4N0M0, RUL NSCLC involving the brachial plexus and T3 vertebral body
- Treatment Rationale: CMT IGRT+CTx to the primary tumor due to involvement of the brachial plexus and encroachment on spinal cord
Newly Dx NSCLC Invading T3 Vertebral Body

Staging Imaging Studies:

- CT demonstrated tumor directly invading the right lung apex chest wall and soft tissues with osteolytic destruction of T3 vertebral body

- PET/CT scan confirms cT4 metabolically active lesion with invasion of T3 vertebral body and no evidence of LAN or distant disease
Newly Dx NSCLC Invading T3 Vertebral Body

Staging Imaging Studies:

• CT demonstrated tumor directly invading the right lung apex chest wall and soft tissues with osteolytic destruction of T3 vertebral body

• PET/CT scan confirms cT4 metabolically active lesion with invasion of T3 vertebral body and no evidence of LAN or distant disease
**Newly Dx NSCLC Invading T3 Vertebral Body**

**Treatment Planning:**
- RapidArc IGRT coplanar 360° arc; PTV = ITV = 169.6cc
- 66 Gy to 83% IDL: 2 Gy x 33 fx
- Plan was superior to 7 beam IMRT plan to PTV respecting tolerance dose to spinal cord, esophagus and total lung
- CI = 1.23; HI = 1.20

**Treatment Delivered:**
- CBCT & ExacTrac for guidance
- Snap for Intrafraction review
- Beam on time = 2 min / Fx
- Total treatment time = 15 min/ Fx
IMRT vs RapidArc: NSCLC Invading T3

▲ Single Arc SBRT
■ 7 Field IMRT SBRT
IMRT vs RapidArc: NSCLC Invading T3

<table>
<thead>
<tr>
<th>Calculation</th>
<th>IMRT</th>
<th>RA</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI 66 Gy</td>
<td>1.17</td>
<td>1.09</td>
</tr>
<tr>
<td>CI 33 Gy (50%)</td>
<td>5.63</td>
<td>4.69</td>
</tr>
</tbody>
</table>

- ITV
- Esophagus
- Spinal Cord
- Total Lung

7 Field IMRT SBRT

Single Arc SBRT
Newly Dx NSCLC Invading T3 Vertebral Body

Treatment Response:

- Complete resolution of RUE weakness and pain
- No post-SRS decline in pulmonary function status
- 4, 8 week CXR and 12 week CT with significant (80%) apical mass reduction
Newly Dx NSCLC Invading T3 Vertebral Body

Treatment Response:

- Complete resolution of RUE weakness and pain
- No post-SRS decline in pulmonary function status
- 4, 8 week CXR and 12 week CT with significant (80%) apical mass reduction
Liver SBRT
Selected Literature Review
RapidArc SBRT Case Example
SBRT for Primary Liver Carcinoma

SBRT for Liver: Selected References

   BMC Cancer. 2008 Nov 27;8:351.

2. Cárdenes HR. Role of stereotactic body radiotherapy in the management of primary hepatocellular carcinoma. Rationale, technique and results. 
   Clin Transl Oncol. 2009 May;11(5):276-83.


5. Wulf J, et al. Stereotactic radiotherapy of targets in the lung and liver. 
   Strahlenther Onkol. 2001 Dec;177 (12):645-55.

Choi BO, et al.

- 31 patients / 32 HCC lesions
  - 23 targeting small nonresectable HCC
  - 9 targeting portal vein tumor thrombosis (PVTT)
- Mean dose: 36 Gy = 12 Gy x 3 Fx
- Med FU 10.5 mo
- Overall response 72% [83% small HCC; 44% PVTT]
  - Medial Survival 12 months & 8 months respectively
Recurrent Hepatocellular Carcinoma

**DEMOGRAPHICS:**
- 67 year old male
- Histology: Hepatocellular carcinoma, 2007

**CLINICAL HISTORY:**
- Referred by: Interventional Radiologist and Oncologic Surgeon
- Presenting History: Abdominal pain and bloating
- Previous Treatment: TACEs x 2 2007, consolidative IMRT 50Gy 2008
- Diagnosis: T3N0 primary HCC, radiographic and symptomatic locally progressive recurrence
- Treatment rationale: Not a candidate for transplant; percutaneous RFA/cryo contraindicated due to cyst; SBRT best treatment option
Recurrent Hepatocellular Carcinoma

Staging Work-up:

- Non contrast CT scan demonstrates contrast (lipiodol) from TACE in the medial cyst and tumor.
- Pre/Post MR: SPGR and T2WT+ SE demonstrates cystic recurrence with mural wall mass.
- PET shows increased FDG uptake in the anterior cystic mural wall nodule.
Recurrent Hepatocellular Carcinoma

Staging Work-up:

- Non contrast CT scan demonstrates contrast (lupiodol) from TACE in the medial cyst and tumor
- Pre/Post MR: SPGR and T2WT+ SE demonstrates cystic recurrence with mural wall mass
- PET shows increased FDG uptake in the anterior cystic mural wall nodule
Hepatic RapidArc SBRT Method

• Dose
  – 48-60 Gy in 3 fractions
  – Dose prescribed to IDL covering PTV (generally 80-90% IDL)
  – Normal Tissue Constraints: > 700 mL uninvolved normal liver receive cumulative dose <15Gy during entire course of treatment
  – Mean dose to uninvolved liver 3.3-23.9 Gy (median 15.3 Gy)

• Radiation Technique
  – Immobilized with body frame with reference fiducial markers
  – Breath-hold or abdominal compression
  – Planning CT images often fused with diagnostic CT images, MRI, or PET
  – 6-23 MeV multiple RapidArc or multiple non coplanar static IMRT beams
  – Tissue heterogeneity corrections used
  – At least one repeat verification cone beam CT of patient in treatment position in addition to daily orthogonal ExacTrac images

• Margins
  – GTV = CTV
  – PTV = CTV + 5 mm radial, 10 mm CC
RapidArc-Partial Arc SBRT: Recurrent HCC

**Treatment Planning:**
- RapidArc SBRT: CTV = 77.1cc
- Three axial arcs delivered at: 320°, 60°, 220°
- 30Gy to 85% IDL: 6Gy x 5 fx
- Plan was superior to IMRT plan
- CI 30Gy = 1.27; CI 15Gy = 4.6

**Treatment Delivered:**
- CBCT (embolized lipiodol) and Novalis-Tx ExacTrac guidance
- Snap for Intrafraction review
- Beam on time = 4 min / fx
- Total treatment time = 20 min / fx
RapidArc-Partial Arc SBRT: Recurrent HCC

DVH

Liver
Bowel

GTV
PTV
HCC+Cyst
RapidArc-Partial Arc SBRT: Recurrent HCC

Treatment Response:

- Complete resolution of abdominal pain 1 week post-SBRT; no post-SRS hepatitis symptoms; KPS and QOL improved
- 8 week CT scan without significant change
Intracranial and CNS SRS
Selected Literature Review
Case Examples
SRS to Surgical Bed: Selected Cranial Refs


Soltys

- 72 patients / 76 cavities
- Median marginal dose 18.6 Gy
- Tumor vol – 9.8 cc
- 65 evaluable patients (w/ imaging for LC)
- Median follow-up 8.1 mo; survival 15.1 mo
- Distant failure in 49% of patients
- 6 & 12 mo LC : 88% & 79% respectively
RapidArc for Brain: Selected References


**Schiffner**
- 8 patients / 13 targets to the brain
- RapidArc was one arc; IMRT was 7-14 fields
- RapidArc & IMRT plans has similar CI and HI
- Average beam-on: 2.9 and 12.5 min respectively

**Lagerwaard**
- RapidArc compared to 1 or 5 dynamic conformal plans (1DCA & 5DCA) for vestibular schwannomas (VS)
- Dosage was 12.5 Gy to 80% isodose line
- RapidArc: 30% higher CI than 5DCA
- Treatment time: 5 vs 20 min for 5 DCA
- RapidArc - has replaced 5-arc SRS for VS
DEMOGRAPHICS:

- 60 y/o m, right handed former smoker, mild pre-senile dementia
- Histology: Non-small cell CA, squamous cell carcinoma

CLINICAL HISTORY / SBRT Treatment Rationale:

- Referred by: Neurosurgeon
- Presenting History: Developed morning HA, left partial hemiparesis and confusion over 3-5 days
- Previous Treatment: S/P LUL lobectomy 4-2007 for T1N0M0 NSCLC followed by adjuvant CTx
- Diagnosis: 5cm solitary intracranial
- Treatment Rationale: Improve LC and avoid potential WBI toxicity
SRS to Solitary Intracranial Met Surgical Bed

Pre-operative MRI

Post-operative MRI
SRS to Solitary Intracranial Met Surgical Bed

Planning MRI

3 Partial Arc SRS
**SRS to Solitary Intracranial Met Surgical Bed**

**Treatment Planning:**
- RapidArc SBRT; 3 non-coplanar arcs; GTV = 83.29 cc
- 27Gy to 89% IDL: 9Gy x 3
- RA plan was superior to 7 field IMRT plan
- CI = 1.06; HI = 1.12

**Treatment Delivered:**
- Novalis-Tx ETX for guidance
- Snap for Intrafraction review
- Beam on time = 4 min / fx
- Total treatment time = 15 min / fx
RapidArc II: MultiAngle-NonAxial-PartialArc

20Gy Fx; < 4 min beam-on; < 6 min treat
3- 145° arcs; Yaw: ±30° & 90°, 1:55 min/arc
SRS to Solitary Intracranial Met Surgical Bed

DVH

3 Partial Arc SRS
RapidArc SRS vs IMRT SRS

7 Field IMRT SRS

3 Partial Arc SRS
RapidArc SRS vs IMRT SRS

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<thead>
<tr>
<th>Calculation</th>
<th>IMRT</th>
<th>RA</th>
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<tbody>
<tr>
<td>CI 27 Gy</td>
<td>1.06</td>
<td>1.06</td>
</tr>
<tr>
<td>CI 13.5 Gy (50%)</td>
<td>3.00</td>
<td>2.79</td>
</tr>
<tr>
<td>V10 Motor Strip</td>
<td>57.34%</td>
<td>6.71%</td>
</tr>
<tr>
<td>V5 L Front Lobe</td>
<td>39.68%</td>
<td>18.02%</td>
</tr>
<tr>
<td>V5 Brain Stem</td>
<td>2.09%</td>
<td>0.11%</td>
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7 Field IMRT SRS
3 Partial Arc SRS
Treatment Response:

- Post-SBRT neurologically stable, no left-sided motor deficits, no change in MS, rapid discontinuation of corticosteroids
- 3 month post-MRI pending
Otolaryngology and Skull Base SBRT
Selected Literature Review
Case Examples
SBRT for Head & Neck: Selected References


- Phase I dose-escalation trial to 44 Gy
- 25 patients
- Five fractions over 2 weeks
- No Grade 3 or 4 toxicities
- Median time to progression 4 mo; OS 6 mo
- Reirradiation up to 44 Gy is well tolerated


- Primary (P), Recurrent (R), Metastatic (M)
- 44 patients / 55 lesions: P=10, R=21, M=13
- Dose: N=1 Fx, 13-18 Gy; N=5-8, 36-48 Gy
- Response (complete + partial): 77%
- Tumor Volume Reduced: 52%
- Overall Survival (mo): P=28.7, R=6.7, M=5.6
- Tumor Control Rate (1-yr): P=83.3%, R=60.6%


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<th>RapidArc for Head &amp; Neck: Selected Refs</th>
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<th>RapidArc for H &amp; N: ASTRO-09</th>
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**Verbakel**
- Dosimetric comparison verified with film dosimetry
- N=12 H&N patients
- RA plans with 60% average reduction in MU/fraction
- RA=IMRT plans for sparing OAR
- Double arc RA plans provide superior PTV dose homogeneity
Left Jugular Foramen Schwannoma

**DEMOGRAPHICS:**
- 55 year old female
- Histology: schwannoma

**CLINICAL HISTORY:**
- Referred by: Otolaryngologist and Neurosurgeon
- Presenting History: 6 month history of fainting spells with “negative brain MRI” done EW with increasing dysphagia and otalgia
- Previous Treatment: Surgical debulking via left neck approach with left parapharyngeal mass resection and left neck dissection
- Diagnosis: Subtotally resected glossopharyngeal nerve schwannoma with post-operative hoarseness, dysphagia and ipsilateral glossal atrophy
- Treatment Rationale: Adjuvant SRS to complete definitive Rx
Left Jugular Foramen Schwannoma

Pre-operative MRI

Post-operative MRI
Left Jugular Foramen Schwannoma

Pre-operative MRI

Post-operative MRI
Left Jugular Foramen Schwannoma

2 Partial Arc SBRT
Left Jugular Foramen Schwannoma

**Treatment Planning:**
- Number & type of arcs:
  - Two 360° Arcs; 60° collimator offset
- 25 Gy = 5 X 5 Gy fractions to 70% IDL
- GTV = 9.77 cc
- CI 25Gy = 1.58; CI 12.5Gy = 7.09

**Treatment Delivered:**
- Novalis-Tx ETX for guidance
- Snap for Intrafraction review
- Beam on time = 3 min / fx
- Total treatment time = 12 min / fx
Left Jugular Foramen Schwannoma

DVH

- Cerebellum
- Brain Stem
- Left Parotid
- Spinal Cord
- GTV
Left Jugular Foramen Schwannoma

Treatment Response:

• Improved, slow recovery of speech quality and swallowing dysfunction
• No new post SRS neurological deficits; 6 month post-SBRT MRI pending
# Multiply Recurrent H&N SCC

## DEMOGRAPHICS:
- 80 year old female
- Histology: Retromolar trigone squamous cell carcinoma

## CLINICAL HISTORY:
- Referred by: Otolaryngologist
- Presenting History: Right facial pain, dysphasia
- Previous Treatment: T1N0 GTR 6-2008 with no adjuvant Rx; 10-2008 recurrence, composite right hemimandibulectomy followed by adjuvant IMRT 5940 cGy + cetuximab
- Diagnosis: Recurrent left mandibular rpT4N0M0 (mandible involvement) invasive MD keratinizing SCC within the 5940 cGy field
- Tmt. Rationale: Palliative SBRT within a previously irradiated field
Multiply Recurrent H&N SCC

Staging Work-up:

- Comparison non-contrast CT scan demonstrates mass recurrence

- Comparison PET scans show increased FDG uptake in the muscle and mandible

- T2 FSE MRI + Gad demonstrating prior NED status
Multiply Recurrent H&N SCC

Staging Work-up:

- Comparison non-contrast CT scan demonstrates mass recurrence
- Comparison PET scans shows increased FDG uptake in the muscle and mandible
- T2 FSE MRI + Gad demonstrating prior NED status
Multiply Recurrent H&N SCC

Single Arc SBRT
Multiply Recurrent H&N SCC

Single Arc SBRT
TREATMENT DETAILS:
- Number of arcs: Single 360 degrees
- 30Gy = 6Gy x 5 fractions to 86% IDL
- GTV = 33.3cc; PTV = 53.7cc
- CI = 1.07; mandible D5% = 23Gy; mandible D2cc = 23Gy

Treatment Delivered:
- CBCT & Novalis-Tx ETX for guidance
- Snap for Intrafraction review
- Beam on time = 4 min / fx
- Total treatment time = 11 min / fx
Multiply Recurrent H&N SCC

5 Field IMRT SBRT

Single Arc SBRT
Multiply Recurrent H&N SCC

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<td>2.99</td>
</tr>
<tr>
<td>V23 Mandible</td>
<td>17.73%</td>
<td>5.00%</td>
</tr>
<tr>
<td>V15 Pharynx</td>
<td>23.35%</td>
<td>0.48%</td>
</tr>
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▲5 Field IMRT SRS  ■ Single Arc SRS
Multiply Recurrent H&N SCC

Treatment Response:

- Improved facial pain, reduced narcotic requirements and swallowing dysfunction
- 10 weeks post-SRS, no mucositis, dermatitis, osteonecrosis or other related side effects
Time Study: RA vs IMRT SRS/SBRT

Average set-up times:
- IGRT (CBCT): 10 (8-21) minutes
- SBRT (CBCT+ET): 18 (10-30) minutes
- SRS (CBCT+ET): 12 (9-22) minutes

Average total treatment times:
- IGRT (CBCT): 13 (10-24) minutes
- SBRT (CBCT+ET): 28 (14-44) minutes
- SRS (CBCT+ET): 17 (12-32) minutes

Average 1-3 minute total treatment time savings per IMRT field.
RapidArc – Clinical Applications I

Schwannoma  Glioblastoma  SRS multiple metastases  SRT brain mets + whole brain RT  Hippocampus sparing PCI

Head and neck  Bilateral Breast  Partial Breast  NSCLC
Radiation Oncologists of Central Arizona

SRS/SBRT with RapidArc Summary

• Radiosurgical tumor ablation
  – High dose radiation delivered with high accuracy
  – 1 to 5 treatment fractions
• Benefits relative to surgery
  – Minimally or non-invasive procedure
  – No anesthesia
  – Medically and surgically inoperable patients
• Benefits relative to radiotherapy
  – Evidence of improved local control
  – Improved surrounding critical structure sparing
  – Improved radiobiological effects on some tumors
• Additional clinical studies and follow-up still needed
Banner Good Samaritan: Our Team & Facility

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Thank you for your attention