IMRT Planning Basics
AAMD Student Webinar

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Disclosures

The presenter has received speaker honoraria from Varian Medical Systems.

Presentation Sponsored by Varian Medical System

Medical Advice Disclaimer
Varian as a medical device manufacturer cannot and does not recommend specific treatment approaches. Individual treatment results may vary.
Varian Medical Systems
Fair Balance Safety Statement

Intended Use Summary
Varian Medical Systems’ linear accelerators are intended to provide stereotactic radiosurgery and precision radiotherapy for lesions, tumors, and conditions anywhere in the body where radiation treatment is indicated.

Safety
Radiation treatments may cause side effects that can vary depending on the part of the body being treated. The most frequent ones are typically temporary and may include, but are not limited to, irritation to the respiratory, digestive, urinary or reproductive systems, fatigue, nausea, skin irritation, and hair loss. In some patients, they can be severe. Treatment sessions may vary in complexity and time. Radiation treatment is not appropriate for all cancers.
IMRT Planning Concepts

- Definition of IMRT
- Beam setup
- Objectives and NTO
- Optimization
- Fluence smoothing
- Leaf Motion Calculator
- Advanced techniques: base plans, SIB
What is IMRT?

**Intensity Modulated Radiotherapy**

Can include:

- **VMAT:** Volumetric Modulated Arc Radiotherapy aka RapidArc  
  - Conventional fractionation schemes, gantry, dose rate can vary

- **SBRT:** Stereotactic Body Radiotherapy  
  - Higher dose per fraction, extra-cranial, less fractions

- **SRT:** Stereotactic Radiotherapy  
  - Higher dose per fraction, multiple fxs, inter-cranial

- **SRS:** Stereotactic Radiosurgery  
  - Higher dose per fraction, one fraction, inter-cranial

http://aapp.org/blog/health-care-acronyms-wtcheck/
Fixed-Gantry IMRT

Use MLCs to create non-uniform fluences for many fields to create uniform dose distribution within the target that spares critical structures simultaneously.
The MLC: **MultiLeaf Collimator**

“Tertiary” collimator

**Figure 2.** Generic schematic of a photon collimation system with upper and lower jaws and a tertiary multileaf collimator. The Y1 jaw has been omitted for clarity. The field dimensions in the planes at isocenter are indicated.
Common Types of Varian MLC

Millennium 120 MLC
- 0.5 cm inner
- 1 cm outer

HD-MLC
- 0.25 cm inner
- 0.5 cm outer
Leaf Sequencing

MLC leaf sequencing – tells the MLCs how to move in order to deliver given fluence

- **MSS**
  - Multiple static segment
  - “Step-and-shoot”
  - Segmental MLC

- **Sliding Window**
  - Sweeping gap
  - Moving window
Multiple Static Segments

- Beam is placed on hold
- Shape is modified
- MU delivered
Leaves are continuously moving in one direction while beam is on.
Amount of radiation is controlled by the speed of the leaves and the gap between the leaves.
The Optimization Process

1. Physician’s Prescription
2. Define Optimization Objectives
   - Optimize Fluence
     - Calculate Leaf Motions
     - Evaluate Dose Distributions
3. Choose Beam Geometry: BAO/ templates
4. Post-Process Structures: Smooth, Create Opt structures, PRVs, PTV expansions
The Optimization Process

Post-Process Structures: Smooth, Create Opt structures, PRVs, PTV expansions

Choose Beam Geometry: BAO/ templates

Physician’s Prescription

Define Optimization Objectives

Optimize Fluence

Calculate Leaf Motions

Evaluate Dose Distributions
Post-Process Structures

- Creating planning structures such as PTV
- PRV: Planning Organ at Risk Volume
- Smoother PTVs = smoother fluences (more on this later)
- Optimization structures for overlapping structures

ICRU 62 (1999) - "Prescribing, Recording and Reporting Photon Beam Therapy (Supplement to ICRU Report 50)"

The Optimization Process

Post-Process Structures: Smooth, Create Opt structures, PRVs, PTV expansions

Choose Beam Geometry: BAO/ templates

Define Optimization Objectives

Optimize Fluence

Calculate Leaf Motions

Evaluate Dose Distributions

Physician’s Prescription
Field Setup

- **Beam Energy:** At our institution: generally use 6MV or 10MV... avoid >10MV neutron contamination

- **Typical setups:**
  - 9 field Head&Neck
  - 7 field Prostate
  - 5 field Brain
  - Usually 5,7,9* beams evenly spaced
  *notice odd numbers

- **BAO:** Beam Angle Optimizer
Avoid Parallel Opposed Beams

Allow the system better achieve a solution
The parallel opposed fields share the same beamlets/fluence map

5 degrees or more apart are recommended
Field Geometry

Avoid Beams Directed Through Radiosensitive OARs

Non co-planar beams.

Example:
- Avoid Eyes/Lens in Brain Cases
- Vertex Beam (non coplanar)
Optimized Collimator Rotation

Fixed/Locked Jaws

Fixed Field

Pacemaker = 2Gy

Tumor Dose = 48Gy

Jaw Transmission ~ 0.1% compared to MLC ~ 1.5%
But Remember!

- Be practical
  - Time to treat at machine: couch kicks are time consuming
  - Patients can move
- Weigh the benefit of a more complicated plan
- And, be nice to your therapists
The Optimization Process

Post-Process Structures: Smooth, Create Opt structures, PRVs, PTV expansions

Choose Beam Geometry: BAO/ templates

Define Optimization Objectives

Optimize Fluence

Calculate Leaf Motions

Evaluate Dose Distributions

Physician’s Prescription
### Physician’s Prescription

#### Treatment Prescription
- **Rx Status:** Approved
- **Site:** HEAD & NECK
- **Prescription Name:** Right Parotid
- **Start Fractions:** 33
- **Prescribe To:** PTV66 85 Gv 2 Gy / Frac
- **Model:** Photon
- **Technique:** VMAT
- **Primary/Boost:** PRIMARY
- **Energy:** 6X
- **Frequency:** Once Daily

#### Treatment Management
- **Imaging Frequency:** CBCT/PreTx, Other frequency: Daily
- **Simulation:** Yes

#### Prescription Coverage Constraints
- **PTV66**
  - **Min:** 95 %
  - **Max:** 110 %
  - At least: 95 % of PTV66 at 95 %
  - No more than: 20 % of PTV66 at 110 %

#### Organ at Risk Constraints
- **Spinal Cord**
  - Mean: < 45 Gy
- **Brain Stem**
  - Mean: < 45 Gy
- **Left Brachial Plexus**
  - Mean: < 50 Gy
- **Right Brachial Plexus**
  - Mean: < 50 Gy
- **L Eye**
  - Mean: < 45 Gy
- **R Eye**
  - Mean: < 45 Gy

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**PTV and Rx**

**OARs**
Translate Rx to Optimization

Objectives
What the optimizer needs to know…

- Type of objective: upper vs lower
- Normal tissue objective
- Clinical goal dose
- Priority

Note: These are just starting points…optimization is interactive and changes can be made during optimization
3 Types of Objectives
Lower Objectives: PTV

- Used to define "shoulder" of PTV
- Set "Dose" to prescription dose
- Set Priority to 100 (relative)
- Set "Volume" to 100%
Upper Objectives: PTV

Set "Dose" to 105 - 108% of prescription dose

Set "Volume" to 0%

Set Priority to 100 (relative)

Used to define "tail" of PTV
Upper Objectives: OARs

Recall:

Set "Dose" to Goal

Set "Volume" to 0% for MAX

Set Priority (relative)
Upper Objectives: OARs

Recall:

Set "Dose" to Goal

Set "Volume" to 50%

Set Priority (relative)
Normal Tissue Objective

Set Priority (relative)
Virtual “Ring” of Healthy Tissue

4 Parameters

- Distance from target border (cm): 0.3
- Start dose (%): 100
- End dose [%]: 60
- Fall-off: 0.3

X-axis shows distance from tumor surface.
Y-axis shows dose multiplier.

100% 60%
Fluence Smoothing
Fluence Smoothing

- High frequency noise is produced during optimization
- Smoothing helps to remove noise
- Noise can increase modulation, increase MU, and strain MLC delivery
Too **little** smoothing
- Fluence is too noisy
- Increase MU
- Decrease deliverability of the plan

Too **much** smoothing
- Affect your dose gradients
- Effect dose to OARs
- Slow dose fall off to normal tissues

These numbers are weightings similar to “Priority” (relative to PTV)
The Optimization Process

Post-Process Structures: Smooth, Create Opt structures, PRVs, PTV expansions

Choose Beam Geometry: BAO/ templates

Define Optimization Objectives

Optimize Fluence

Calculate Leaf Motions

Evaluate Dose Distributions

Physician’s Prescription
Optimization: The optimizer

Dose Volume Optimizer (DVO)
- Gradient based method
- Try to minimize the overall “penalty”

Gradient methods are quick!

However, you may get stuck in a local minimum

These are often clinically acceptable solutions

Penalty Function

- HUGE animation goes here
Penalty Function: Summary

- Iterative process:
  - Assume an initial set of beamlet weights
  - Compute the dose at point
  - Compare calculated and goal doses
  - Calculate penalty
  - Obtain correction factor to adjust weight of beamlet
  - Apply correction, calculate dose to point
  - Repeat

- Try to find the minimum penalty
Interactive Optimization

- Very user friendly!
- Can observe the progress and modify the dose objectives (volume/dose/weight) in real time
- Helps you make clinical tradeoffs as the plan evolves
The Optimization Process

Post-Process Structures:
- Smooth, Create Opt structures, PRVs, PTV expansions

Choose Beam Geometry:
- BAO/ templates

Define Optimization Objectives

Optimize Fluence

Calculate Leaf Motions

Evaluate Dose Distributions

Physician’s Prescription
Leaf Motion Calculator

Now that we have this optimal fluence we need to deliver this fluence using the MLCs

- Takes into account of dosimetric characteristics of the MLC (transmission, DLG) measured by a physicist during commissioning
- Mechanical limits of the MLC (speed and leaf span)
- Calculates the actual fluence that will be delivered to the patient
- Calculates Monitor Units
Leaf Motion Calculator

Different MLC delivery methods
Final 3D Dose Calculation

- Calculate dose to patient from the fluences and MUs calculated from the LMC
- Use your dose calculation algorithms: Anisotropic Analytic Algorithm (AAA) or Pencil Beam Convolution (PBC)
- Apply heterogeneity corrections
The Optimization Process

Post-Process Structures: Smooth, Create Opt. structures, PRVs, PTV expansions

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Define Optimization Objectives

Optimize Fluence

Calculate Leaf Motions

Evaluate Dose Distributions

Physician’s Prescription
Evaluating Your Plan

Basic Tools:
- Dose Volume Histograms (DVH)
- Dose color wash/ Isodose lines
- “Show DMAX”

What to look for:
- Conformality
- Coverage
- Dose to OARs
- Hot/Cold spots
- Low dose region

CI = \frac{V_{Rx \cap PTV}}{PTV}
Turn ON/OFF structures to simplify
PTV Coverage

95% of the PTV volume RECEIVES 98.5% of the Prescription Dose
## Prescription Review

**Diagnosis:** FRONTAL LOBE  
**Intent:** Unknown  
**Template:**

### Treatment Prescription
- Rx Status: Retired  
- Site: CRANUM  
- Prescription Name: right temporal lobe  
- Start:  
- Fractions: 23  
- Prescribe To: PTV 46 Gy 2 Gy / Frac  
- Mode: Photon  
- Technique: IMRT  
- Primary/Boost: PRIMARY  
- Energy: 6X  
- Frequency: Once Daily

### Treatment Management
- Imaging Frequency: W/W, PreTx, W/W, PreTx  
- Gatings:  
- Bolus:  
- Breakpoints:  
- Labs:  
- Simulation: Yes

### Prescription Coverage Constraints

<table>
<thead>
<tr>
<th>PTV</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>95%</td>
<td>110%</td>
</tr>
</tbody>
</table>

- At least: % of PTV at %
- No more than: % of PTV at %

### Organ at Risk Constraints

<table>
<thead>
<tr>
<th>Optic Chiasm</th>
<th>Mean</th>
<th>&lt;</th>
<th>Gy</th>
</tr>
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<tbody>
<tr>
<td>Max</td>
<td>&lt;</td>
<td>Gy</td>
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<tr>
<td>Any volume</td>
<td>&lt;</td>
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<table>
<thead>
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<th>Optic Nerve</th>
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<td>Gy</td>
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<tr>
<td>Any volume</td>
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<table>
<thead>
<tr>
<th>Brain Stem</th>
<th>Mean</th>
<th>&lt;</th>
<th>Gy</th>
</tr>
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<tbody>
<tr>
<td>Max</td>
<td>&lt;</td>
<td>Gy</td>
<td></td>
</tr>
<tr>
<td>Any volume</td>
<td>&lt;</td>
<td>46</td>
<td></td>
</tr>
</tbody>
</table>

- Use OAR constraints if contoured

**Approved:** Tue, 1/21/2014 at 2:00 PM EST
Glioma: PTV46

Default: No plan normalization
Normalization Methods

- Some methods are more suitable for 3D, such as "points" or isocenter
- Easy normalization by scaling
- Or according to physician’s Rx or preference
95% of the PTV volume RECEIVES 100% of the Prescription Dose.
Remember your OAR doses will scale up as well!
<table>
<thead>
<tr>
<th>Field</th>
<th>Dose (Gy)</th>
<th>Prescription</th>
<th>Field Alignments</th>
<th>Plan Objectives</th>
<th>Optimization Objectives</th>
<th>Dose Statistics</th>
<th>Calculation Models</th>
<th>Plan Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTV 46</td>
<td>46.000</td>
<td>2.000</td>
<td>20</td>
<td>46.000</td>
<td>PTV [PTV opt]</td>
<td>100.0</td>
<td>100.0</td>
<td>No plan normalization</td>
</tr>
</tbody>
</table>

**Notes:**
- The image shows a medical scan with dose distribution for PTV 46.
- The table details the dose prescription and characteristics for the plan.

**Image Details:**
- The scan includes color-coded dose distributions for different regions, likely indicating radiation therapy planning.
- The software interface indicates various planning parameters and dose settings.

**Image Source:**
- Henry Ford Health System.
Conformality
Advanced Techniques

SIB:
Simultaneous Integrated Boost
Different volumes going to different doses
Thank you!
And, Thank you to all the dosimetrist!