IMRT/VMAT: Practical Treatment Planning

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IMRT Planning: What you need to get started?

• Structures delineated on CT
  • CT with accurate CT numbers
  • Target structures (GTV, CTV, ITV, PTV)
  • Critical Structures
  • Planning organ at risk volumes
  • Planning structures to shape dose
  • Ability to remove (and replace couch) from image

• Clearly defined dose constraints
### Clear Plan Objectives

<table>
<thead>
<tr>
<th>Organ</th>
<th>Plan Goals</th>
<th>Priority</th>
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<tr>
<td>PTV 600 C</td>
<td>V98% ≥ 99% *</td>
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<tr>
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<td>V95% ≥ 95% *</td>
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<td>Rectum</td>
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<td>V65Gy ≤ 17% &amp;</td>
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<td></td>
<td>V70Gy ≤ 10cc</td>
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<td>Bladder (intact prostate) □</td>
<td>V65Gy ≤ 50% $</td>
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<td></td>
<td>V70Gy ≤ 35% $</td>
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<td>V75Gy ≤ 25% $</td>
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<td>V80Gy ≤ 15% $</td>
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<td>Bladder-CTV (post-prostatectomy)</td>
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<td>Femoral Head L</td>
<td>V50Gy ≤ 10%</td>
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<td>Femoral Head R</td>
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<tr>
<td>Penile Bulb</td>
<td>Dmean Mean 52.5Gy *</td>
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</table>

*Note: The table includes objectives for various organs, such as PTVs, composite areas, rectum, bladder (intact prostate), bladder-CTV (post-prostatectomy), femoral heads, and penile bulb. The table lists the target volumes and corresponding priorities assigned to these organs.*
How to Determine Plan Objectives?

• Protocols
• Consensus Guidelines
• Population Based
  • Must know what you are able to achieve through rigorous data collection
• Patient specific factors
• Not all dose objectives have the same impact and should be weighted accordingly.
Planning Process

- Segment
- Enter constraints
- Determine Weights
- Optimize Fluence
- Segmentation
- Full Scatter Calculation
- Evaluate
CT Segmentation
What if Structures Overlap?
Subtract Voxels
Ways to Account for Overlap

• Manually adjust contours to simplify the problem

• Overlap Priority
  • Number in order of priority
  • Set a fraction of the weight to one structure versus another

• Clarifying the overlap is one way that you avoid conflicting goals
Structures to Improve Conformity

Pictures from Philips Pinnacle3 Training Manual
Disclaimer: This is not an endorsed planning method, only an example taken from a clinical plan.
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Structures to Limit Dose to Non-Delineated Structures

Contours for external – PTV or external – (PTV + Margin)

Large avoidance regions in sensitive areas

Pictures from Philips Pinnacle3 Training Manual
Rings multiple dose Levels

7 Rings
Planning Organ at Risk Volumes

Cord PRV for 3 Dose Levels
6996cGy – Blue
5940cGy – Yellow
5412cGy – Green
Optimization PTV (PTV opt)

- Modify the PTV that the optimizer sees if coverage will be impossible
- PTVs should be cropped from the skin surface to avoid facing a very high fluence in air
  - Dangerous for moving targets
- Patient can be scanned with bolus if full dose is desired at the surface.
- Reporting should be clear
How many structures do you need?

• Recommendations from vendor (manual?) or vendor training
• Trial and error
• Create templates/standardize
• Will vary based on the planning system and patient specific factors
• Generally use PRVs around serial organs
Adding Objectives

• Goals should be realistic and not conflicting
• Some structures may require more than one objective
Let’s say these are the objectives:
Prostate – V10Gy ≥ 99%
Rectum – Max dose 4Gy  X
Femoral Head – V5Gy<10%
Bladder – V2Gy<5%  X

It will be harder to ask for things that are not achievable. These conflicts would be worse in the PTV were to overlap with the bladder and rectum.
What about unassigned voxels

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Normal Tissue Objective or BodyExternal Etc.

Ring and Structure will overlap
Final Distribution

Avoids bladder and rectum

More low dose laterally
Planning Strategies

• The order that the objectives are introduced and their weighting may matter
• Read user manual and talk to the vendor
• If you are stuck in a solution of the optimization that is unacceptable, major changes may be required to get out of it (some system require resetting beams)
Modulation

• Tomotherapy defines a modulation factor (maximum divide by average leaf opening for all non-zero leaf openings) but modulation varies in all systems
  • In Tomo, diminishing returns over a MF of 3.0

• High modulation makes delivery verification more difficult and slows treatment time

• May be able to come up with a less modulated solution by limiting intensity levels or simplifying the problem
Field Limits

- Max leaf span is usually limited
- Modulation may be compromised for wider fields
- Can change collimator angles to better cover fields
Interleaf Leakage Considerations
Treatment Couch
How do you know you have the best plan

• You don’t!
• Planner experience and training matters
• Must be able to compare solutions from different optimization attempts
• Planner should be able to compare against other planners (plan challenge/plan scoring)
• Peer review
Commissioning

- IMRT and VMAT can be available usually with small hardware and software upgrades
- Validation can be challenging
- Commissioning is require for both planning and delivery
IMRT/VMAT – MLC tests

• Additional MLC tests may be required
  Dosimetry  
  • Leaf gap  
  • Transmission
  Mechanical  
  • Speed  
  • Positioning

MLC Characteristics

From Shende et al. Reports of Practical Oncology & Radiotherapy Volume 22, Issue 6, November–December 2017, Pages 485-494

A film exposed to the 1-mm-wide picket fence pattern with “intentional” errors in fence width and position.
Image of a film that was exposed twice to the 1-mm-wide picket fence pattern, once at stationary gantry angle and a second time in RapidArc mode.
Film exposed to a RapidArc QA plan, combining different dose-rates, gantry ranges, and gantry speeds, to give the same monitor unit (MU) to the different parts of the field.
MLC Tests for VMAT

RapidArc® MLC

- **Test 0.1**: dMLC Dosimetry
- **Test 0.2**: Picket Fence Test vs. Gantry Angle
- **Test 1.1**: Picket Fence Test during RapidArc®
- **Test 1.2**: Picket Fence Test during RapidArc® with Intentional Errors
- **Test 2**: Accurate Control of Dose Rate and Gantry Speed during RapidArc® Delivery
- **Test 3**: Accurate Control of Leaf Speed during RapidArc® Delivery

RapidArc® is a registered trademark of Varian Medical Systems, Inc.

https://radimage.com/solutions/mlc-qa/
IMRT/VMAT Commissioning - TPS

- AAPM MPPG 5a recommends the following tests
- VMAT, Segmental IMRT, and Dynamic IMRT need to be validated separately

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<thead>
<tr>
<th>Test</th>
<th>Description</th>
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<td>Verify small field PDD</td>
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<td>2</td>
<td>Output for small MLC defined field</td>
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<td>3</td>
<td>AAPM TG-119 tests</td>
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<td>4</td>
<td>Clinical tests</td>
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<tr>
<td>5</td>
<td>External Review</td>
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Other IMRT/VMAT Commissioning


- ESTRO Booklet 9

- Read the manual!