IMRT AND VMAT: CURRENT AND FUTURE BEST PRACTICES

(OR: DON'T FORGET ABOUT IMRT AND HOW TO SETUP STATIC FIELDS)

Anthony Magliari MS, CMD
DISCLAIMER:

- I am employed by Varian Medical Systems on the Medical Affairs team
- My job currently includes testing new products and providing feedback
- I’ve spent over a year planning with Varian’s newest delivery platform: Halcyon (510k pending, not for sale)
- I used Eclipse to create the Halcyon plans used in this presentation (it is currently the only commercially available Treatment Planning System for Halcyon)

- I will focus on treatment planning concepts not specific product features where possible (however, screenshots will be utilized where required)
- The views expressed in this presentation are mine, and mine alone. They do not represent those of Varian Medical Systems
- All Halcyon case examples shown here can be viewed/downloaded from: http://medicalaffairs.varian.com
• I’ve been working with Treatment Planning Systems since 2002 and have been a clinical dosimetrist since 2011

• I married a dosimetrist and my sister is a dosimetrist

• Last year, at the 2016 AAMD annual meeting, I spoke about Knowledge Based Planning and the role for the dosimetrist as a model creator

• In the clinic I often annoyed therapists by creating IMRT plans when they would’ve preferred to treat the patient with VMAT

• I’m a big fan of Plan Challenge / Plans Studies (www.proknowsystems.com) and love using them as benchmark cases to study differences in delivery systems and treatment planning systems (even algorithms / version differences)

• For the record: I’ve never “won” any fully public plan study or plan challenge

• I’m not going to include silly pictures in this presentation, subject matter should be enough to keep people interested

• And, I like questions
OUTLINE

• Background overview of delivery system specifications for the plans I will show
  – “IMRT comeback”?
• When to use IMRT or VMAT based on target shape and/or OAR relative shape/position
  – Examples of cases where IMRT can potentially provide greater OAR sparing
    • IMRT beam arrangements selected in transverse view based on target shape and OAR
      – Brain (sequential boost GBM)
      – Breast/chestwall (on traditional delivery systems)
      – Head and Neck (simultaneous integrated boost)
  – Example cases where VMAT can provide greater homogeneity or more uniform dose fall-off
    • Head and Neck (slight increase in target homogeneity potential)
    • SBRT Prostate and Spine (SRS/SBRT quick dose falloff in all directions primary goal)
  – Review IMRT vs VMAT depends on target shape and planning goals – pick the right technique
• The importance of utilizing unique collimator rotations for each field/arc (esp. with larger leaf sizes)
  – Examples selecting collimator rotations from Beams Eye View for IMRT and VMAT plans
• General optimization tips/best practice
  – Target/OAR relative weight/priority and associated cost function – do they “make sense”?
    • IMRT specific: Relative smoothing factor priorities for fluence based optimization
    • VMAT specific: Min/max MU settings
  – Non OAR / Normal Tissue Optimization strategies based on number of fields / arc (non)coplanar
  – “Thorough optimization”
• Plan Challenge / Plan Study Retrospective: applying these principles against prior benchmarks
• Considering the present and future
  – IMRT: where it is best for the patient/plan
  – VMAT: hypofractionated breast with Simultaneous Integrated Boost meeting all RTOG 1005 arm2 dose constraints

IMRT and VMAT: current and future best practices

Anthony Magliari, MS CMD
DELIVERY SYSTEM SPECIFICATIONS FOR THESE CASES

- 6X FFF beam at 800 MU/min (all plans require beam modulation)
- 28x28 max field size (greater size requires a multi-isocenter plan)
- Traditional “wind up” gantry, treats from -180 to +180 as per standard (not helical)
- No couch rotation (coplanar delivery only)
- Dual layer “stacked and staggered” MLC
  - Each leaf can reach across the entire 28cm field
    - No more split field delivery / carriage shifts
    - Full field modulation
  - 1cm physical leaf width at isocenter
    - Stacked and staggered hardware design allows for a 5mm effective leaf width
      - Initial software release uses 1cm effective leaf width
      - Stacked and staggered design results in “per leaf jaw tracking” effect
    - Drastically reduced leaf leakage (0.01%)
      - No jaws needed
Stacked and staggered MLC example
• 4RPM gantry rotation speed (4x traditional speed)
• 2RPM gantry speed with “beam on” (2x traditional speed)
• 5cm/second MLC leaf speed (2x traditional speed)
• 2.5RPM collimator rotation speed (faster or the same depending on comparison)
• 800MU/min dose rate often maintained during IMRT sliding window delivery (~2x norm)

= 9 field IMRT on this system has similar treatment time to 2 arc VMAT on current systems!
Treatment speed example: 2012 AAMD / ROR Plan Challenge (https://www.youtube.com/watch?v=QKpc2OGtFuo)
Advanced Stage Lung 63Gy / 35fx

IMRT 8F (2:27) treatment field delivery time
VMAT 5PA (2:01) treatment arc delivery time

(both cases score >100% of cases submitted in 2012 AAMD/ROR Lung Plan Challenge)

IMRT and VMAT: current and future best practices
Anthony Magliari, MS CMD
Many institutions implement VMAT in their clinic and “forget about IMRT”

IMRT is always faster to optimize
- Iterate through plan versions quicker
- Thoroughly optimized plans don’t take much longer

Carefully selected static gantry angles can provide better dosimetric result than VMAT
- Depends on target shape, OARs and planning goals

IMRT is often ideal for controlling low dose with beam angle selection
- Thorax targets (protecting heart and healthy lung)
  - Esophagus
  - Lung
  - Breast/chestwall
    - Manually avoiding treating through metal implants
    - Manually avoiding exit dose through pacemaker/ICD

But IMRT is slower to deliver (especially with split fields/carriage shifts)
- maybe not in the future... ”IMRT comeback”?
IMRT BEAM ANGLE SELECTION EXAMPLE 1:
BRAIN GBM RTOG 0825 60GY(46GY/23FX+14GY/7FX SEQUENTIAL)
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IMRT BEAM ANGLE SELECTION EXAMPLE 1: BRAIN GBM RTOG 0825 60GY (46GY/23FX+14GY/7FX SEQUENTIAL)

Boost target is round, use VMAT
IMRT BEAM ANGLE SELECTION EXAMPLE 2: BREAST/CHESTWALL (ON TRADITIONAL DELIVERY SYSTEMS)
When starting the beam arrangement be sure not to overlap too many fields over contralateral breast.
"crossup beams" en face effect with less exit dose through ipsilateral lung
early lateral and opposing directly between first medial beams
IMRT BEAM ANGLE SELECTION EXAMPLE 2: BREAST/CHESTWALL (ON TRADITIONAL DELIVERY SYSTEMS)

opposing directly between first medial beams

and beyond for a concave beam arrangement
IMRT BEAM ANGLE SELECTION EXAMPLE 3: HEAD & NECK (2017 QADS/PROKNOW PLAN STUDY)
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**IMRT BEAM ANGLE SELECTION EXAMPLE 3: HEAD & NECK (2017 QADS/PROKNOW PLAN STUDY)**

<table>
<thead>
<tr>
<th>METRIC</th>
<th>RESULT</th>
<th>MIN REQ</th>
<th>IDEAL</th>
<th>POINTS</th>
<th>WEIGHT</th>
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<tbody>
<tr>
<td>Volume (% of the PTV70 covered by 70 (Gy))</td>
<td>95.00</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>14.99</td>
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<tr>
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<tr>
<td>Dose (Gy) covering 0.03 (cc) of the PTV70</td>
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<tr>
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<td>Conformation Number (53.2 (Gy), PTV56)</td>
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<td>Dose (Gy) covering 0.03 (cc) of the SPINAL_CORD</td>
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<td>Dose (Gy) covering 0.03 (cc) of the BRAINSTEM</td>
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<td>Dose (Gy) covering 0.03 (cc) of the LT COCHlea</td>
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<td>✔️</td>
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<td>✔️</td>
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<tr>
<td>Structure(s) containing the global max dose point</td>
<td>(7 values)</td>
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<td>✔️</td>
<td>✔️</td>
<td>5.00</td>
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<tr>
<td>Estimated beam-on time, all beams (minutes)</td>
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<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Cumulative meterset over all treatment beams</td>
<td>21 (of 21)</td>
<td>17 (of 21)</td>
<td>144.49</td>
<td>150.00</td>
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</tr>
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</table>

IMRT and VMAT: current and future best practices

Anthony Magliari, MS CMD
### IMRT Beam Angle Selection Example 3: Head & Neck (2017 QADS/ProKnow Plan Study)

#### Metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Result</th>
<th>Min Req</th>
<th>Ideal</th>
<th>Points</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume (%) of the PTV70 covered by 70 (Gy)</td>
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<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
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<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Dose (Gy) covering 0.03 (cc) of the PTV70</td>
<td>47.03</td>
<td>✔️</td>
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<td>Dose (Gy) covering 0.03 (cc) of the LT COCHELEA</td>
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<td>Volume (%) of the LIPS covered by 30 (Gy)</td>
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<td>✔️</td>
<td>✔️</td>
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<td>Volume (%) of the MANDIBLE covered by 70 (Gy)</td>
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<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
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<td>Mean dose (Gy) to the LARYNX</td>
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<td>✔️</td>
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<td>Structure(s) containing the global max dose point (7 values)</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
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<tr>
<td>Estimated &quot;beam-on&quot; time, all beams (minutes)</td>
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<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Cumulative meterset over all treatment beams</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
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<td><strong>TOTALS</strong></td>
<td>21 (of 21)</td>
<td>18 (of 21)</td>
<td>145.39</td>
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</tbody>
</table>

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**IMRT and VMAT: current and future best practices**

Anthony Magliari, MS CMD
**WHAT ABOUT VMAT?**

**HEAD&NECK (2017 QADS/PROKNOW PLAN STUDY)**

Top 5% scorers out of 238 submissions:

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
<th>Country</th>
<th>TPS</th>
<th>Modality</th>
<th>Score</th>
<th>Dose QA Device</th>
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<td>Jonathan Stenbeck</td>
<td>Greenville Health System</td>
<td>United States</td>
<td>Eclipse</td>
<td>VMAT</td>
<td>146.9</td>
<td>ArcCHECK</td>
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<td>VMAT</td>
<td>146.0</td>
<td></td>
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<tr>
<td>Rik Westendorp</td>
<td>Behandelloca ( i o Deventer )</td>
<td>The Netherlands</td>
<td>RayStation</td>
<td>Tomotherapy</td>
<td>145.8</td>
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<td>Joakim Nilsson</td>
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<td>Anthony Magliari</td>
<td>Varian Medical Systems</td>
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<td>ArcCHECK</td>
</tr>
</tbody>
</table>

Due to the scoring metric design, at the high end, target homogeneity was key factor, prioritized over OAR sparing.

VMAT has slight advantage in homogeneity potential.


Anthony Magliari, MS CMD
VMAT OBVIOUS CHOICE FOR SMALL ROUND TARGETS
SBRT PROSTATE (2016 AAMD/RSS PROKNOW PLAN STUDY)

IMRT score: 140.2
VMAT score: 141.1

VMAT is king when it comes to providing uniform, rapid dose fall off

IMRT and VMAT: current and future best practices

Anthony Magliari, MS CMD
VMAT OBVIOUS CHOICE FOR SMALL ROUND TARGETS
SBRT SPINE (2017 TROG PROKNOW PLAN STUDY)
IMRT AND VMAT: WHEN TO CHOOSE WHICH

- **IMRT**
  - Larger target
  - Target with obvious straight line edges and beams to mimic those edges
  - Maximum possible OAR sparing is required and beams bisect that/those OAR(s)
  - Less time is available for optimization and plan iterations
  - Patient treatment time less of a concern... perhaps no longer valid in the future

- **VMAT**
  - Small target
  - Round target without any obvious straight line edges
  - Uniform or very rapid dose fall off is highly desirable
  - More time is available for optimization and plan iterations
  - Maximum possible target homogeneity is required
  - Shorter treatment time needed... perhaps no longer valid in the future
  - Low confidence in ability to choose good static gantry positions

- However
  - Either technique can create very high quality plans in almost all cases
  - These are just tips to help you create the **best possible plans** based on your goals

IMRT and VMAT: current and future best practices  
Anthony Magliari, MS CMD
IMRT BEAM SELECTION BEST PRACTICE SUGGESTIONS

GENERAL CASES:
• Don’t use equally spaced beams (this is just lazy) a better result is likely with VMAT
• Space the beams every 20-40 degrees, on average, sometimes >40 degrees can be good
• Avoid using directly opposing beams
  – Consider opposing beams by ~10 degrees to make straight line divergence on one side for extreme gradient (PTV/rectum, PTV/spinal cord, PTV/parotid, etc)
• Beams should follow or mimic your target shape and bisect abutting highest value OARs
• Don’t be afraid to go back and adjust beams or add a new beam where needed
  – If you see strange “dose spill” from one side or corner of your target before trying to fix it with a dose control structure in the optimizer – check your beams!

BREAST CASES (on traditional delivery systems):
• Start as far over towards the contralateral breast as you can (50-60 degrees)
• Space your first 3 beams close together (20 degrees or less)
• Consider nearly AP (often 5-10 degrees offset towards contralateral side) and nearly lateral
  – Use either a single 45-50 degree beam or 2 “crossup beams” at +/- 10 degrees
• Place your last 3-4 beams opposing between your first 3 beams and beyond for concaveity
  – Consider fixing the jaws on these beams to avoid treating through lung
• Always make sure the resulting beam arrangement is concave
• Consider manually splitting fields and mixing energies between the sides
• Be prepared to manually extend fluence into air on tangent oriented beams for flash
TIP: ALWAYS ROTATE THE COLLIMATOR

- Plan with all beams/arcs utilizing unique and well spaced collimator positions
  - This especially important when utilizing wider MLC leaves
  - The more unique collimator rotation positions in a plan the better
    - Consider increasing the number of arcs used for more unique collimator positions
      » If the machine can deliver VMAT at 2x speed, consider 2x arcs
        - With the new delivery system I often use:
          - 4 arcs on standard fraction (usually 315, 0, 45, 90)
          - 6 arcs on large fractions (usually 300, 330, 0, 30, 60, 90)
- Select collimator rotations from a Beams Eye View for IMRT
  » Look for concavity in target shape
  » Follow general shape of target
  » Consider at least one beam with collimator at 90
    - I often make the most AP or PA field 90 degree collimator
COLLIMATOR ROTATION EXAMPLES

DO THIS

NOT THIS

IMRT and VMAT: current and future best practices

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OPTIMIZATION TIP: TARGET/OAR RELATIVE PRIORITY

- General optimization priority / weighting example
  - Targets 100-170
    - Often start with:
      » Max dose “lower objective” priority 110
      » Min dose “upper objective” priority 140
  - OARs 40-100
    - Often start with:
      » Very low priority OARs multiple “lower objectives” priority 40
      » Normal priority OARs multiple “lower objectives” priority 50
      » Higher priority OARs multiple “lower objectives” priority 60
      » Very high priority OARs multiple “lower objectives” priority 70-75
      » Max dose serial OAR single “lower objective” priority 100
        - And/or consider using “upper gEUD” with a=40
  - DMPO (Pinnacle/RaySearch) uses 0-100 but same concept
  - Always watch the real-time cost function graph to make sure structure order makes sense
OPTIMIZATION TIP: TARGET/OAR EXAMPLE

Make sure the cost function graph structure order and relative cost look right.

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OPTIMIZATION: IMRT SMOOTHING & VMAT MIN/MAX MU

IMRT optimal fluence smoothing:

*X and Y smoothing priority values are relative to all other priorities* – don’t let these values drift too far from your others or your MU will increase too much and plan be become over modulated

(DMPO: similar to control points per field)

VMAT MU Objective:

Lots of misconceptions, actually most useful to use “Minimum MU” slightly more than current plan to force additional modulation in certain plans to increase plan quality.
OPTIMIZATION: NORMAL TISSUE

• Consider:
  • compromised beam geometry (beams/arcs on only one side of patient)
  • Uniform dose fall off -or- OAR sparing (tradeoff)

Example NTO setting: starting point for compromised geometry plan (breast/chestwall)

Every TPS has a tool or multiple tools (Monaco) for implementing normal tissue sparing
OPTIMIZATION: NORMAL TISSUE

Coincidentally, falloff value used seems to have some correlation to number of fields

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**OPTIMIZATION: THOUROUGHNESS**

IMRT: Increase max iterations and max time, turn off auto mode, wait until cost line is flat
-- DMPO (Pinnacle/RaySearch) you can increate the “stopping tolerance” to E07-E08 or even 0

VMAT: Pause the VMAT optimizer at each MR substep (MR1: 5 times, MR2&3: twice, MR4:once) 10 pauses total, letting the cost line get flat before unpausing (automated method in the works)
FUTURE LOOK

– Don’t forget about IMRT
  • Practice making plans IMRT plans and setting up static fields today
    – Keep your beam angle selection skills sharp, could be often useful again
    – It is the current best solution for multifield breast IMRT
    – Often a great choice for large irregular target shapes
      » Head and Neck
      » Lower dose (often irregular) nodal targets
      » When maximum OAR sparing is valued over uniform dose fall-off

– VMAT isn’t going away either
  • In the future VMAT could become a popular solution for breast treatment utilizing protocols like RTOG 1005 arm2: hypofractionated breast with simultaneous integrated boost
    – Possible to meet all dose constraints due to drastically reduced leakage MLC with “per leaf jaw tracking” effect
FUTURE LOOK: VMAT BREAST

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Anthony Magliari, MS CMD
FUTURE LOOK: VMAT BREAST ARC’S EYE VIEW

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QUESTIONS?

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