Clinical Implementation of SRS/SBRT
Anil Sethi, PhD
Loyola University Medical Center
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Disclosures
Speaker:
BrainLAB
Standard Imaging
Research collaboration:
RaySearch

Overview
- Physics Considerations
- SRS Program
- SBRT Program
Physics Considerations
- System QA (Image, Plan and Treat)
- Equipment Selection
- Beam Data Measurement
- Data Validation
- End-to-End Test (Process QA)
- Tips and Tricks

System QA
- Winston Lutz Test
- Process QA
- Image-Fusion Test

Output/PDD/Profiles
- Beam Output Check: TG-51
- Send for RPC TLDs
- Beam Scans (PDD/Profiles) for MLC & cones
- Scatter factors
Small Field Challenge: Output Factors

Das et al., 2000.

Large vs. Small Fields

Wrong Detector....

- Dose
- Penumbra
- FWHM

• Under-estimated
• Broadened
• Unaffected
Which Detector to Use?

- Ensure detector size < (¼ * Field Size)
- Small ion chamber (<0.1cc): stem effect/leakage.
- Medium ion chamber (0.1 – 1.0 cc): volume averaging
  - CA is under-dosed, penumbra broadened

Recommend:
- Unshielded diode for small fields and
- Ion chamber for large fields

SRS Detectors

- CC13 (0.13cc active volume)
- A16
- Exradin D1H and D1V
- IBA SFD
- Edge detector
- PTW White diode (60018)

Pitfalls
Beam Misalignment

6 x 6 mm
1 degree offset

Beam Misalignment

6 x 6 mm
1 degree offset

Depth (mm)

Dose (%)

1 degree offset

Beam Data Measurement Tips

- Check water surface (use $d_{\text{max}}$ as reference)
- Effective point of measurement
- Align scanning system/ detectors with beam axis. Drive Up!
- Scan small field profile (< 2 cm) to verify detector centering & depth correction if needed
- Repeat with MLC and cones
Measurement Tips

- Verify 10x10 cm PDD/profiles
- Compare in-house or from a comparable SRS machine
- Output (scatter) factors with at least two diode detectors + small volume ion chamber
- Perform cross calibration before each measurement
- Daisy chain at ~4x4 cm: Perform measurements with large chamber for known MU and then deliver same MU to the small detector. Use charge ratio of output for large detector to adjust output with small detector.

More Tips

- For small fields, no ref detector
- Stealth detector (IBA)
- Slow speed, 20+ pts/meas
- Eliminate noise!
- Watch for Penumbra asymmetry
- Check leakage and subtract from Output if necessary

Detector Compare

- PDD 6 x 6 mm
- Dose vs. Depth for different detectors
Detector Compare

Off-axis distance (mm)

Detector Compare

30 x 30 mm PDD

Detector Compare

30 x 30 mm
### Detector Compare

#### Penumbra Measurements

<table>
<thead>
<tr>
<th>F.S. (mm)</th>
<th>100 x 100</th>
<th>30 x 30</th>
<th>12 x 12</th>
<th>6 x 6</th>
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<tbody>
<tr>
<td>Detector</td>
<td>Vendor</td>
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<tr>
<td>CC13</td>
<td>IBA</td>
<td>5.2</td>
<td>4.9</td>
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<td>2.6</td>
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<td>IBA</td>
<td>3.5</td>
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<td>2.5</td>
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<tr>
<td>SP6</td>
<td>IBA</td>
<td>3.1</td>
<td>2.4</td>
<td>2.3</td>
</tr>
<tr>
<td>TN 60018</td>
<td>PTW</td>
<td>3</td>
<td>2.2</td>
<td>2.3</td>
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#### Output Factors

Field size (mm)

#### Output factors of Conical Cones

<table>
<thead>
<tr>
<th>Cone size (mm)</th>
<th>4</th>
<th>5</th>
<th>7.5</th>
<th>10</th>
<th>12.5</th>
<th>15</th>
<th>17.5</th>
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<tr>
<td>Output factors</td>
<td>0.880</td>
<td>0.846</td>
<td>0.770</td>
<td>0.719</td>
<td>0.602</td>
<td>0.540</td>
<td>0.500</td>
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</tbody>
</table>

- **Edge**: 90.0 ± 1.2 | 84.1 ± 1.0 | 80.6 ± 0.9 | 77.0 ± 0.8 | 75.5 ± 0.7 | 75.0 ± 0.6 | 75.0 ± 0.5 |
- **SP6**: 95.0 ± 1.6 | 92.0 ± 1.3 | 89.0 ± 1.1 | 86.0 ± 0.9 | 85.0 ± 0.8 | 85.0 ± 0.7 | 85.0 ± 0.6 |
- **Photon diode**: -2.0 ± 0.5 | -1.0 ± 0.4 | -0.5 ± 0.3 | -0.2 ± 0.2 | -0.1 ± 0.1 | -0.1 ± 0.0 | -0.1 ± 0.0 |
- **CC13**: -10.0 ± 2.0 | -7.0 ± 1.5 | -4.0 ± 1.0 | -2.0 ± 0.5 | -1.0 ± 0.0 | -1.0 ± 0.0 | -1.0 ± 0.0 |
- **Paguett**: -4.0 ± 2.0 | -2.0 ± 1.5 | -1.0 ± 1.0 | -0.5 ± 0.5 | -0.2 ± 0.2 | -0.1 ± 0.1 | -0.1 ± 0.0 |

N. Wen, Henry Ford
**TPS Validation**
- Independent MU to Dose Calc
- TG-119 (Planar Array/ ion-chamber/film)
- MU vs. Measurement for MLC and Cone plans
- Hetero Correction vs. Field size
- Verify Select Fields Dose/MU
- RPC/RTOG credentialing

**Fusion QA: CT/MR**
- CT/CT : 0.48 ± 0.07 mm
- CT/MR : 1.09 ± 0.65 mm

**Process QA: Hidden Target Test**
Scan, Plan, Treat, and Verify!
Position: 1.14 mm  
Dose: < 2%

Summary
- Select **appropriate set of detectors** for small fields
- Ensure **positioning** and alignment with respect to central axis
- **Redundancy** of measurements
- **Cross check** with standard data
- RTP commissioning/verification: for typical treatment fields
- System QA: Imaging/TPS/Linac
SRS Treatment Planning

SRS Rx Dose
- Target Volume, Type, and Location
- SRS Rx dose (RTOG 95-08) max tolerable vs. GTV diameter:
  - < 2cm: 24 Gy
  - 2.1 - 3cm: 18 Gy
  - 3.1 - 4cm: 15Gy
- Mets/AVM typically treated with SRS
- Malignant lesions with SRT

SRS Treatment Planning
- Follow RTOG guidelines (www.rtog.org)
- Use DVHs to get:
  - target Rx Dose or D_min
- Volume of healthy tissue irradiated
  - Conformality index
- Target dose homogeneity (max/min target dose)
  - homogeneity index
- **SRS dose homogeneity is relaxed in favor of dose Conformality**
SRS Treatment Planning
- Draw separate GTVs on CT & MR
  - PTV = GTV (SRS)
  - PTV = GTV + 2mm (SRT)
- Use composite GTV (CT + MR) for planning
- OARs (auto segmentation but verify)

SRS Treatment Planning
- Target size, location, proximity to OARs
dose fractionation.
- 3-4 VMAT Arcs
- Can also use conformal fixed fields or circular arcs
Dose constraints

<table>
<thead>
<tr>
<th>Structure</th>
<th>Dose (Gy)</th>
<th>Endpoint</th>
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<tbody>
<tr>
<td>Optic chiasm</td>
<td>10</td>
<td>Neuritis</td>
</tr>
<tr>
<td>Cochlea</td>
<td>12</td>
<td>Hearing loss</td>
</tr>
<tr>
<td>Brainstem</td>
<td>15</td>
<td>Cranial neuropathy</td>
</tr>
<tr>
<td>Cord</td>
<td>14</td>
<td>Myelitis</td>
</tr>
</tbody>
</table>

Optic, auditory< trigeminal <motor CN

SRS Plan Evaluation

- Draw “Irradiated_OARs” for long structures such as cord, brain stem for accuracy.
- Examine DVHs, Rx Isodose coverage, and OAR sparing
- Conformality index (V100/PTV)
- Homogeneity index (D5/D95)
Case 1: Brain Met DVH

22Gy @ 80% isodose volume

CI = 1.29

Case 2: Rt Occipital Met

4 VMAT arcs, 4 table angles, 18Gy, single fraction

Conformality Index vs. Target size
SBRT Planning

4DCT Scanning
- Free breathing (FB) scan
  - 3x3mm slices
- 4D scan with Varian’s RPM
  - ROI: (±5 cm around PTV)
  - 2-3 mm slice width.
- Create MIP (maximum intensity projection) data set.
- Transfer FB images & 4D sets (0%, 50%, MIP & Ave. Int. projection) to TPS

Image Fusion
SBRT OARs
- Rt + Lt lung (pulmonary window)
- Heart, Trachea, Carina
- Esophagus_irrad. (± 3cm sup/inf around PTV)
- Spinal cord_irrad. (± 3cm sup/inf around PTV)
- Liver, kidneys, Small bowel, Pancreas
- *Do not include GTV/PTV in lung definition

SBRT Targets
- GTV on FB, 0%, 50% CT sets; ITV on MIP
- PTV = ITV + 3 - 5mm
- Create D2cm = PTV + 2cm (high dose spillage)

SBRT Dose Rx.
Loyola:
- For lung patients:
  - 10 - 12Gy/fx x 5 fractions = 50-60Gy
  - BED ~ 100-150 Gy
  - M-W-F treatments
SBRT Treatment Planning

- 6 – 10 MV X-rays,
- VMAT: 3 – 4 VMAT non-coplanar arcs or
- 3DCRT: 8 – 12 non-coplanar, non-opposing fields.

SBRT Plan Evaluation

- **Target Coverage**: 95% of PTV and 100% of GTV
- Hot spot must be less than ~10-15% & within PTV.
- **Target Dose Homogeneity**: < 15-20%
- **Dose spillage**: V50/PTV (see RTOG table)

SBRT Plan Evaluation

- **Dose Conformality**: V100/PTV = 1.2 - 1.5 (higher values for smaller targets)
- Tighten up PTV - MLC margin or adjust beam parameters to achieve better Conformality index (CI).
- Ensure small calc. grid (1mm) for small structures.
SBRT Plan Evaluation

Table 1: Conformity of Prescribed Dose for Calculations Based on Deposition of Photon Beam Energy in Heterogeneous Tissue

| Fraction | Prescription Isocenter Volume (cc) | Ratio of Prescription Isocenter Volume to Mean Lung Volume | Ratio of 50% Prescription Isocenter Volume to Mean Lung Volume | Maximum Dose (% of dose prescribed) | Percent of Lung Receiving 20 Gy
<table>
<thead>
<tr>
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<tr>
<td>14.4</td>
<td>1.0</td>
<td>0.8</td>
<td>0.5</td>
<td>100.0</td>
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<tr>
<td>10.4</td>
<td>1.0</td>
<td>0.8</td>
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<td>100.0</td>
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<td>0.8</td>
<td>0.5</td>
<td>100.0</td>
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From: RTOG 0813

OAR Dose Constraints

From: Timmerman, R.D., Seminars in Radiation Oncology 18(4), 215 (October 2008)

Dose Calculation Algorithms in Lung SBRT

From: Timmerman, R.D., Seminars in Radiation Oncology 18(4), 215 (October 2008)
Depth dose, 15 MV, 4 cm off-axis, “light lung”, Several algorithms

Problems with algorithms that do not model electron transport.
Electronic equilibrium? No problem.
Better agreement between Pinnacle CC and Monte Carlo than between Eclipse AAA and Monte Carlo.

MC Treatment Planning

RUL T1aN0 NSCLC, 10.7 cm³ PTV
PTV 50 Gy in 5 fractions, 9 conformal, non-coplanar 6 MV beams

PB vs. MC Non-optimized
**Dual Lung Phantom**

![Graph showing dose vs distance for dual lung phantom.]

**Lung Phantom: 12x12 PDD**

![Graph showing dose vs distance for lung phantom.]

Significant differences between MC and PB in the cork region.

**Challenging Cases - 1**

Patient had 3D treatment for lung target 2 years ago and recurred. Prev Cord dose = 49 Gy, deliver minimum dose to cord. Beam arranged to not enter thru cord, exit only. Cord as OAR in optimization.
A patient with left upper lobe lesion (17 x 22 mm). Significant left lung obstruction. Opened up after three fx. Replanning required. Significant (up to 10%) change in dose to PTV.

Summary

- Ensure adequate resources are available:
  - Imaging,
  - Txt Planning and
  - Delivery
- Acceptance Testing/Commissioning
- Robust System QA (End to End Test)
- IMRT/Arc Check QA
Summary
• Checklists + Independent MU calc
• Follow RTOG Guidelines
• Establish site specific protocols consistent with departmental resources
• Automate Planning and Evaluation methods for efficient and consistent planning
• Follow AAPM/ASTRO/RTOG guidelines

Thank you!
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