VMAT vs. IMRT: Does the Choice Matter?

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- Associate Physicist, Michigan Radiation Oncology Quality Consortium (Funded by Blue Cross Blue Shield of Michigan)

Outline

- Brief Refresher of Intensity Modulated Techniques
- Evidence for choosing VMAT vs. IMRT
- Practical Pros and Cons and Considerations
- Take-Home Message
Beamlet-Based IMRT

Optimization Variables = Beamlet Intensities

Delivery is static or dynamic MLC

Aperture-Based IMRT

Optimization Variables = MLC Positions & Segment Weights

Delivery is static
VMAT Optimization Variables

• MLC positions & segment weights (MU)

Delivery is fully dynamic (gantry, MLC, collimator, but not table), moving linearly between MLC positions while the beam is on with variable dose rate and gantry speed

What does the literature say?

• "Unable to conclude that VMAT provides a (dosimetric) benefit to IMRT" (Quan IJROBP 2012)

• "VMAT and HT are capable of providing more uniform target doses and improved normal tissue sparing or comparable with IMRT/VMAT" (Rao IJROBP 2009)

• "VMAT achieved similar PTV coverage and sparing of organs at risk for breast IMRT" (Rao IJROBP 2009, VMAT vs. IMRT in spine SBRT)

• "VMAT plan quality only slightly superior to IMRT, but inferior to HT. The conformal dose distributions were similar and the VMAT plan was delivered in less time" (Myrehaug IJROBP 2012)

• "VMAT-1 target coverage was similar to that achieved with IMRT, but inferior to HT. The conformal dose distributions were comparable, and the VMAT plan was delivered in less time" (Myrehaug IJROBP 2012)

• "VMAT plan quality was comparable or slightly better than those with coplanar IMRT" (VMAT achieved equal PTV coverage and sparing of organs at risk for breast IMRT) (Holt IJROBP 2011)

• "VMAT-1 target coverage was slightly better than that achieved with IMRT, but inferior to HT. The conformal dose distributions were comparable, and the VMAT plan was delivered in less time" (Myrehaug IJROBP 2012)

• "VMAT can achieve equivalent (and sometimes better) dosimetric plan quality vs. IMRT" (Bedford Med Phys 2008; "VMAT and HT are capable of providing more uniform target doses and improved normal tissue sparing or comparable with IMRT/VMAT")

• "VMAT usually gives low doses (5-15 Gy, for example) to larger volumes of contralateral normal tissues. With many (12 or more) IMRT beams, IMRT plan quality may be superior" (Bedford Med Phys 2008)

• "VMAT is much faster than IMRT and typically gives fewer MU" (Bedford Med Phys 2008)

• "1 arc is better for target coverage and normal tissue sparing for moderate/complex geometries (Bedford Med Phys 2008)"
SAM Question 1

1. The main advantage of VMAT compared to IMRT is:
   a. Improved target coverage
   b. Improved delivery efficiency
   c. Reduced integral patient dose
   d. Improved sparing of normal tissues
   e. Faster dose calculations

SAM Answer 1

• Answer: b


Prostate IMRT vs VMAT
(Princess Margaret Hospital)

• Retrospective comparison of sequential cohorts
  – The last 146 prostate patients treated with IMRT
  – The first 147 prostate patients treated with VMAT
• Identical prescription doses, contouring, IGRT, QA
Prostate IMRT vs VMAT
(Princess Margaret Hospital)

7 minutes
1.1 minutes

Acute GI Toxicity

Acute GU Toxicity

Cuthbert, Lindsay, Craig, Catton (PMH)
VMAT represents the use of a technology only, not a standard of care.

Prostate IMRT vs VMAT (Princess Margaret Hospital)

Rejected Plan

Accepted Replan

Cuthbert, Lindsay, Craig, Catton (PMH)

No Significant Theoretical Advantage to IMRT

100 IMRT Beams

10 IMRT Beams

10 IMRT Beams delivered in a sweeping 180 deg arc

Bortfeld PMB 2010

Take Home Message from Literature

- Treatment planning comparisons between IMRT and VMAT are very dependent
  - Planning system
  - Planner experience
  - Comparison methods (i.e. normalization)
- VMAT and IMRT are capable of producing similar dosimetric quality in most situations with major differences in
  - Delivery time
  - Planning time/iterations (including dose calcs)
  - Special geometric situations
Commissioning of New Planning Techniques is Critical

- Due to the differences encountered in VMAT and IMRT planning, the transition to VMAT for certain body sites should be properly commissioned
  - Planner training and hands-on practice
  - Physician review of plan quality including differences noted in low dose and DVH shape changes
  - Physicist review of plan quality, monitor units, and quality assurance needs

VMAT and IMRT Trends at UM

Pros and Cons of VMAT vs. IMRT at Michigan

**PROS**
- Significantly faster delivery
- Reduced MU (30-40% in many cases)
- Typically fewer normal tissue hotspots and easier planning for complex cases
- Improved optimization tools in planning system

**CONS**
- Only 3/6 machines are VMAT capable
- Flash is very difficult to add for tangential VMAT arcs
- Arc clearance challenging for some geometries (prone, extremities, tilt-board)
- Iterative planning required to reduce V5 when a concern (i.e. lung)
VMAT and IMRT Trends at UM (2015)

- Initial VMAT Plan
- IMRT Replan to Avoid Rt Eye

IMRT Replan for Low Dose Avoidance

- Flash is difficult to add for VMAT
  - Methods include adding fake bolus for optimization
  - Breast planning studies may ignore flash due this issue [Tsai JACMP 2012]
- Most planning systems have fluence or segment editing capabilities to add flash for IMRT
Iso Placement & Clearance

- In order to safely rotate around the patient, the lateral + vertical distance from table to isocenter must accommodate clearance of the head and imaging devices

SAM Question 2

1. Flash is most easily added to
   a. Static beam IMRT treatment plans
   b. Tomotherapy treatment plans
   c. Single arc VMAT treatment plans
   d. Dual arc VMAT treatment plans
   e. 3DCRT treatment plans

SAM Answer 2

- Answer: e

Tsai P-F et al. The feasibility study of using multiple partial volumetric-modulated arcs therapy in early stage left-sided breast cancer patients. JACMP 13 (2012)
An Informal Poll

<table>
<thead>
<tr>
<th>Institution</th>
<th>Use of VMAT vs. IMRT</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Moving toward VMAT for all sites except breast; Only use IMRT in sites where a VMAT procedure hasn’t been commissioned yet; Issues that delay implementation: dose calculation time constraints and low dose splash</td>
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<tr>
<td>2</td>
<td>Moving toward VMAT for all sites but may still choose IMRT on short timelines when planner is more comfortable</td>
</tr>
<tr>
<td>3</td>
<td>Majority VMAT except for larger thorax/abdomen cases (worry about low dose); Avoid modulation in cases with &gt;1-1.5 cm motion</td>
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<tr>
<td>4</td>
<td>VMAT unless there isn’t sufficient time (takes longer to plan than IMRT); Don’t use VMAT or IMRT for breast</td>
</tr>
<tr>
<td>5</td>
<td>85% VMAT, 15% IMRT. Many prostate and brain cases still IMRT due to only 3/6 machines having VMAT; Avoid VMAT for breast, cases with flash, clearance issues</td>
</tr>
</tbody>
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Unique Considerations

- VMAT delivery efficiency is extremely beneficial for larger tumors but leads to:
  - Field size concerns
  - Low dose spread concerns

Large Field Concerns

- Some MLCs cannot travel all the way across the jaw extent
  - For IMRT, this results in split fields

[Optimized Fluence Pattern]
[Split Field IMRT Delivery]
Large Field VMAT

• For VMAT, this:
  – Limits conformity and modulation potential for large field cases

Solution
  – Use multiple arcs with limited jaw extent
  – Utilize complementary collimator angles

Disadvantages of off-axis VMAT

• For VMAT, this:
  – Limits conformity and modulation potential for large field cases
  – Causes unnecessary irradiation of normal tissue for off-axis isocenters
Low Dose Concerns

- Low dose, such as V5 Gy for lung, is a concern with unrestricted full arcs
- Par@als Arcs can be created by explicitly defining a start and end range or by using an avoidance sector

Tong Zhu

Partial Arcs/Avoidance Sectors

Despite high priority in objecCve funcCon, the entrance dose rate through contralateral lung remains high
Another Option: Hybrid 3D + IMRT/VMAT Techniques

AP/PA 3DCRT w/ segments + Single Arc VMAT (Optimized on top of 3D plan)

Another Option: Hybrid 3D + IMRT/VMAT Techniques

Composite Hybrid Lung Plan

SAM Question 3

1. The volume of normal tissue receiving low dose (i.e. about 10% Rx Dose) to the contralateral side of the body is likely highest with
   a. A 7 field IMRT plan
   b. A 5 field IMRT plan
   c. A full arc VMAT plan
   d. A partial arc VMAT plan
   e. A 3 field 3DCRT plan
**SAM Answer 3**

- Answer: c

Popescu CC et al. Volumetric modulated arc therapy improves dosimetry and reduces treatment time compared to conventional intensity-modulated radiotherapy for locoregional radiotherapy of left-sided breast cancer and internal mammary nodes. *Int J Radiat Oncol Biol Phys.* 76 (2010)


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**Take Home Message**

- VMAT and IMRT are both capable of providing high quality dosimetric plans
- Commissioning a procedure for any new technique is critical
  - inverse plan quality is highly dependent on planner experience
  - VMAT and IMRT have different unique issues that should be investigated during commissioning of a body site – not “on the fly”
- The increase in efficiency with VMAT makes it the modulated technique of choice in many clinics with exceptions in cases where there are concerns regarding resource utilization, planner experience, flash/clearance, and low dose spread

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