IMRT-Theory and Practice

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Dosimetry Review Course, 2009

UT Health Science Center San Antonio

Agenda

- What is IMRT?
- Why use IMRT?
- What needed for IMRT?
- How to do IMRT plan?
- How to deliver IMRT plan?

What is IMRT?

I'M Really Tired?

Intensity Modulated RadioTherapy

What is intensity?

- In physics, **intensity** is a measure of the time-averaged energy flux (http://en.wikipedia.org/wiki/Intensity) ☹
- How about brightness?

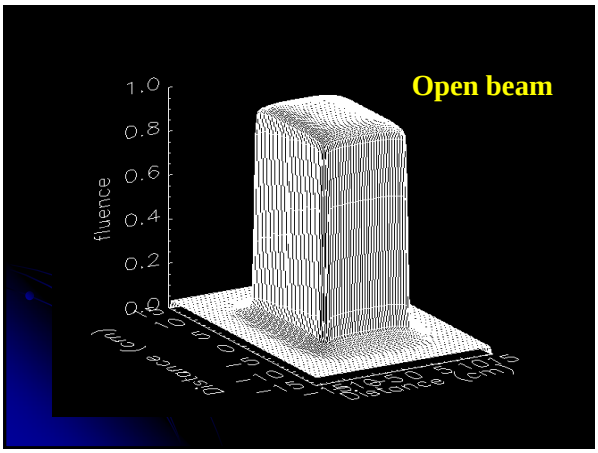
- How about beam amount?

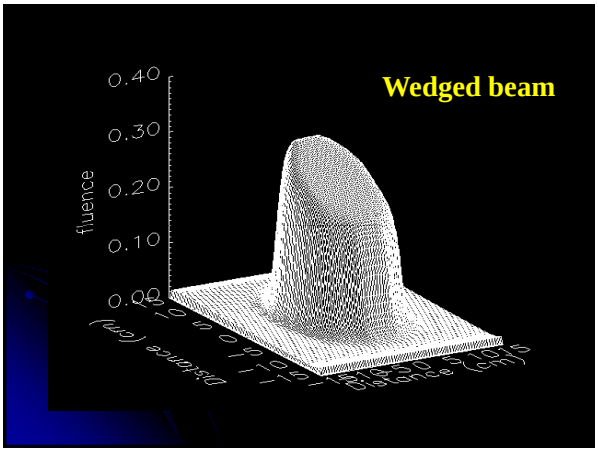
What is modulation?

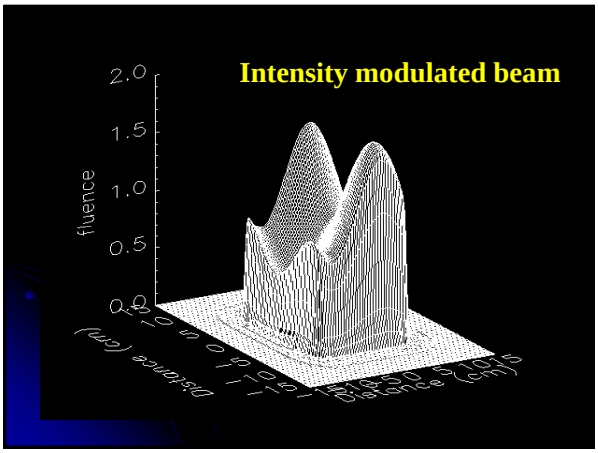
- In telecommunications, **modulation** is the process of varying a periodic waveform, i.e. a tone, in order to use that signal to convey a message, in a similar fashion as a musician may modulate the tone from a musical instrument by varying its volume, timing and pitch. ☹
- How about adjust the brightness or amount?

What is IMRT?

- In Dr. Shi's word, IMRT means adjusting the beam amount to do radiotherapy.


Open beam
1.0
0.8
0.6
0.4
0.2
0.0
fluence


Wedged beam
0.40
0.30
0.20
0.10
0.00
fluence


Intensity modulated beam
2.0
1.5
1.0
0.5
0.0
fluence

Agenda

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- What needed for IMRT?
- How to do IMRT plan?
- How to deliver IMRT plan?

Why use IMRT?

- Clinical benefits
  - Complex target shapes
  - Conformal radiation dose to PTV
  - Decrease complications
  - Increase dose to target

Why use IMRT?

- Economical benefits
  - Higher reimbursement rate
  - More complexity, higher cure rate?
  - More man-power, more jobs?

Agenda

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What needed for IMRT?

- Facility Issues:
  - Machine with IMRT ability
  - Shielding requirement
  - Network (DICOM-RT)
- Staffing Issues:
  - Physics
  - Dosimetry
  - Others (therapists, nurses etc.)

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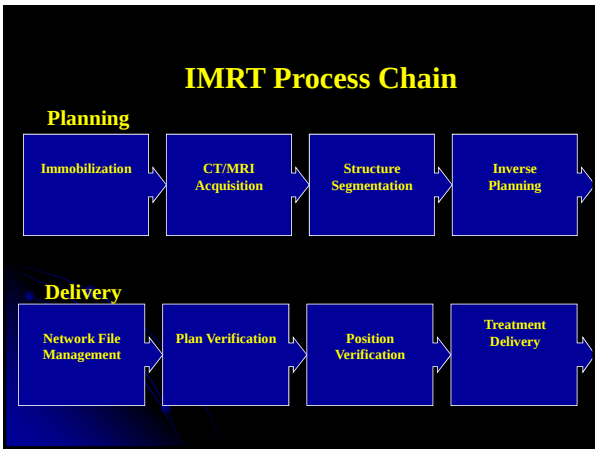
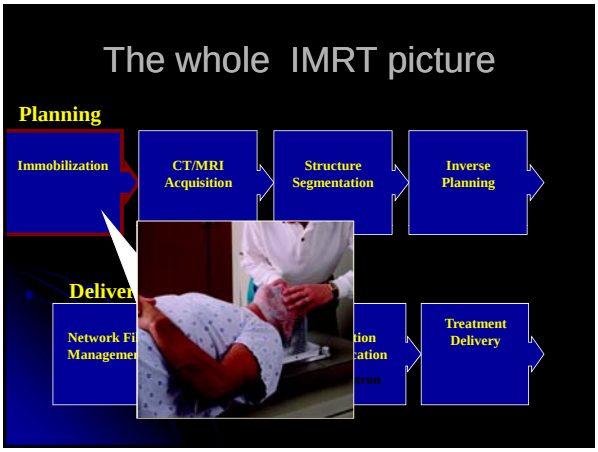
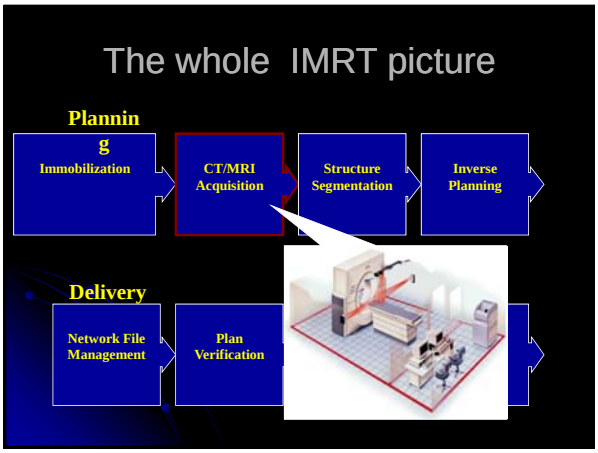

IMRT Process Chain
Planning
Immobilization
CT/MRI Acquisition
Structure Segmentation
Inverse Planning
Delivery
Network File Management
Plan Verification
Position Verification
Treatment Delivery


The whole IMRT picture
Planning
Immobilization
CT/MRI Acquisition
Structure Segmentation
Inverse Planning
Treatment Delivery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Plannin g
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Plan Verification

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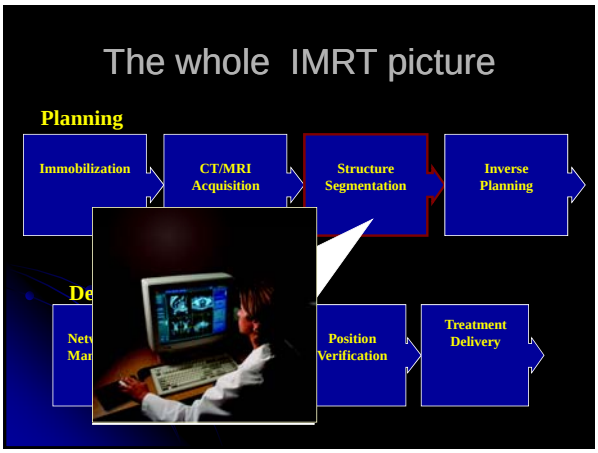

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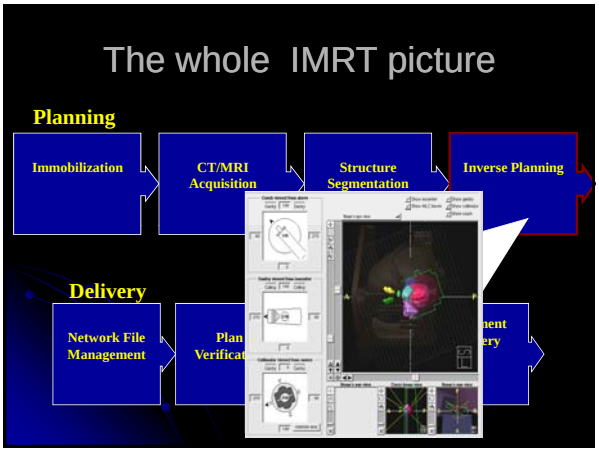

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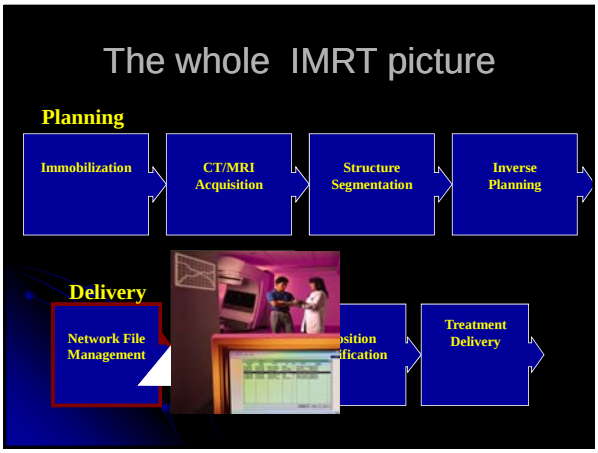

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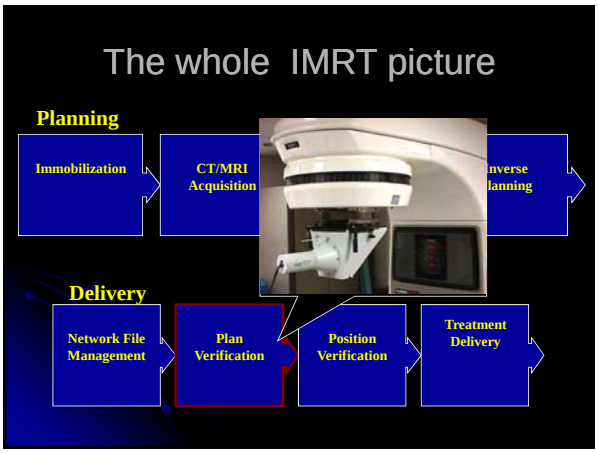

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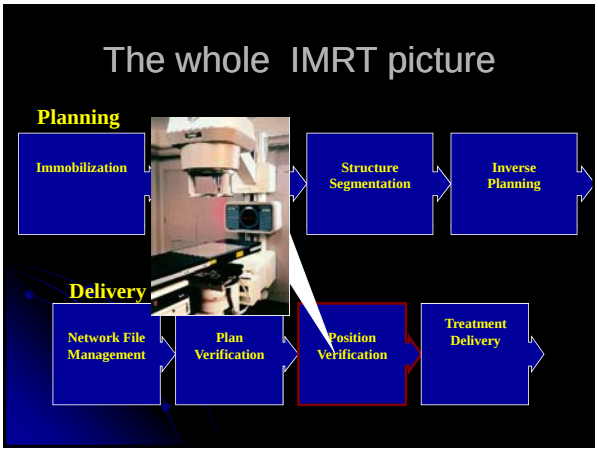

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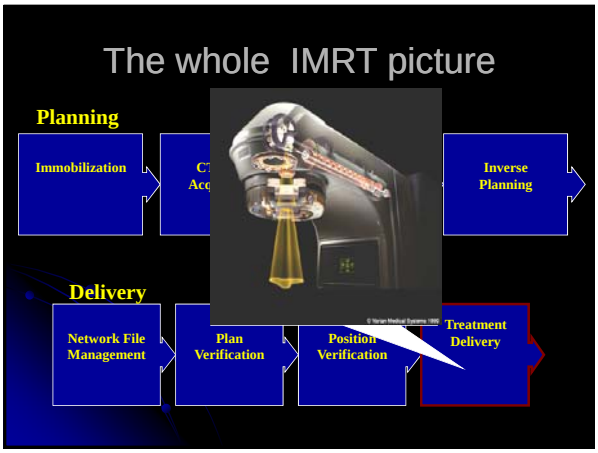
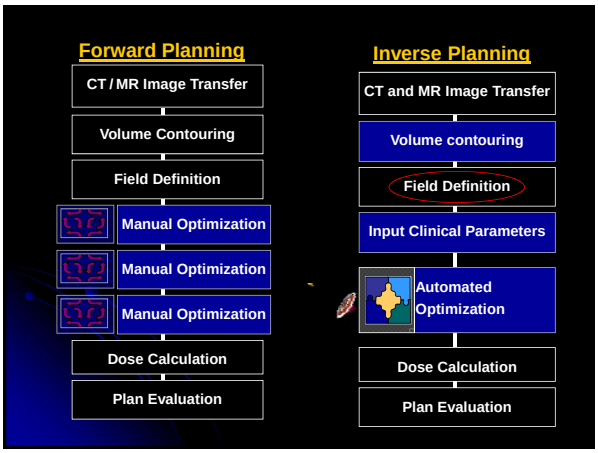
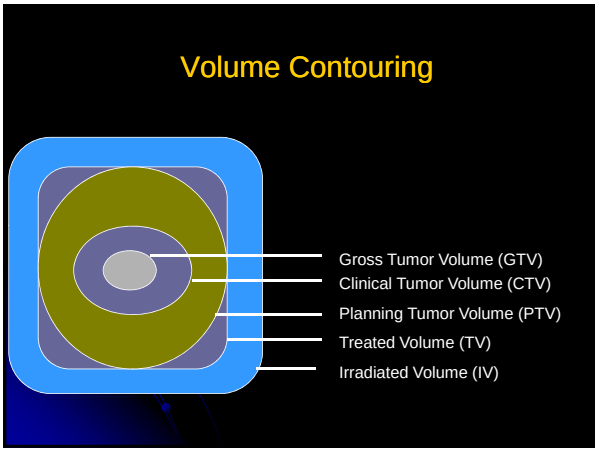
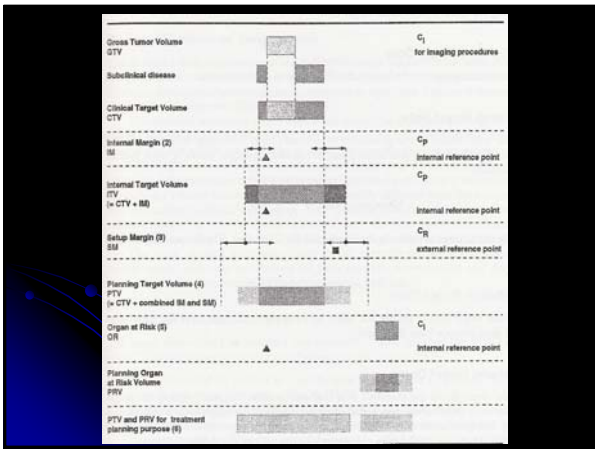



Forward Planning
CT / MR Image Transfer
Volume Contouring
Field Definition
Manual Optimization
Manual Optimization
Manual Optimization
Dose Calculation
Plan Evaluation
Inverse Planning
CT and MR Image Transfer
Volume contouring
Field Definition
Input Clinical Parameters
Automated Optimization
Dose Calculation
Plan Evaluation

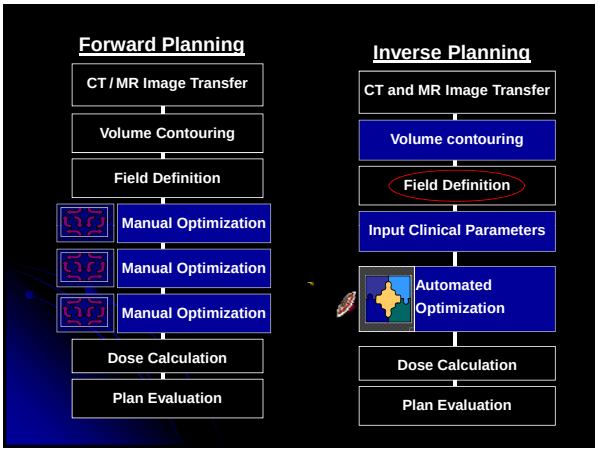

Volume Contouring
Gross Tumor Volume (GTV)
Clinical Tumor Volume (CTV)
Planning Tumor Volume (PTV)
Treated Volume (TV)
Irradiated Volume (IV)



Volume Contouring

Dummy Contours:

1.Ring---help to shape dose gradient in around target
2.Avoid structure---help to protect organ at risk
3.Other helpful structures



Field Definition

• In theory, the more fields you have, the better solution will be.
•In reality, treatment efficiency and limitation needs to be considered.
• Co-planar fields are preferred, no opposite fields.

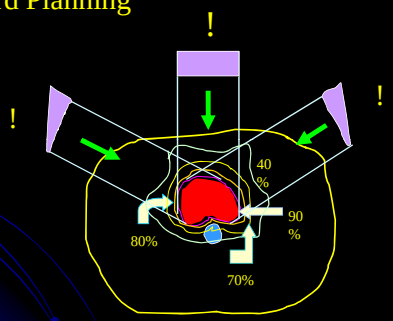
How can we determine the individual beamlet weights for IMRT ?

Conventional treatment planning starts with a set of beam weights and obtains a plan by a trial-and-error process.

This procedure won't work for IMRT since there are too many unknowns (>2000 beamlet weights).

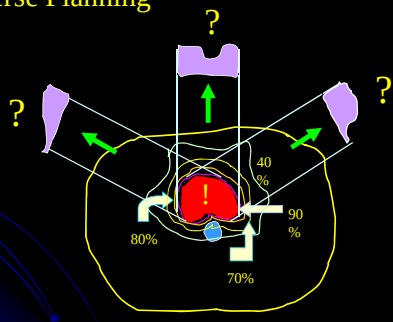
Conventional Treatment Planning

Forward Planning

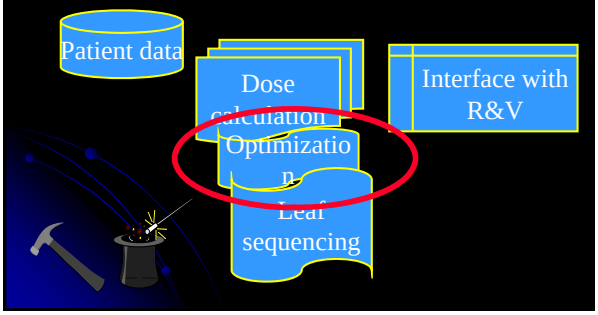


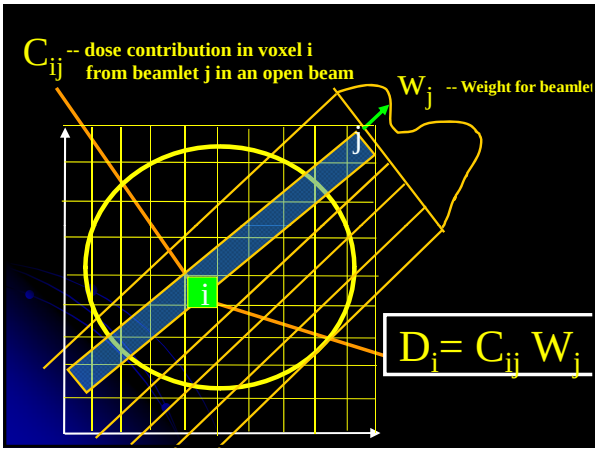
IMRT Treatment Planning

Inverse Planning

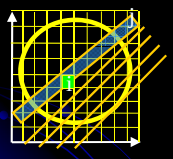


What is in an Inverse Planning System?





Dose Calculation for IMRT



- Total dose in voxel i

$$D_i = \sum_{j=1-n} C_{ij} W_j$$

- Or dose in any voxel in a more generic form

$$\mathbf{D = CW}$$

What's Inverse Planning ?

- Assume D_0 is the desired dose

$$\mathbf{D}_0 = \mathbf{C}\mathbf{W}_0$$

- and W_0 the required beamlet weights and we

$$\mathbf{W}_0 = \mathbf{D}_0/\mathbf{C} = \mathbf{D}_0\mathbf{C}^{-1}$$

$\mathbf{W}_0 = \mathbf{D}_0\mathbf{C}^{-1}$ is an exact mathematical expression of inversely derived beamlet weights for a desired dose distribution $\mathbf{D}_0$

However,

Unfortunately this inverse process does not work in most, if not all, realistic treatment cases.

Practically, what we want is a set of beamlet weights that will give us the best available dose distribution !

A Simple Example

Donation!

Suppose we have enough money to donate and we only donate in unit of 1 $.

Case 1:

Donate $1 from one person.

Solution: only 1 result.

A Simple Example

Case 2:
Donate $2 from two persons.

Solution: 3 possible results.
$2 for #1, $0 for #2 2 0
$1 for #1, $1 for #2 1 1
$0 for #1, $2 for #2 0 2

A Simple Example

Case 3:
Donate $3 from three persons.

Solution: How many possible results?

3 0 0 1 2 0 0 3 0 0 1 2 (10 results)
2 1 0 1 0 2 0 0 3
2 0 1 1 1 1 0 2 1

A Simple Example

Case 4:
Donate $4 from four persons.

Solution: How many possible results?

4 0 0 0 ; 3 1 0 0 ; 3 0 1 0; 3 0 0 1;
2 2 0 0 ; 2 0 2 0; 2 0 0 2; 2 1 0 1;
2 0 1 1 ; 2 1 1 0; 1 3 0 0; 1 0 3 0;
1 0 0 3 ; 1 2 0 1; 1 2 1 0; 1 1 2 0;
1 1 0 2 ; 1 0 2 1; 1 0 1 2; 1 1 1 1;
0 4 0 0 ; 0 0 4 0; 0 0 0 4; 0 3 1 0
0 3 0 1 ; 0 2 2 0; 0 2 0 2; 0 2 1 1; 0 1 3 0
0 1 0 3 ; 0 1 2 1; 0 1 1 2; 0 0 4 0; 0 0 0 4
0 0 3 1 ; 0 0 1 3; 0 0 2 2;. (37 results)

A Simple Example?

How about $5 from 5 persons? Do you still think it is a simple example?

Results:

Think about 2000 beamlets!

What's Our Solution ?

- Assume D_0 is the desired dose and W_0 the required beamlet weights

$$\mathbf{D}_0 = \mathbf{C}\mathbf{W}_0$$

Ideal but may be a pie in the sky!

- What we want is to derive D_b the "best achievable" dose and W_b the corresponding beamlet weights

$$\mathbf{D}_b = \mathbf{C}\mathbf{W}_b$$

Not ideal but achievable

The question is how do we know D_b is good enough compared with D_0?

What's an Objective Function ?

- An objective function is a mathematical evaluation of a treatment dose distribution (wrt. the desired dose distribution).

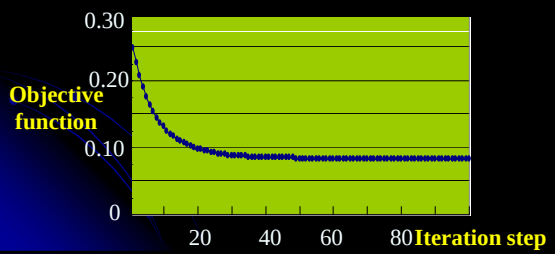
$$Objective function = f(D_0 - D_b) \text{ or } f(D_0, D_b)$$

- Ideally, it should include all of our knowledge of radiotherapy: physical as well as biological dosimetric requirements.
- The question now is how to "optimize" a given objective function.

A Sample Objective Function

- A simple dose-based objective function takes the form

$$O = \{D_0(1) - D_b(1)\}^2 + \{D_0(2) - D_b(2)\}^2 \ldots$$



Back to our example

P1+P2+P3+P4+P5=5

$f=(P1+P2+P3+P4+P5-5)^2$

Initial guess: P1=P2=P3=P4=P5=0

$f_0=25$

1st iteration: P1=1, P2=P3=P4=P5=0

$f_1=16$ (right direction!)

2nd iteration: P1=2, P2=P3=P4=P5=0
f_2=9 (right direction!)
3rd iteration: P1=3, P2=P3=P4=P5=0
f_3=4 (right direction!)
4th iteration: P1=4, P2=P3=P4=P5=0
f_4=1 (right direction!)
5th iteration: P1=5, P2=P3=P4=P5=0
f_5=0 (Bingo!)

DISCUSSIONS!

What can we learn from the example?

Initial guess or initial value is important!
Think about P1=9999999999

Objective function is important!

Need constrains to find a "good" result!

Optimization of a Multi-Dimensional Objective Function

Computer simulated annealing (Corvus)

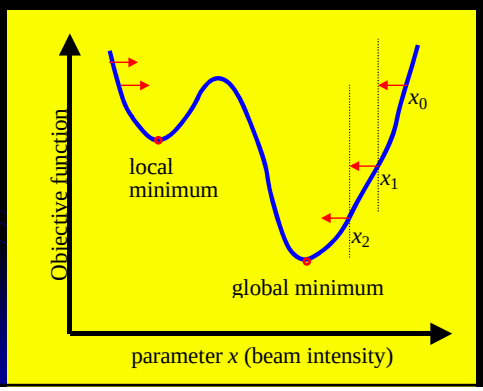
Gradient method (Helios, Pinnacle)

Filtered back-projection (Konrad)

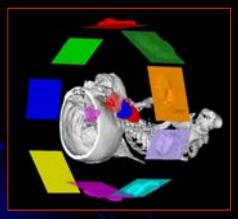
Least squares minimization (Tomotherapy)

Others…

Problem:



Philips Radiation Oncology Systems



presents:

Inverse Planning with P³IMRT

Isocenter placement

- Center of the target volume
- Geometric center of all targets
  - Specify your treatment prescription to a normalization POI located within the CTV or PTV
- Consider any dosimetry, QA, or patient setup issues that might be affected by the isocenter location

Regions of interest (ROIs)

- You must delineate every target area that requires dose, and every critical structure
- You will generally contour more ROIs than you do for 3D planning
- You may add additional margins around critical structures to partially account for organ motion, patient movement and setup uncertainties
- Try to avoid extending ROIs outside the patient's external contour

Number of beams

- To reduce planning, setup, and delivery time, do not use more beams than are necessary to meet your treatment objectives
- An acceptable IMRT plan can usually be generated using 5 to 9 beams
- The number of beams required may depend on the complexity of the target shape and its proximity to critical structures

Beam directions

- Try using equally-spaced coplanar beams
- Select directions that not only produce the best possible dose distribution, but also maximize the ease of planning, setup, and delivery
- Use a Hot Script to place a standard beam set
- Try to angle the beams to miss critical structures, the treatment table, and immobilization devices
- Try to avoid using opposing beams
- You can use non-coplanar beam arrangements if necessary

Beam modifiers

- Unless you plan to treat with a compensator, do not add blocks
- You can add wedges for intensity-modulated beams if you think it will improve the plan
- Do not turn on MLCs (the program will turn on MLCs during the control point conversion)
- Do not leave the autosurround function turned on

Beam weights

Weight all beams equally before you begin the optimization to give the algorithm a better starting position

Collimator rotation

To maximize the blocking of a critical structure, you may rotate the collimator for each beam so that the MLC leaves are as close to perpendicular to the long axis of the tumor as possible

Setting Initial beam sizes

1. Turn on the 3D wireframe display for all target ROIs and critical structures
2. Open a BEV window and set the display to Current beam
3. Set the jaws for the first beam to asymmetric
4. Place the jaws to fully expose the objective ROIs plus a 1.5 cm margin (blocking critical structures as much as possible with the jaws)
5. Copy the first beam
6. Change the gantry angle for the second beam
7. Adjust the jaws for the second beam
8. Repeat for all beams

This can all be done with a Hot Script!

Dose-based objectives and constraints

Define the dose levels for the target volume and the organs at risk.

Objectives are defined using:

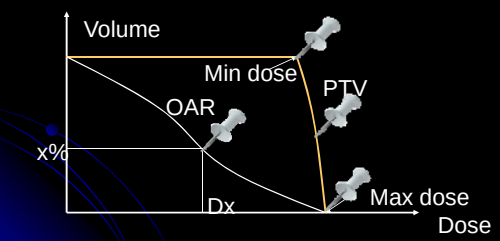
- Minimum and/or maximum dose
- Minimum and/or maximum dose per volume of tissue
- Uniform dose

Constraints are defined using:

- Minimum and/or maximum dose
- Minimum and/or maximum dose per volume of tissue
- Dose uniformity

Constrains Lists

Tumor constrains
Sensitive structure constrains



Blocked: None, complete, directional

Defining objectives and constraints

Try defining only objectives first. If the treatment goals cannot be achieved by adjusting the weights of the objectives, then add constraints.

Adding constraints to a trial makes the optimization slower because constraints require the optimization algorithm to use more memory than objectives do, but the overall optimization may require fewer iterations to achieve the treatment goals.

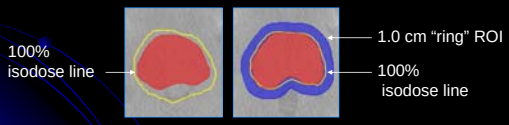
Target objectives

- Start with the target objectives and constraints
- Target objectives will normally be weighted higher than critical structure objectives
- You can specify Min Dose and Max Dose objectives, or a single Uniform Dose objective
- A Uniform Dose or Min Dose objective may be used in combination with a Uniformity constraint
- Don't specify a Min Dose objective to a target that extends into the buildup region or outside the patient's external contour

Using "ring" ROIs

Create a "ring" ROI to conform the dose more closely to the target

1. Create an expanded target ROI plus 0.5 to 1.5 cm
2. Create a "ring" ROI by subtracting the target ROI (and any intersecting critical structures) from the expanded ROI
3. Specify a Max Dose objective for the "ring" ROI between 100% and 95% of the prescribed target dose



Critical structure objectives

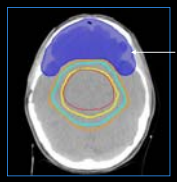
- Developing objectives and constraints that will result in an optimal plan is an iterative process
- Avoid unrealistic or conflicting objectives
- Use the DVHs from your 3D plans as a guide
- Use DVH-based objectives for overlapping structures
- Set objectives aggressively to pull the dose down as low as possible

Critical structure objectives

- Add additional low-weighted objectives to some or all critical structures
- Use dose-shaping ROIs
- Use surrounding tissue ROIs to reduce dose outside the targets

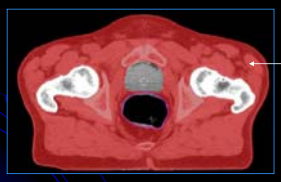
Dose-shaping ROIs

Creating a “dose-shaping” ROI can help the optimization algorithm overachieve goals and direct dose to specific areas. They do not have to correspond to specific anatomical structures.



Surrounding tissue ROIs

A surrounding tissue ROI consists of an external patient contour with other target and critical structure ROIs removed from it. Assign a Max Dose or Max DVH objective to the surrounding tissue ROI.



Protocols

Protocols are stored settings of objectives and constraints. You can create protocols for common classes of treatment specific to your clinic. Tools for loading, adding, saving, and deleting protocols are located on the Optimization panel.

Optimization options

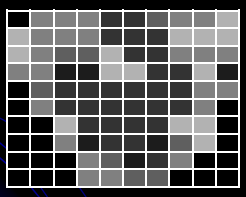
- Intensity modulation
- Beam weight
  - Useful for 3D and IMRT plans
  - Useful for mixed modality plans
- Segment weight
  - Useful for inverse and forward IMRT plans
- No optimization
  - Useful for IMRT boosts and plans for previously treated patients

Optimization

- The optimization algorithm will usually find an optimal solution in 25 to 50 iterations
- It is generally best to optimize for 25 iterations, slightly adjust your objectives and constraints, then optimize again
- When optimizing again, you may want to turn off the convolution calculation to improve the speed
- You may stop the optimization at any time
- If you change beam parameters, add additional objectives, or make significant changes to your current objectives, you should reset the ODM and reset your Prescription prior to restarting optimization

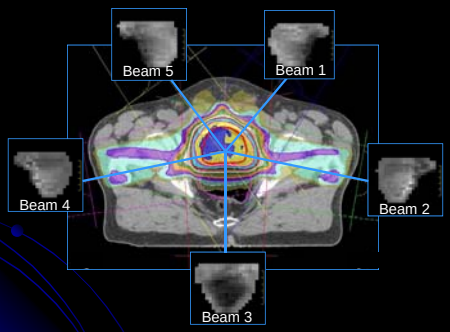
Pencil beam optimization

The intensity of each 5mm x 5mm pencil beam is modulated during optimization. The dose matrix will be recomputed using convolution after a user-specified number of iterations.

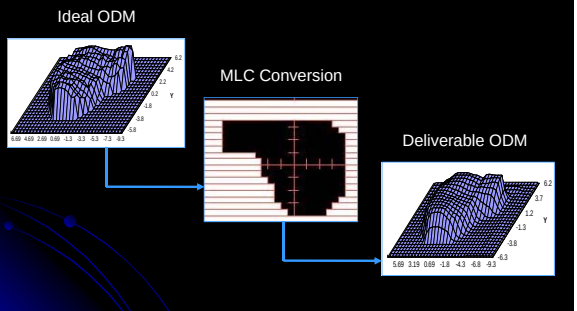


For 5 beams, each 10 x 10 cm, this results in about 400 pencils per beam, or 2000 adjustable parameters!

Optimization produces ideal ODMs



MLC conversion



Conversion algorithms

- K-Means clustering
  - Varian
  - Elekta
  - Mitsubishi
  - Siemens
- IMFAST
  - Siemens
- Physical compensators

Jaw Settings

- Conform to ODM
  - Varian
- Conform to segment
  - Siemens
  - Elekta

Head scatter correction method

- In most cases, final accuracy will be similar for both the Simplex and Matrix inversion methods
- For beams which will have many small-field control points after conversion, the Simplex method may more accurately reproduce the dose after optimization

Error tolerance % (K-means)

- Decreasing the error tolerance % increases the number of clustered intensity levels
- Decreasing the error tolerance % increases the number of control points
- Increasing the error tolerance % decreases the accuracy of the dose distribution
- Increasing the error tolerance % decreases the number of small control points
- The best results are usually achieved with an error tolerance of 3 - 5%

Number of levels (IMFAST)

- The number of levels is number of discrete fluence levels to be used by the clustering algorithm
- Increasing the number of levels increases the accuracy of the dose
- Increasing the number of levels increases the number of control points
- The number of levels should generally be set between 5 and 20
- The number of control points will roughly correspond to the number of levels selected

Number of extracts (IMFAST)

An extract is a deliverable segment shape whose opening densities in the clustered ODM are all larger or equal to a specific minimum value. The extraction process looks for the largest such extract, subtracts it from the clustered ODM, and continues until the user-specified number of extracts have been segmented. The remainder of the clustered ODM will be converted to segments using a method which seeks to minimize delivery time.

The number of extracts should generally be set between 1 and 10.

Minimum segment MUs

- Will degrade the accuracy of the conversion and make the conversion slower
- Should only be used to address the limitations of your linear accelerator

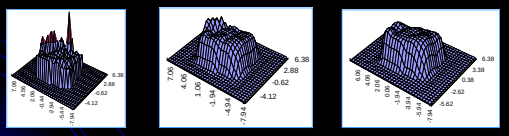
Minimum segment area (cm^2)

- Will degrade the accuracy of the conversion and make the conversion slower

Filter ODM prior to conversion

- Filters the ODM by applying a 3x3 pixel median filter to the ODM prior to conversion
- Removes large spikes from the ODM
- Generally results in fewer control points to deliver the smoother ODM

Ideal ODM | Deliverable unfiltered ODM | Deliverable filtered ODM



Compute ODM difference

- The ODM difference shows the difference between the deliverable ODM and the ideal ODM for the selected beam
  - Black areas where less dose will be delivered by the beam than would have been delivered by the ideal ODM
  - White areas where more dose will be delivered by the beam than would have been delivered by the ideal ODM
  - Shades of grey show the varying degrees of difference between the ideal and deliverable ODMs
- You can use the ODM difference to determine if the dose distribution from the deliverable ODM is acceptable before you calculate dose

Segment weight optimization

- If some of your objectives are not met by the plan after segment conversion, running segment weight optimization immediately after conversion will generally produce a better plan
- Before running segment weight optimization, change your objectives to match the results achieved during optimization to ensure that the dose to those structures is not increased during segment weight optimization

Segment weight optimization

- Since the dose for each control point must be computed for each beam prior to optimization, you can reduce the overall optimization time by selecting Adaptive Convolve rather than CC Convolve prior to starting optimization
- Delete any very low (or zero) weighted control points produced during segment weight optimization prior to delivery

Final plan evaluation

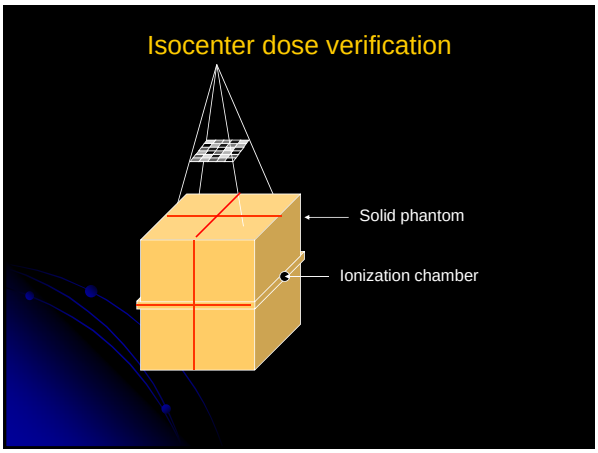
- Review the DVHs
- Review ROI statistics (min, mean, max dose)
- Adjust your prescription percentage if it improves the plan
- Review the isodose distribution in one or more planes
- Review 3D dose clouds
- Check the maximum dose for the plan
- Use multiple trials to compare several plans
- Remember that there may be several different dose distributions that satisfy the same set of dose-based objectives

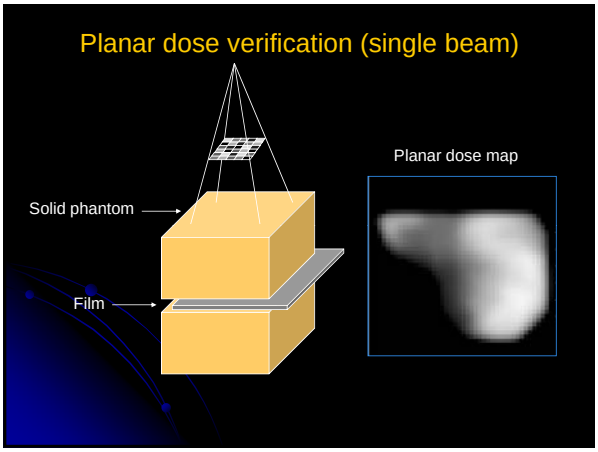
Export plan for QA and delivery

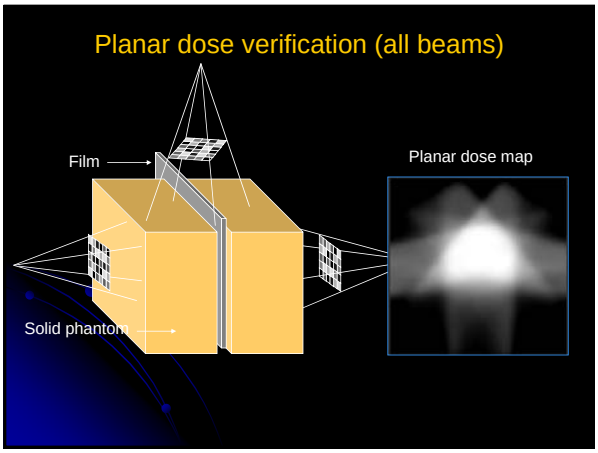
- Export DICOM-RT Plan and Structure Set to VARiS, LANTIS, IMPAC, Elekta
- Export to Varian Shaper
- Export via DME to Mitsubishi (Works in progress – not yet available)

P^{3}IMRT QA tools

- Automatically generate orthogonal DRRs to verify isocenter placement
- Use the profile tool to view the dose profile across the plan between any two points
- Compute the dose distribution for any beam at a given depth in a flat water phantom
- Compute the dose distribution at any plane in the dose matrix
- Transfer the beams from an IMRT plan to a user-defined QA phantom
- Compatibility with film dosimetry systems


Isocenter dose verification
Solid phantom
Ionization chamber


Planar dose verification (single beam)
Planar dose map
Solid phantom
Film


Planar dose verification (all beams)
Film
Planar dose map
Solid phantom

Physics considerations

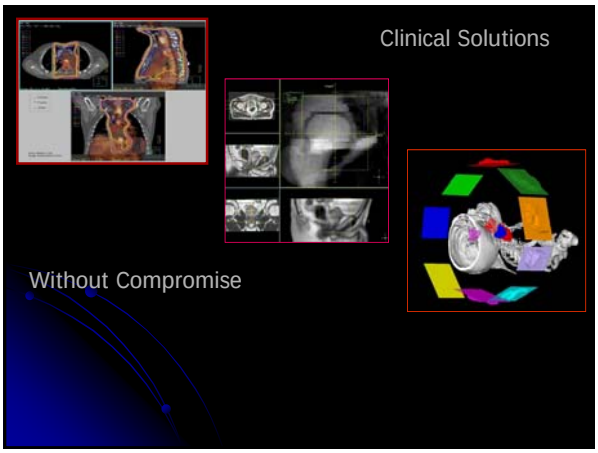
- Make sure your machines are set up to use the correct precision for monitor units. If you do not set the MU precision accurately for your machine, the beam weights delivered will not be exactly the same as those in the plan due to rounding. For most plans, typical fields have a large number of monitor units, so this is a relatively small effect. However, in IMRT, some fields may have a small number of monitor units, so this rounding becomes more important.

Physics considerations

- IMRT involves the use of very small, heavily blocked fields. Validate your machine beam models at each field size you are likely to treat prior to creating IMRT plans. If your MLC is set to replace the jaws, the field size is the actual open area of the field.
- Verify the MLC parameters for each of your machines in the MLC Editor window.

Physics considerations

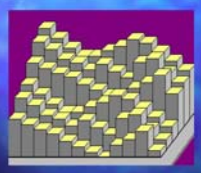
- Verify that the MLCs on your Varian machines are commissioned to allow the leaves to interdigitate. If the "Allow opposite adjacent leaves to overlap" option is set to 'Yes' in the MLC Editor window in the physics tools, then the leaves are allowed to interdigitate. Enabling this option allows Pinnacle to move the junctions between closed leaf pairs underneath the jaws during conversion. If this option is not enabled, the junctions may be positioned within the field.



Agenda

- What is IMRT?
- Why use IMRT?
- What needed for IMRT?
- How to do IMRT plan?
- How to deliver IMRT plan?

Physical Compensators



Physical compensators modulate the intensity by differential attenuation of the x-ray field

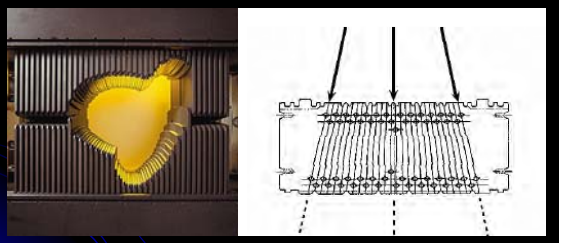
Advantages of Compensator

- Physician and Physicists are more comfortable with the concept of physical compensator than dynamic MLCs
- Milled compensators come the closest to delivering the theoretical intensity maps that inverse planning computers generate
- Compensator based IMRT can be implemented on older linear accelerators without MLCs

Disadvantages of Compensator

- Compensators are costly to manufacture and not reimbursable under the IMRT billing codes G0174 or 77418
- Treatment times are longer because of beam attenuation and the need to physically change the compensators between fields

Multi-Leaf Collimator (MLC)



Properties of MLC

- MLC transmission

  Intra-leaf transmission 0.8%~1.5%

  Inter-leaf leakage 1.1%~2.5%
- Tongue-and groove

  The tongue-and groove design is employed to prevent the primary beam passing between the leafs unattenuated.
- Leaf end design

  The round leaf end caused a nonlinear dependence of field size on leaf position.

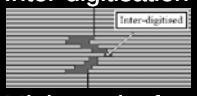
MLC Comparison

Description	Elekta	Seimens	Varian*
Leaf Travel	20cm to -12.5cm	20cm to -10cm	14.5 cm* relative to most retracted leaf
Max Leaf Speed	2.0 cm/sec	2.0 cm/sec	2.5 cm/sec
Interdigitization?	No	No	Yes
Minimum leaf gap	5.0 mm	0.0	0.5 mm
Rounded Leaf end?	Y	N	Y
Jaw Replacement	Upper	Lower	Tertiary
Delivery mechanism	SMLC	SMLC	DMLC or SMLC
Control System	Linac	Linac	Controller workstation
Monitoring	Video	Potentiometers	Potentiometers

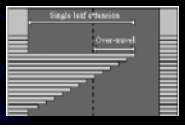
*Differences exist between Mark II and Milennium MLC systems

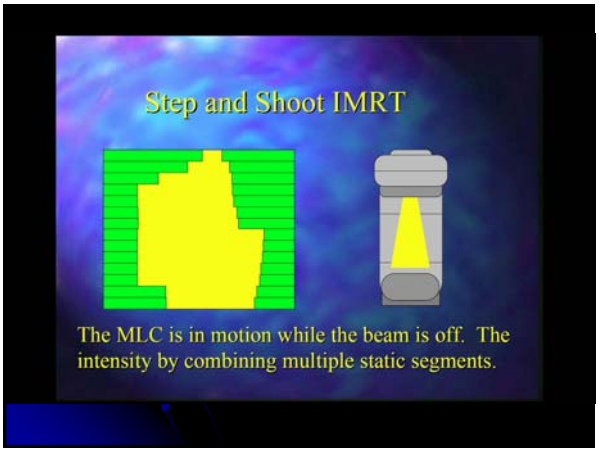
Constraints of MLC

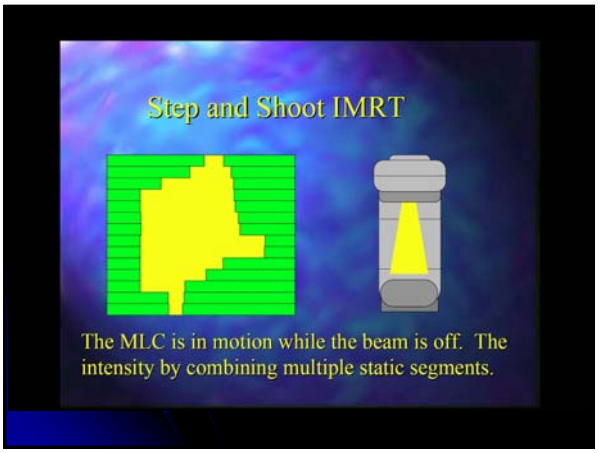
- Inter-digitisation

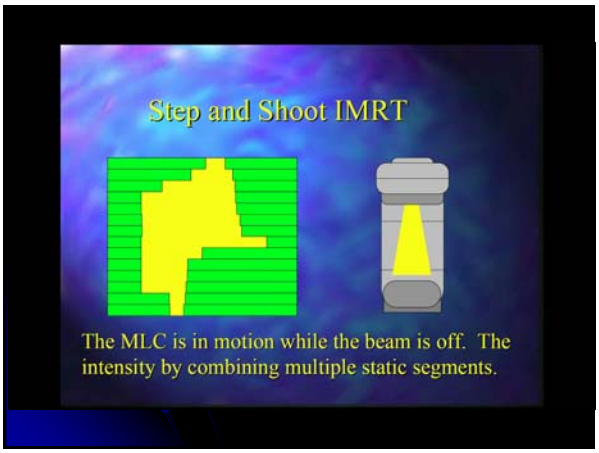


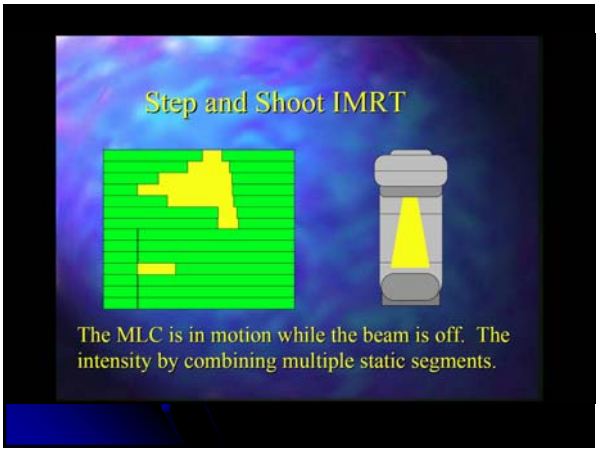
- Minimum leaf gap
- Leaf velocity
- Single leaf extension & Over-travel








Step and Shoot IMRT
The MLC is in motion while the beam is off. The intensity by combining multiple static segments.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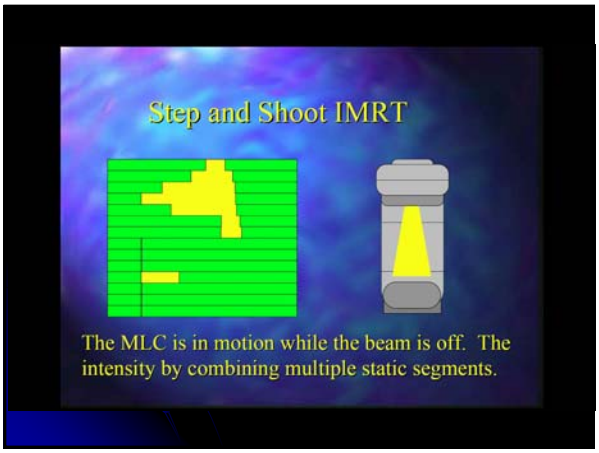
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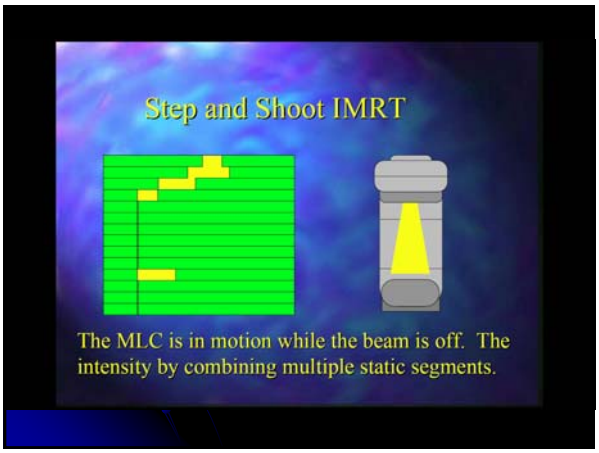
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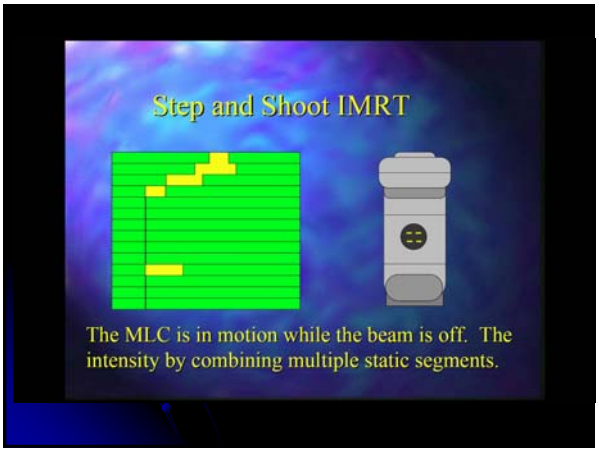
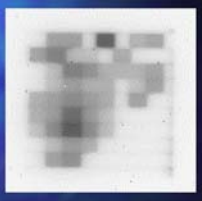

Step and Shoot IMRT
The MLC is in motion while the beam is off. The intensity by combining multiple static segments.

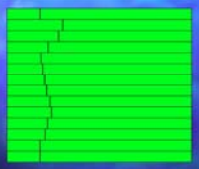

Advantages of Step-and-Shoot
By its very nature, the Step-and-Shoot technique is dosimetrically the easiest form of IMRT to verify
Siemens, Varian, and Elekta linear accelerators all support this delivery technique

Disadvantages of Step-and-Shoot

- May require large number of segments to achieve an acceptable deliverable dose
- Leaf sequencing often results in a "checkerboard" effect with multiple 1x1 cm or smaller sub-segments

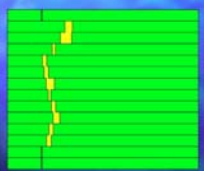


Sliding Window IMRT



The MLC is in motion while the beam is on. The intensity is modulated by varying the gap width

Sliding Window IMRT



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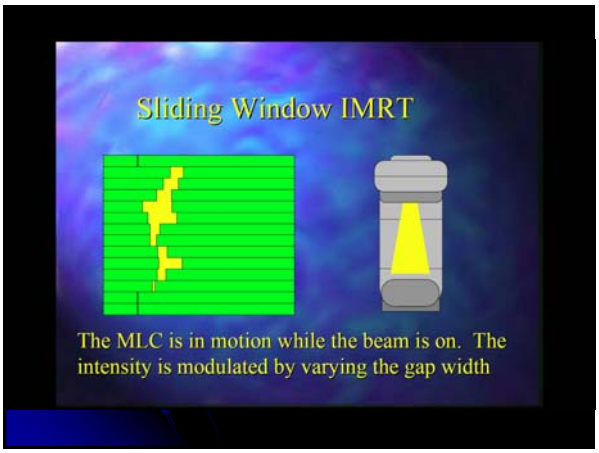
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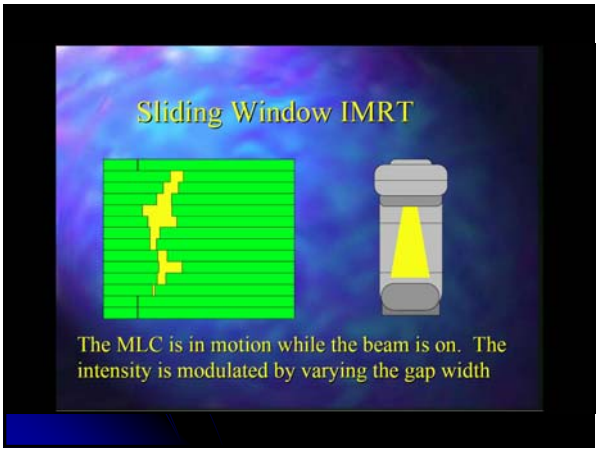
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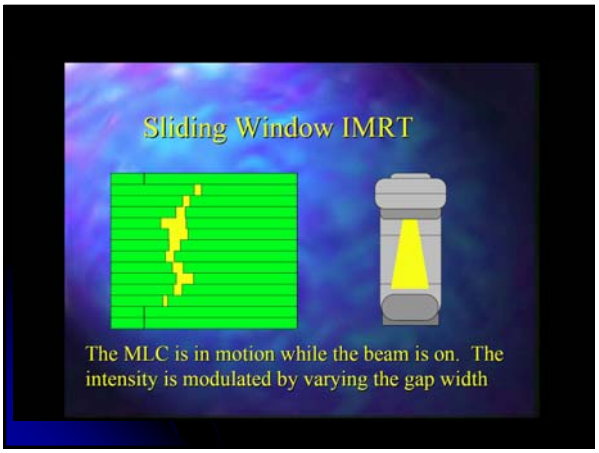
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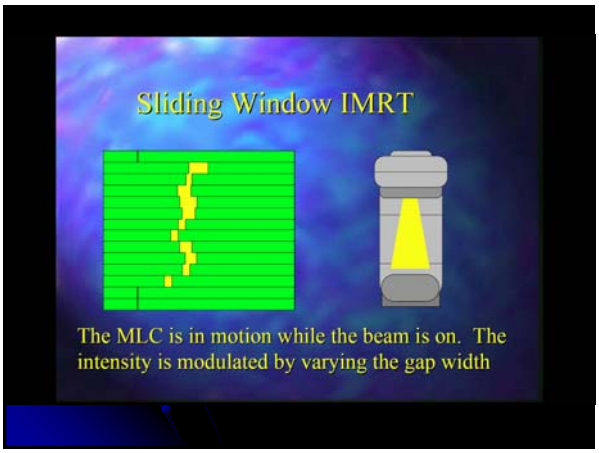
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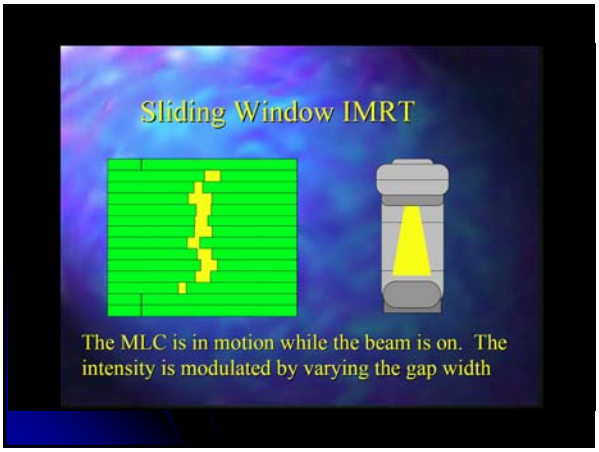
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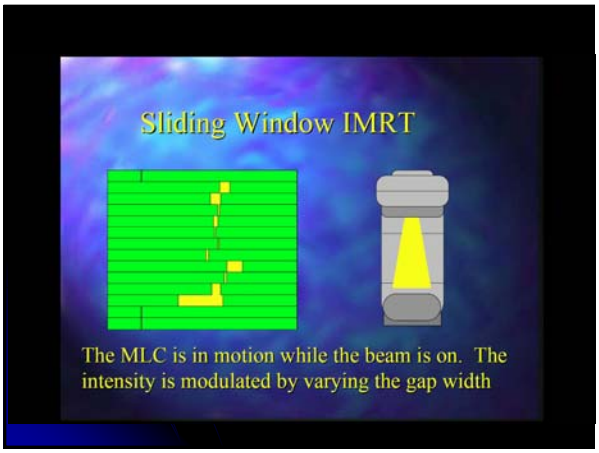
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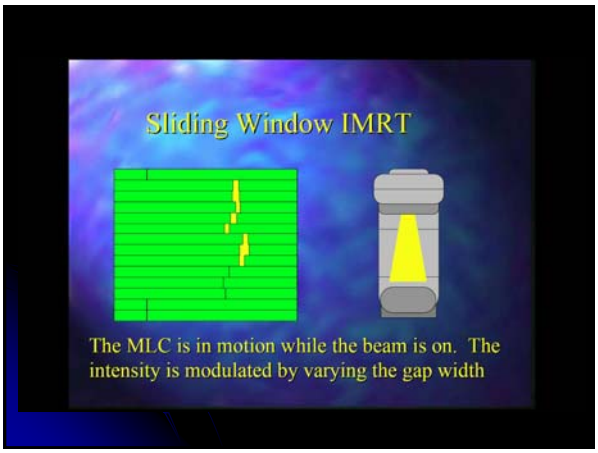
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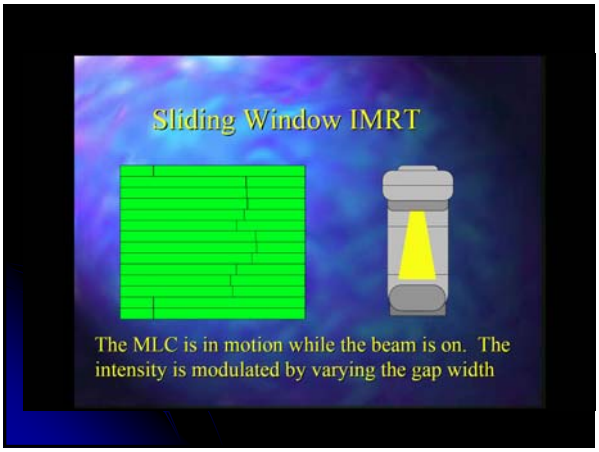
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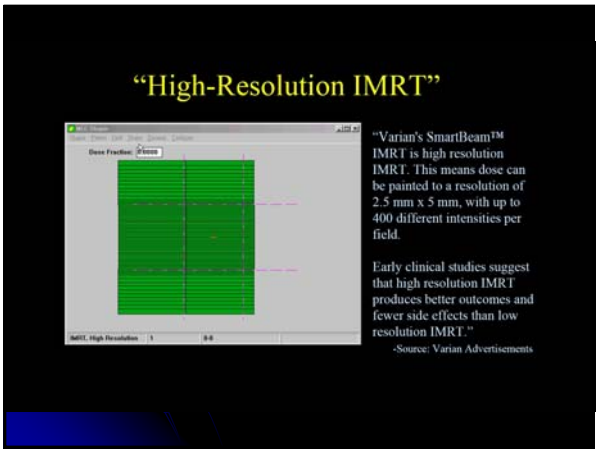

"High-Resolution IMRT"
"Varian's SmartBeam™ IMRT is high resolution IMRT. This means dose can be painted to a resolution of 2.5 mm x 5 mm, with up to 400 different intensities per field.
Early clinical studies suggest that high resolution IMRT produces better outcomes and fewer side effects than low resolution IMRT."
-Source: Varian Advertisements

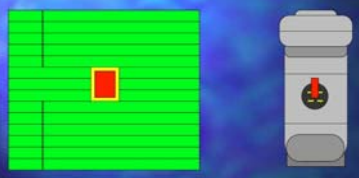
Advantages of Sliding Window

- Sliding Window delivery can generate the smoothest dose distributions [in the direction of leaf motion] of the MLC based IMRT techniques

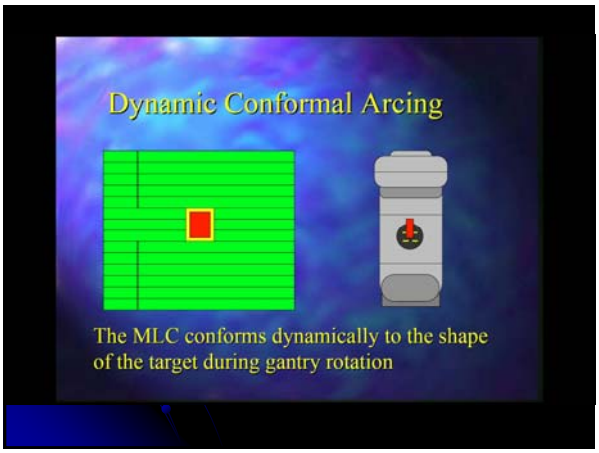
Disadvantages of Sliding Window

- The Sliding Window technique is more difficult to dosimetrically verify because of the steep dose gradients and its dynamic nature
- Leaf penumbra and gap width error can introduce significant dosimetric error

Dynamic Conformal Arcing



The MLC conforms dynamically to the shape of the target during gantry rotation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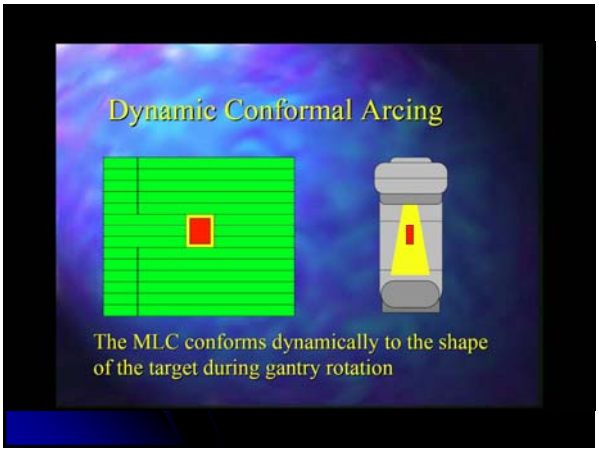
The MLC conforms dynamically to the shape of the target during gantry rotation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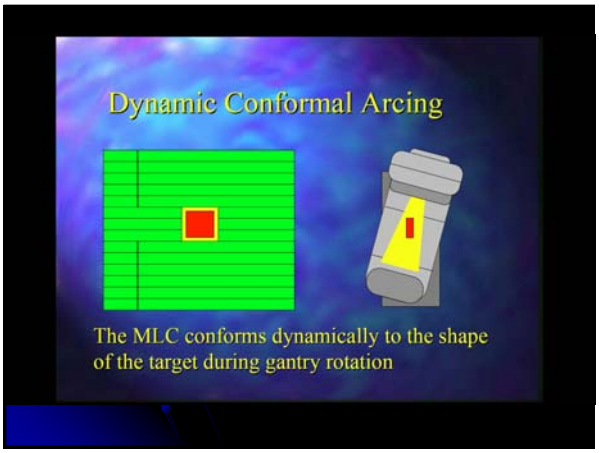
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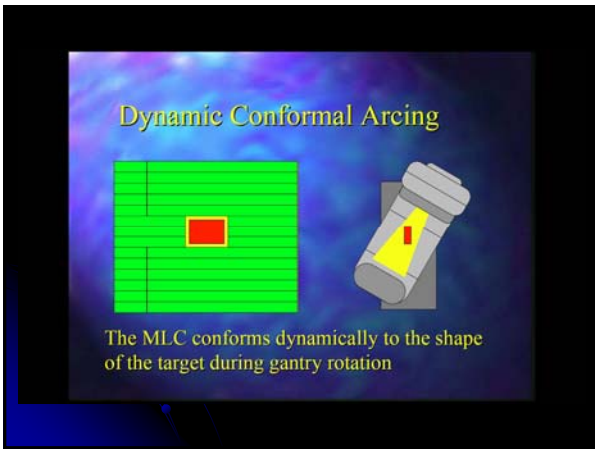
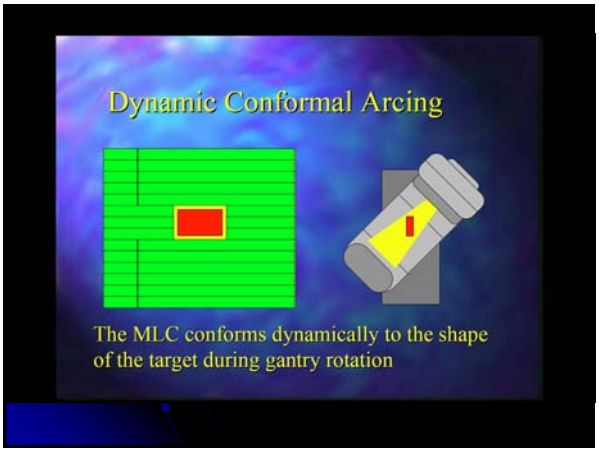

Dynamic Conformal Arcing
The MLC conforms dynamically to the shape of the target during gantry rotation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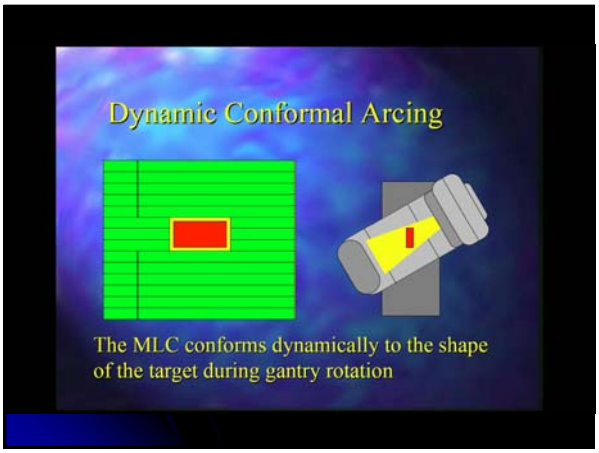
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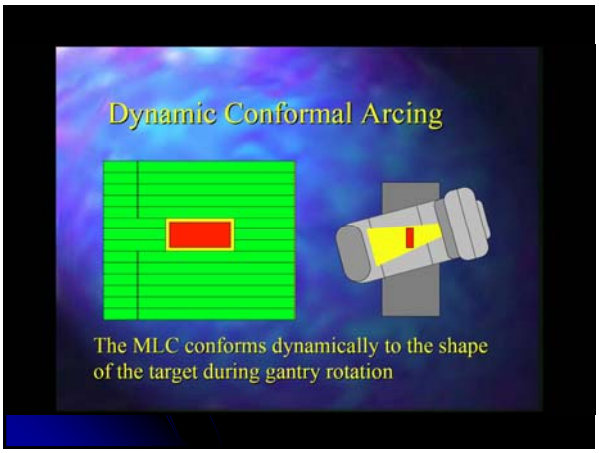
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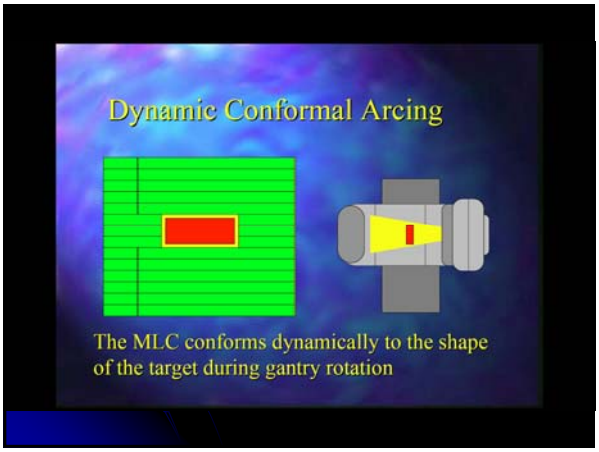
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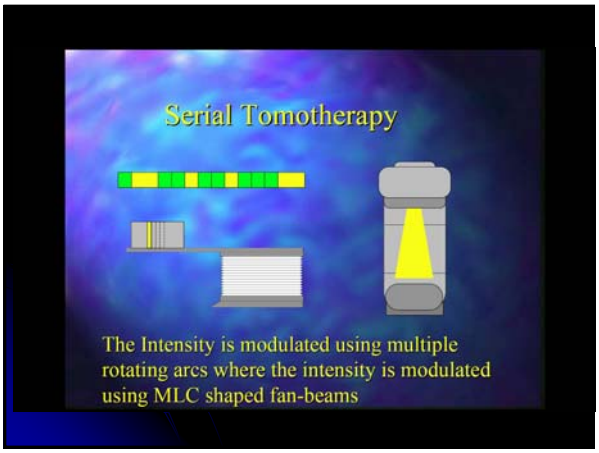
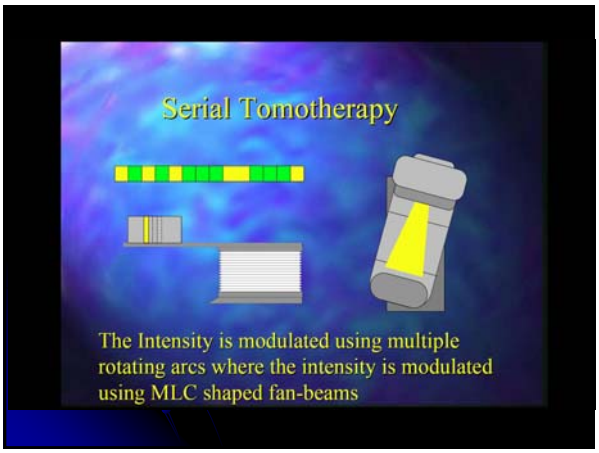

Serial Tomotherapy
The Intensity is modulated using multiple rotating arcs where the intensity is modulated using MLC shaped fan-beams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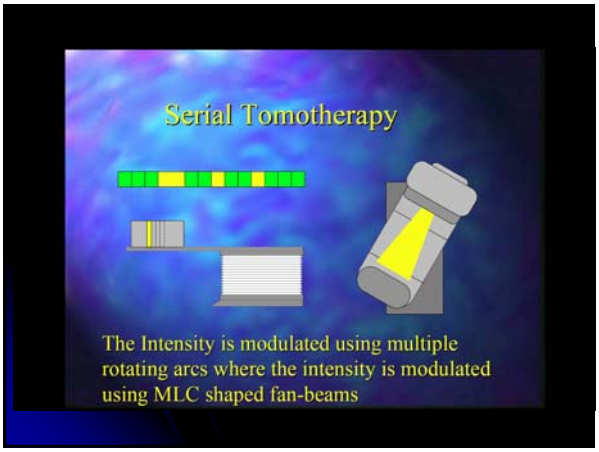
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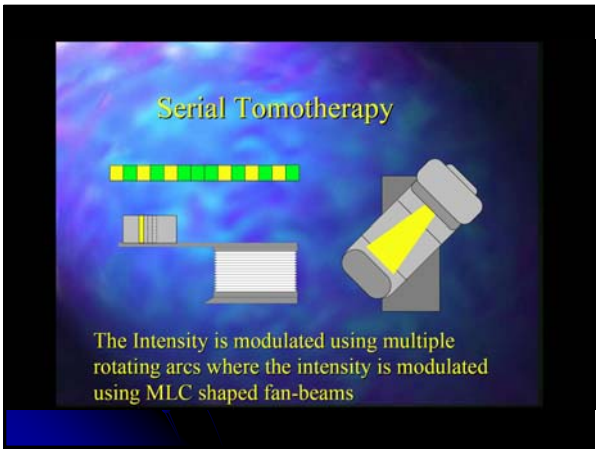
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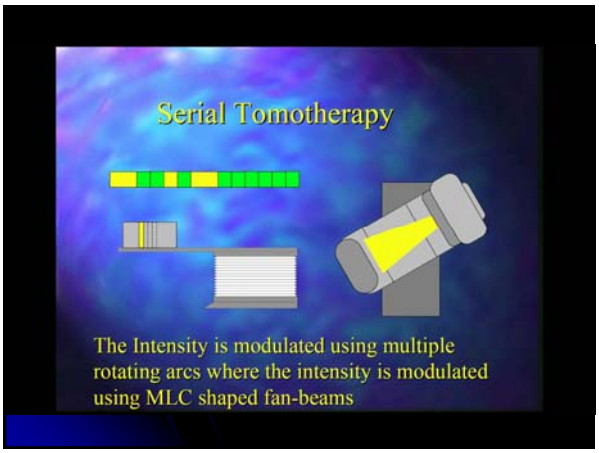
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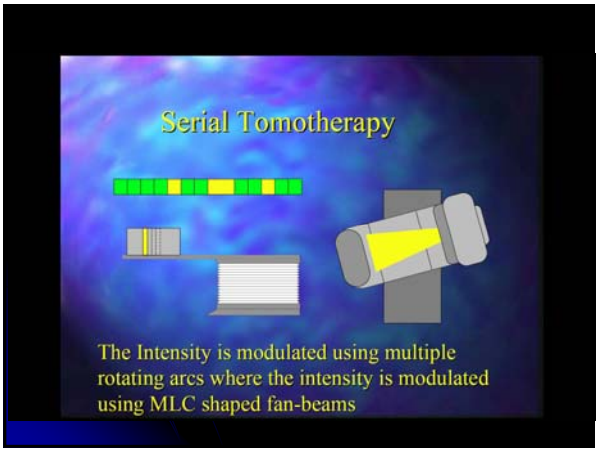
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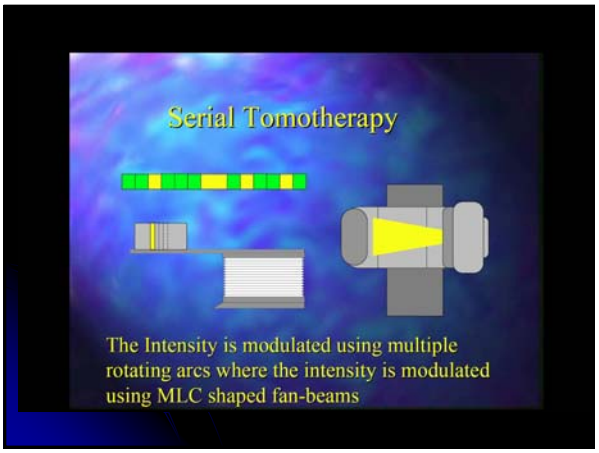
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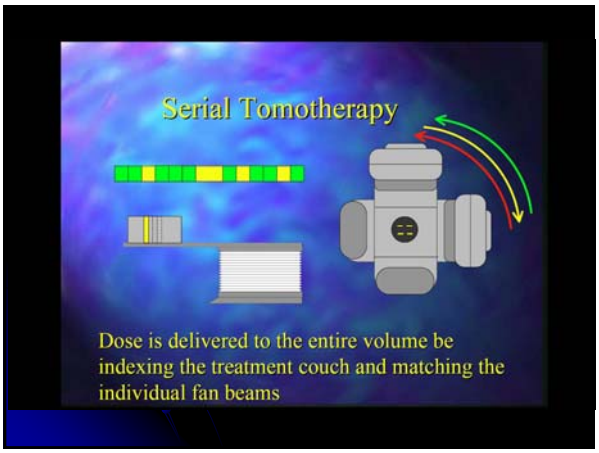
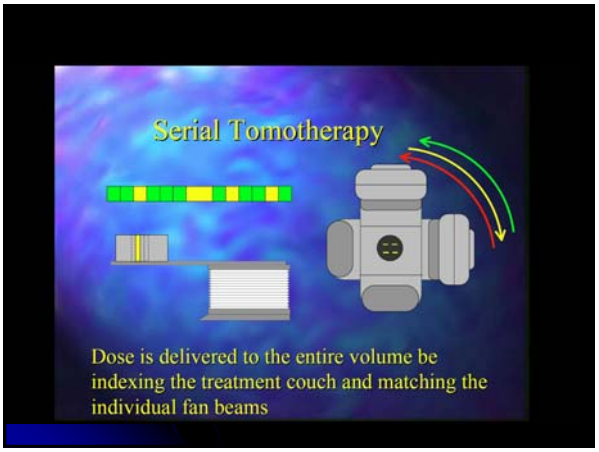

Serial Tomotherapy
Dose is delivered to the entire volume be indexing the treatment couch and matching the individual fan beams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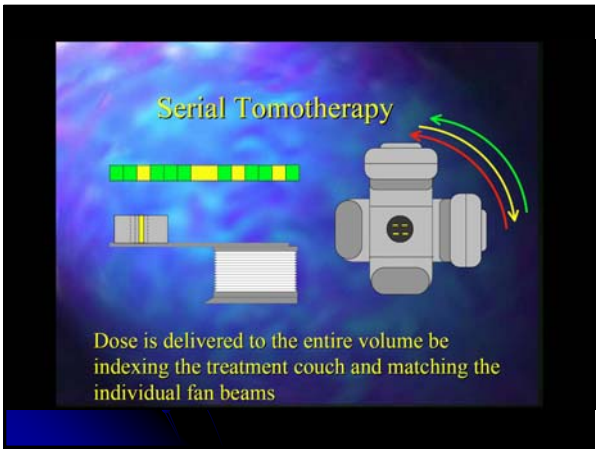
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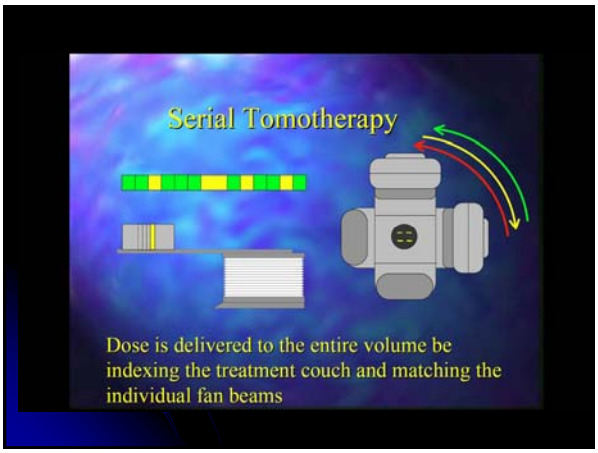
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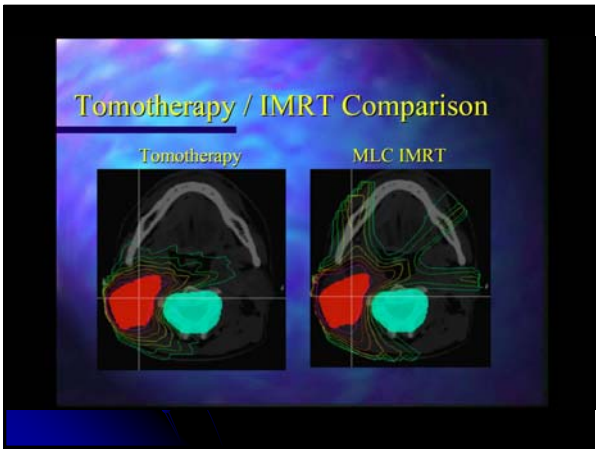
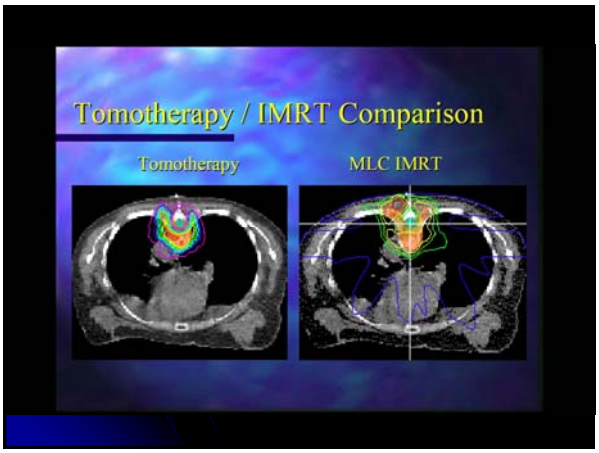
NOMOS MiMiC Tertiary System


Tomotherapy / IMRT Comparison
Tomotherapy
MLC IMRT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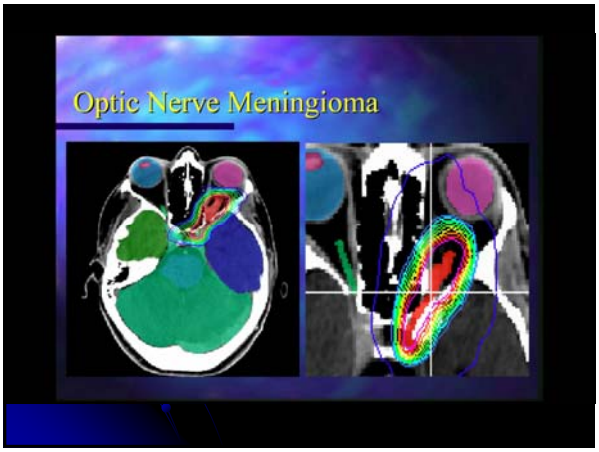
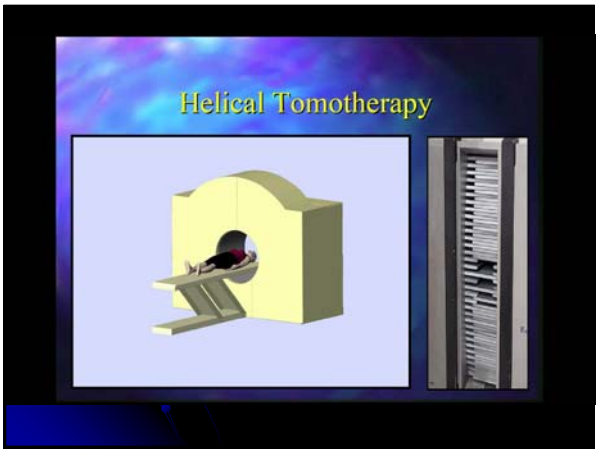
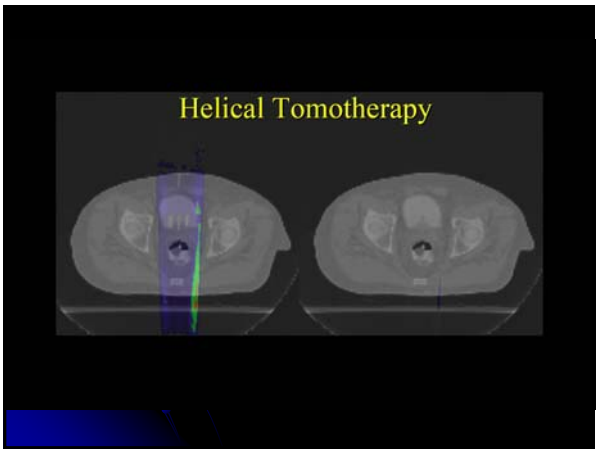

Optic Nerve Meningioma


Helical Tomotherapy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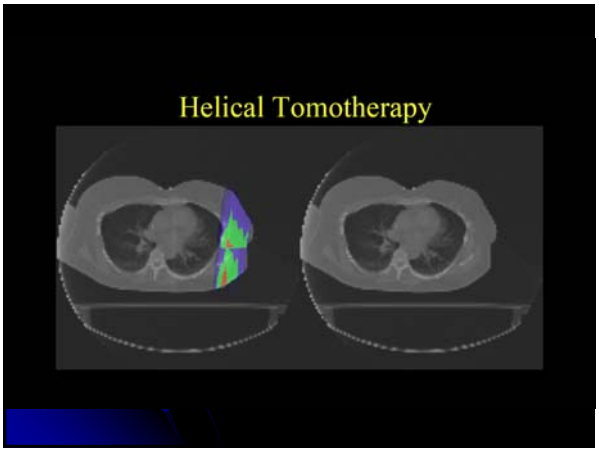
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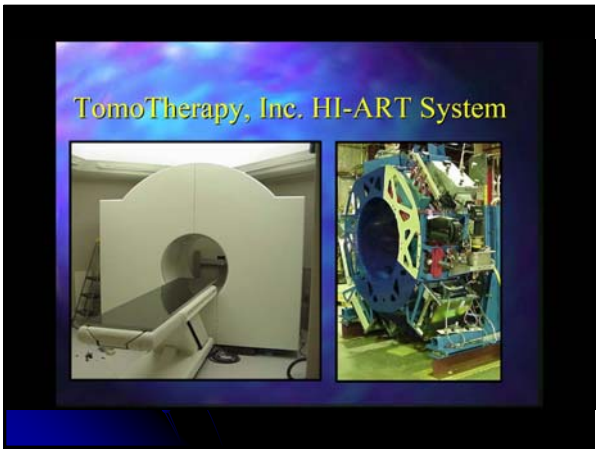

TomoTherapy, Inc. HI-ART System

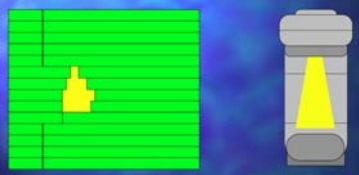
Advantages of Tomotherapy

- Currently, the bulk of clinical experience in IMRT has been with Tomotherapy systems
- Because dose is directed at the target from multiple arc passes, greater normal tissue sparing can be achieved
- Tertiary systems can be attached to linear accelerators without MLCs

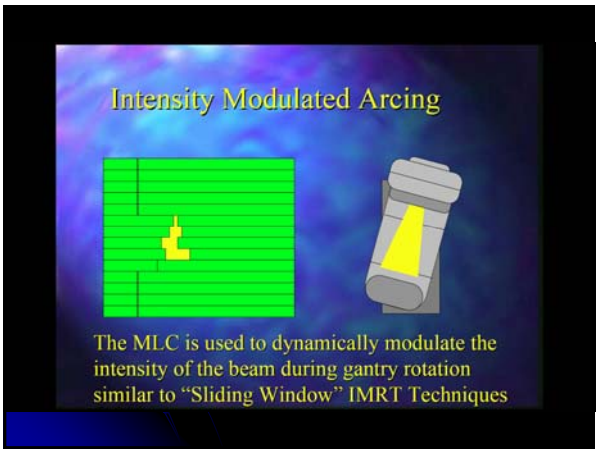
Disadvantages of Tomotherapy

- Tomotherapy can have the longest treatment times of all four techniques depending on the number of arcs and couch positions
- Tertiary MLC's cannot be used to treat conventional cases
- Additional effort is required to match adjacent arcs passes for Serial Tomotherapy

Intensity Modulated Arcing



The MLC is used to dynamically modulate the intensity of the beam during gantry rotation similar to "Sliding Window" IMRT Techniques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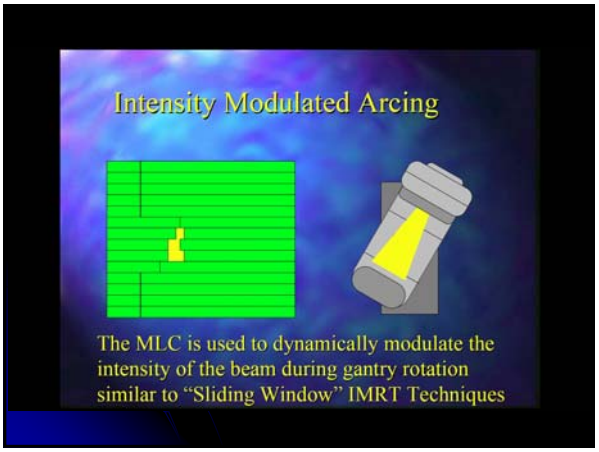
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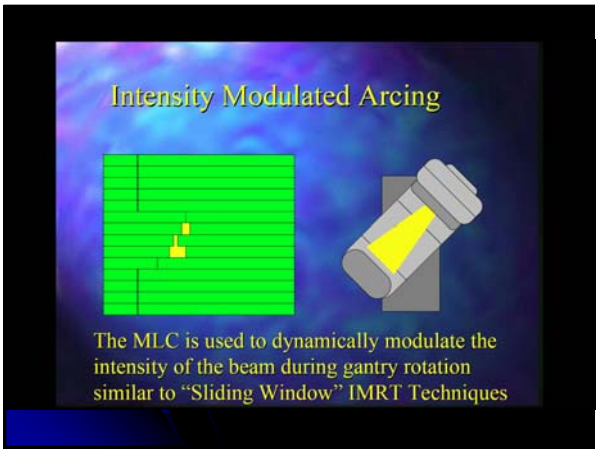
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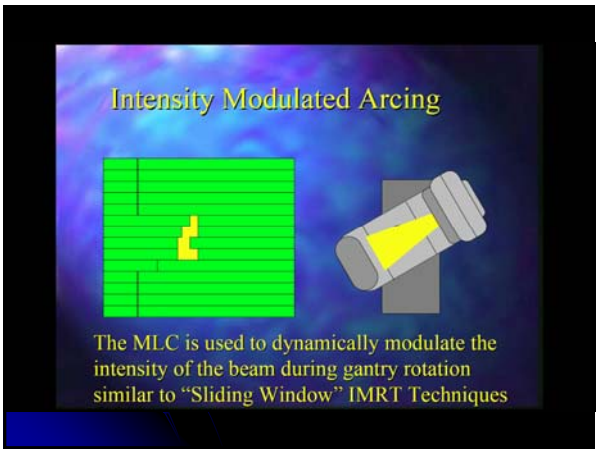
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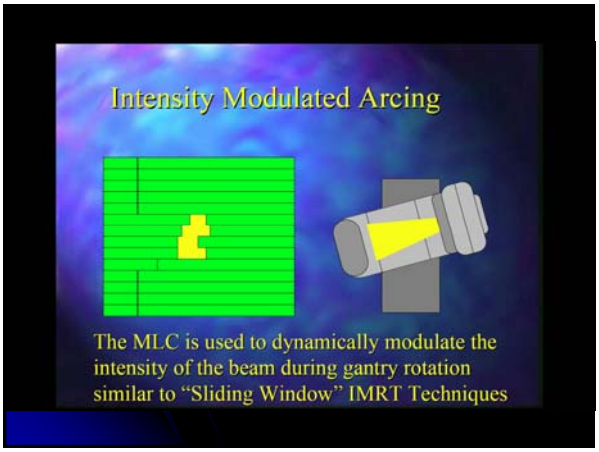
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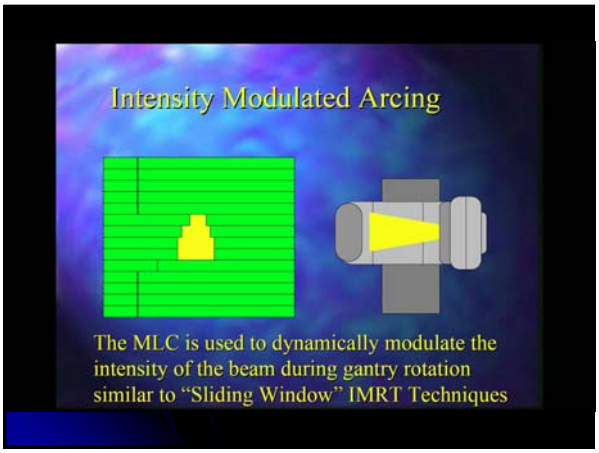
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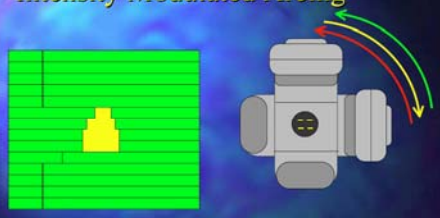

Intensity Modulated Arc Treatments can be delivered with a single arc, or a series of arcs to build complex dose distributions

Advantages of IMAT

- Like tomotherapy, the dose is directed at the target over large gantry angles from multiple arc passes
- IMAT has the potential to deliver dose distributions that are more complex than the Sliding Window or Step-and-Shoot techniques
- Because the intensity is modulated across the entire width of the target volume, IMAT delivery is faster than Tomotherapy delivery

Disadvantages of IMAT

- At present, there are no treatment planning systems capable of performing IMAT inverse planning or leaf sequencing
- The dosimetric verification of IMAT treatments is extremely difficult due to the steep dose gradients and gantry rotation

IMRT Delivery Techniques

- Each IMRT delivery technique is capable of generating similar dose distributions, and thus similar clinical outcomes
- No one delivery technique has demonstrated a particular clinical advantage over another
- At present, preferences are based on other factors such as personal experience, throughput, equipment availability, etc...

During dynamic or sliding window IMRT, "Beam Hold" occurs when:

A. The MLC leaves are "held" at their final position until the required MU are delivered.
B. The dose rate is too high for the MLC leaves to reach their proper positions fast enough. When this happens, the beam is momentarily turned off until the MLC leaves catch up.
C. The beam is "held," or not turned on until all the R&V parameters have been verified.
D. "Beam Hold" only occurs with respiration-gated treatment.

According to ICRU report 62, when treating the nasopharynx with IMRT, a margin of 0.5 cm around the cord would create a(n) _____.

A. OAR
B. CTV
C. PTV
D. PRV
E. IM

Which of the following is ***not*** included in the CTV (clinical target volume) as defined by ICRU Reports 50 and 62:

A. Gross target volume (GTV).
B. Internal margin (IM).
C. Setup margin (SM).
D. Lymphatic spread.

In an IMRT plan, the physician requests that 95% of the PTV be covered by 95% of the prescribed dose, with the maximum not to exceed 105%. A plan is created with only 85% covering 95% of the volume. Possible reasons include ***all of the following except***:

A. The PTV is drawn to include part of the build-up region.
B. Field heights have insufficient margin around the PTV
C. The photon energy is too low
D. The PTV abuts a region to be avoided, which has been given high priority

Verification of "sliding window" IMRT plans can be performed by all of the following ***except***:

A. Hand calculation of the MU settings for each beam.
B. Scanning films exposed in a phantom to each IMRT field.
C. Software designed to independently calculate the MU for each field.
D. Diode arrays irradiated with the IMRT fields.

Which factors influence the construction of a PTV from a CTV?

1. Patient set-up uncertainty.
2. Organ motion.
3. Proximity of critical structure.
4. Extent of microscopic disease.

A. 1,2,3.
B. 1,3.
C. 2,4.
D. 4 only.
E. 1,2,3,4.

IMRT using MLC usually requires an increased number of monitor units compared with conventional radiation therapy because:

A. Of increased leakage through the MLC compared with cut blocks.
B. A fraction of the treatment field is blocked at any given time.
C. IMRT is usually delivered with lower energy photons.
D. Field margins are usually smaller.

All of the following are true of IMRT ***except***:

A. IMRT dose distributions are always more inhomogeneous than conventional 3-D plans.
B. In prostate treatment, IMRT can reduce rectal toxicity.
C. A 3-D data set is required for IMRT planning.
D. Immobilization is more important because of the tighter margins.

Advantages of a multi-leaf collimator over cerrobend blocks for field shaping include all of the following, **except:**

A. Decreased time to generate field shaping.
B. Adjustments to field shaping are faster.
C. Faster set-up (no tray to attach to head of machine).
D. More conformal.

Which one of the following is *required* for generating a conformal treatment plan?

A. GTV
B. CTV
C. PTV
D. Internal margin
E. Set-up error.

Advantages of multileaf collimators (MLCs), compared to conventional cerrobend blocks include:

A. Sharper penumbra.
B. Lower leakage radiation.
C. Can accommodate larger field sizes.
D. Permits Intensity Modulated Radiation Therapy (IMRT).
E. All of the above.

The tongue-and-groove effect is related to which of the following:

A. An increase in dose between two adjacent leaves of a multileaf collimator.
B. A most pronounced field-size effect on the output factor.
C. An decrease in the overall radiation fluence by about 1%.
D. It may be absent in some multileaf design.
E. None of the above.

Thank You

Cancer Therapy and Research Center