Volumetric modulated arc therapy

Richard Popple, Ph.D.

Disclosures

- UAB has research agreements with Varian Medical Systems
- Speaking honoraria from Varian Medical Systems

Outline

- Patient-specific QA
- SRS, SBRT, and flattening filter free VMAT
- Respiratory motion management
- Starting a VMAT program
**Patient Specific QA devices**

- IBA IMRT/VMAT phantom
- Sun Nuclear ArcCheck
- PTW Octavius
- Scandos Delta
- IBA Matrixx Evolution

---

**Beam Profile – Flattening Filter**

---

**Common SBRT sites**

- Spine
- Lung
- Liver and other abdominal targets
CNS Radiosurgery Efficiency

12-30 Gy in 1-5 fractions (n=27)

Beam on time = mean 81s
Clinical Dose Rate = 1840 MU/min

Prendergast BM et al., Jour of Radiosurgery and BRT 1(1) 1-12 (2011)

For spine SBRT, the technique with the fastest delivery time is:

1. 8-12 field DMLC IMRT 20%
2. 1 arc VMAT 19%
3. 2 arc VMAT 19%
4. Depends on prescription dose 23%
5. Depends on target volume 20%
For spine SBRT, the technique with the fastest delivery time is:

1. 
2. 
3. 2 arc VMAT
4. 
5.

Reference:

---

Treatment Efficiency for FFF Lung SBRT

Ten Lung SBRT clinical cases on a modified Clinac 21EX:
• Similar plan quality for FFF vs non-flat
• 6MV beam time reduced by 2.3 (1400 MU/600 MU)

---

Lung

---

Fig. 1. Beam setups for three different treatment techniques for a representative example case.

**Figure 3.** Dose-volume histograms for example case shown in Figure 2.


---

**Table 5.** Measured maximal skin dose for total treatment of 3 x 18 Gy

<table>
<thead>
<tr>
<th>Tumor location</th>
<th>Coplanar VMAT</th>
<th>Noncoplanar IMRT</th>
<th>Coplanar IMRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventral</td>
<td>3.1</td>
<td>3.4</td>
<td>4.1</td>
</tr>
<tr>
<td>Dorsal</td>
<td>10.9</td>
<td>10.4</td>
<td>11.3</td>
</tr>
</tbody>
</table>

---

**Table 3.** Summary of fit parameters

<table>
<thead>
<tr>
<th>Variable</th>
<th>Delivery time (min)</th>
<th>Dose (Gy)</th>
<th>Coplanar VMAT</th>
<th>Noncoplanar IMRT</th>
<th>Coplanar IMRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>VMAT</td>
<td>6.9 (1D-3D)*</td>
<td>175.0</td>
<td>175.5</td>
<td>175.0</td>
<td>175.0</td>
</tr>
<tr>
<td>IMRT</td>
<td>17.3 (2D-20D)</td>
<td>175.0</td>
<td>175.5</td>
<td>175.0</td>
<td>175.0</td>
</tr>
</tbody>
</table>

For lung SBRT, the technique that minimizes skin dose is:

1. IMRT using coplanar beams (21%)
2. IMRT using non-coplanar beams (19%)
3. VMAT using a coplanar arc (20%)
4. Both 1 and 3 (20%)
5. Both 2 and 3 (21%)

References:

What is your clinic’s preferred technique to manage respiratory motion?

1. Internal target volume (ITV) (22%)
2. Abdominal compression (20%)
3. Breath hold/Active breathing control (ABC) (20%)
4. Gating (20%)
5. About equal split between two or more of the techniques above (18%)
Measurement summary

- Chamber difference < 0.5%
- Gamma index for gated film relative to ungated
  - >99.9% pass for 3%/3mm
  - >99.5% pass for 2%/2mm

RPC Gated VMAT Lung

Respiratory motion management for Elekta VMAT

- Respiratory motion management for Elekta VMAT is a work in progress
- Elekta’s motion management solution has been forced breath-hold based gating (Active Breathing Coordinator – ABC)
- Beam latency time on Elekta linacs has been a barrier to gated beam delivery. Recent latency time reductions have mitigated the clinical significance of beam latency.
Respiratory input: Surface imaging and spirometry

- C-Rad Catalyst
  - Surface mapping solution
  - Monitors the surface motion as a surrogate for respiration.

- Elekta ABC system
  - Turbine spirometer measures airflow
  - Research version provides gating interface.

Gating test – Experiment setup

Latest Gating Results

<table>
<thead>
<tr>
<th>#</th>
<th>Gating window</th>
<th>Delivery time (min)</th>
<th>Ideal time (min)</th>
<th>Beam-on latency (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100%</td>
<td>5.32 (5.89)</td>
<td>4.99</td>
<td>0.22 (1.06)</td>
</tr>
<tr>
<td></td>
<td>77%</td>
<td>7.08 (9.7)</td>
<td>7.80</td>
<td>0.61 (3.96)</td>
</tr>
<tr>
<td></td>
<td>66%</td>
<td>8.41 (8.42)</td>
<td>7.80</td>
<td>0.66 (3.96)</td>
</tr>
<tr>
<td>2</td>
<td>100%</td>
<td>5.32 (5.89)</td>
<td>6.51</td>
<td>0.10 (1.00)</td>
</tr>
<tr>
<td></td>
<td>77%</td>
<td>6.40 (9.20)</td>
<td>7.37</td>
<td>0.11 (1.66)</td>
</tr>
<tr>
<td></td>
<td>66%</td>
<td>7.47 (13.84)</td>
<td>7.37</td>
<td>0.11 (1.66)</td>
</tr>
<tr>
<td>3</td>
<td>100%</td>
<td>5.32 (5.89)</td>
<td>5.35</td>
<td>0.12 (1.07)</td>
</tr>
<tr>
<td></td>
<td>77%</td>
<td>5.32 (8.13)</td>
<td>6.35</td>
<td>0.12 (1.07)</td>
</tr>
<tr>
<td></td>
<td>66%</td>
<td>4.89 (12.1)</td>
<td>6.35</td>
<td>0.12 (1.07)</td>
</tr>
</tbody>
</table>
Dosimetric Accuracy

- Gamma passing rates are all > 99.0% for measured vs. planned dose distributions.
- Gamma passing rates are all = 100% (3mm/3%) for gated vs. un-gated deliveries, difference can only be observed with 1mm/1% gamma index passing criteria.

Elekta Gating Summary

- Elekta has not offered a free-breathing solution for beam gating.
- Elekta’s latest solutions make it possible to deliver gated treatments including gated VMAT with reasonable beam latencies.
- Tests have included using both the C-RAD Catalyst (surface mapping) and ABC (turbine) as the tool for providing the gating signal.

Do you use VMAT in your clinic?

- 26% 1. Don’t have VMAT, no plans to start VMAT
- 24% 2. Planning to start a VMAT program
- 26% 3. Just started
- 25% 4. Our VMAT program is well established
Starting an IMAT program

- Time and resource allocation
- Training
- Case selection

Time and resource allocation

- Form an implementation team
  - Physicists
  - Dosimetrists
  - Therapists
  - Physicians
- Develop an implementation plan
  - Establish a timeline
  - Develop written procedures
  - Evaluate training needs

Physicist tasks

- Acceptance
- Commissioning
  - Delivery system
  - Treatment planning
- Development of planning protocols (joint with dosimetrists)
- Development of QA procedures
  - Patient specific
  - Machine
- Development of treatment protocol (joint with therapists)
Dosimetrist tasks

- Development of planning protocols (joint with physicists)

Therapist tasks

- Development of treatment protocol (joint with physicists)

Physician tasks

- Identify cases appropriate for initial patient cohort
Timeline

- Developed in coordination with vendor(s)
- List of all milestones, including training
- Example excerpt from UAB plan:
  - Therapist RapidArc training
  - Develop dry-run plan
  - Perform QA on dry run plan
  - Have therapists deliver dry run plan, including CBCT (with chambers & film).
- Make reasonable time estimates
- Have a contingency plan!

Training

- Vendor training
  - Delivery
  - Planning
  - Physics
  - Implementation team to develop internal training
    - Planning procedures
    - Treatment procedures
  - QA
  - Implementation team should also develop a post-implementation training plan

Case selection

- Simple targets
  - < 12 cm diameter
  - Spherical or cylindrical – no bifurcations

Start with this... not this
Case selection

- Suggestions
  - Prostate – low or intermediate risk
  - High-risk prostate boost
  - Brain
  - Head and neck boost

Initial cohort – standard plans

- For initial cohort of cases, develop “standard” plans
  - Use as reference for comparison with IMAT plans
  - Available as contingency treatment plan

Post-implementation

- Initial implementation period is preclinical to completion of the initial patient cohort
  - Initial patient cohort typically 5 to 20 cases
- Implementation team should develop a training plan for the general clinic
- Implementation is an ongoing process that will last significantly beyond the first patient cohort
- Implementation team should continue to monitor process
Thank you