# Intensity Modulated Radiotherapy (IMRT) with Conventional MLC's

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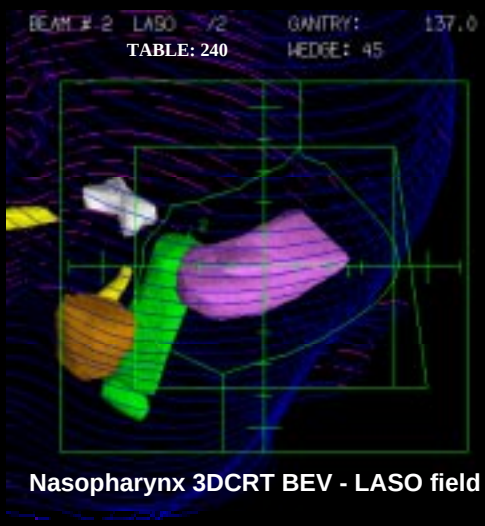
## Limitations of 3DCRT

- Need large number of beams unless target shape is very simple
- Optimal beam angles often non-axial and difficult or impossible to use
- In H/N area, large number of sensitive tissues so few beam directions work
- No acceptable plan for concave target




Nasopharynx 3DCRT BEV - LASO field

## Working Definition of IMRT

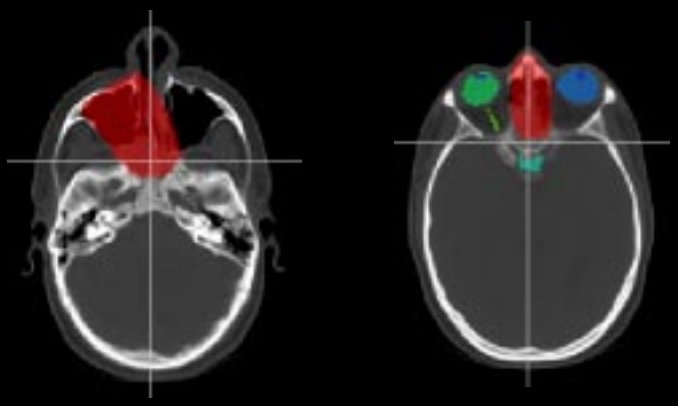
- Beam intensity is modified across each beam in complex way (excludes wedges, includes iterative few segment IMRT)
- In general, each beam treats only a portion of the target
- Can be planned by either standard "forward" or inverse iterative methods

## IMRT Methods to be Considered

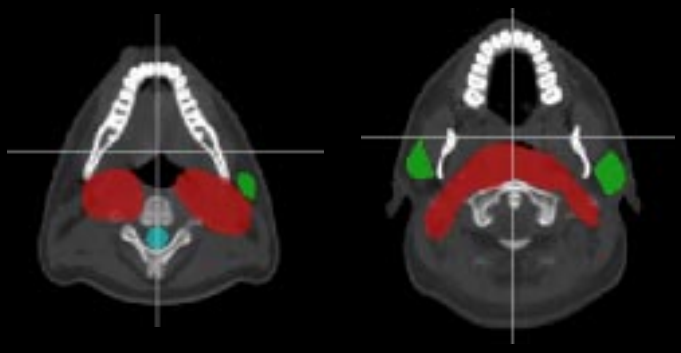
- "Simple Methods" which can be planned with conventional 3D treatment planning programs:
  - Each field consists of 2 or more subfields
  - Each subfield defined by conventional MLC
  - Relative intensity of subfields determined by iteration and implemented by varying MU per subfield
  - Planning goals can include improved dose uniformity or concomitant boost or normal tissue sparing

## IMRT Treatment Examples

- Examples of "simple IMRT" treatments developed at UCSF include:
  - Boost treatments of Nasopharynx cancer
    - » 5 axial fields with 2 MLC subfields each
    - » 8 - 10 axial fields with wedging and clever beam angle choices to limit normal tissue dose and get uniform dose to target
  - Boost treatments to MRS-positive portion of prostate gland (Dominant Intraprostatic Lesion - "DIL")
    - » 7 axial field directions
    - » Simultaneously boost DIL to 90 Gy and remainder of prostate gland to 73.8 Gy



Complex Nasopharynx Target Volumes (Sup)



Complex Nasopharynx Target Volumes (Inf)

## IMRT Methods to be Considered

- **General Methods of IMRT are those that require the use of “inverse” treatment planning programs**
  - **Begin with prescription of dose goals to target and normal tissues by physician**
  - **Planner defines number of beams, beam directions, delivery method and maximum acceptable complexity of intensity pattern**
  - **Program optimizes plan and returns with intensity pattern of each beam needed to approximate desired dose distribution**

## IMRT Delivery Methods Using Conventional MLC's

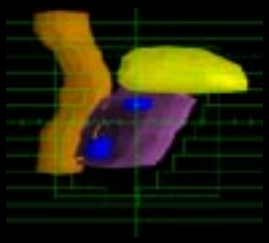
- Proposed IMRT delivery methods include:
  - "Stop-and-shoot" static IM RT using multiple MLC shapes per field (SMLC-IMRT) - includes both forward and inverse planning examples
  - Dynamic IMRT with fixed gantry and moving MLC leaves (DMLC-IMRT) - includes both fully dynamic and pseudo-dynamic
  - Intensity-modulated arc therapy using a full-field MLC (IMAT)

## "Stop and Shoot" SMLC-IMRT

- Advantages of this method of IMRT:
  - Portal verification of intensity pattern feasible
  - Easy to understand clinically
  - Easy to resume interrupted treatment
  - Relatively simple accelerator control system needed
  - Both forward and inverse planning possible
- Disadvantages of this method:
  - Complex problems require lots of segments
  - Time required for treatment can be significant

## Example of Prostate Forward-Planned IMRT

- MRS scan used to identify cancerous regions of prostate
- MRS and MRI scans fused with CT treatment planning scan
- MRS/MRI positive regions identified as dominant intra-prostatic lesions (DIL)
- Treatment plan devised to simultaneously deliver 75.6 Gy to prostate and 90 Gy to DIL
- Imbedded gold seeds used to verify location of prostate using portal imager



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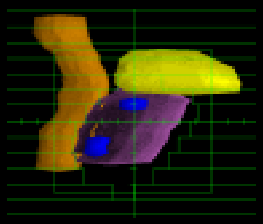

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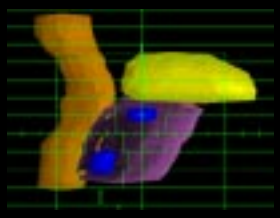

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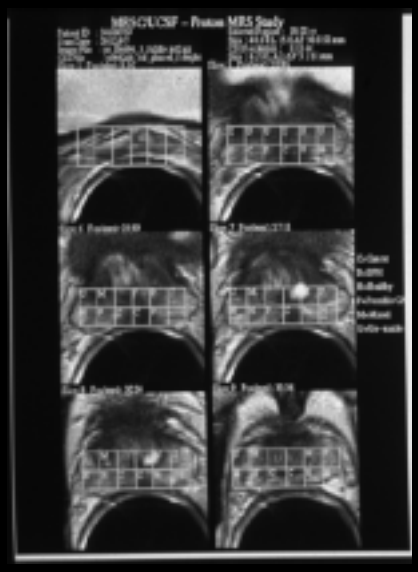
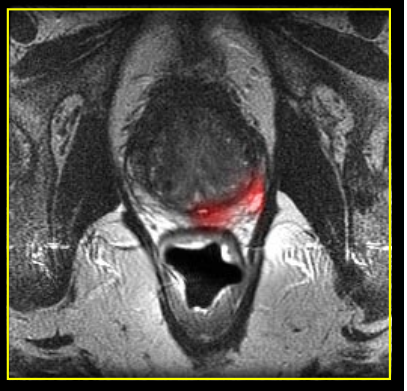


**MRS prostate study showing 1cm x 1cm pixels designated as (C)Cancer, (B)BPH, (H)Healthy, (P)Possible cancer, (M)Mixed, or (U)Unusable**

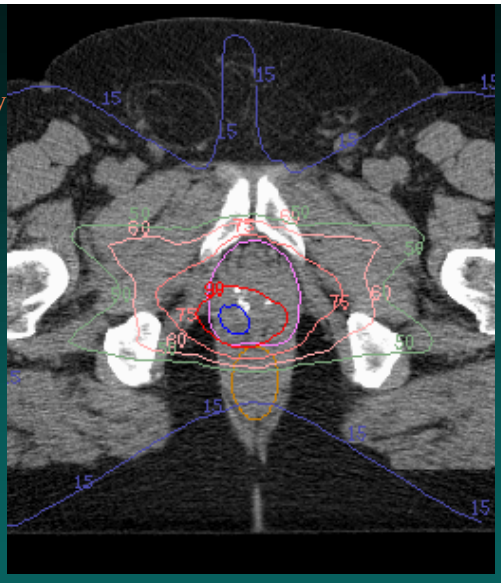
CT Scan

MR Spectroscopy



apical axial view

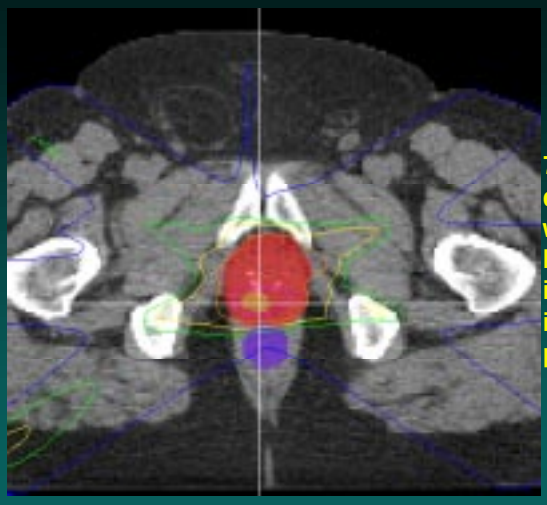
90 Gy
75.6 Gy
60 Gy
50 Gy
15 Gy



3D-CRT
Slice #10

**7 beam directions, 2-3 segments per beam, total of 18-20 segments, forward planned**

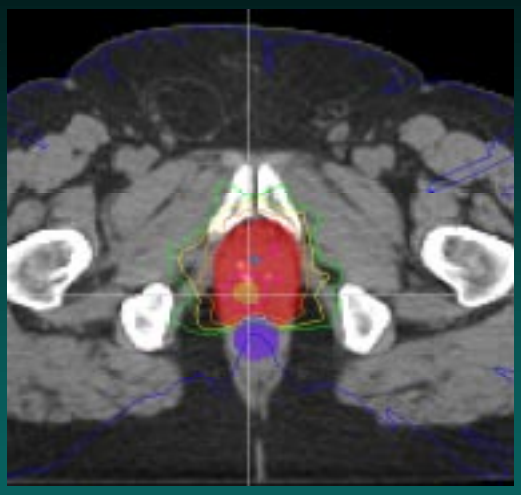
90 Gy
75.6 Gy
60 Gy
50 Gy
15 Gy



7/10
Slice #10

**7 beam directions with 10 levels of intensity, inverse planned**

90 Gy
75.6 Gy
60 Gy
50 Gy
15 Gy

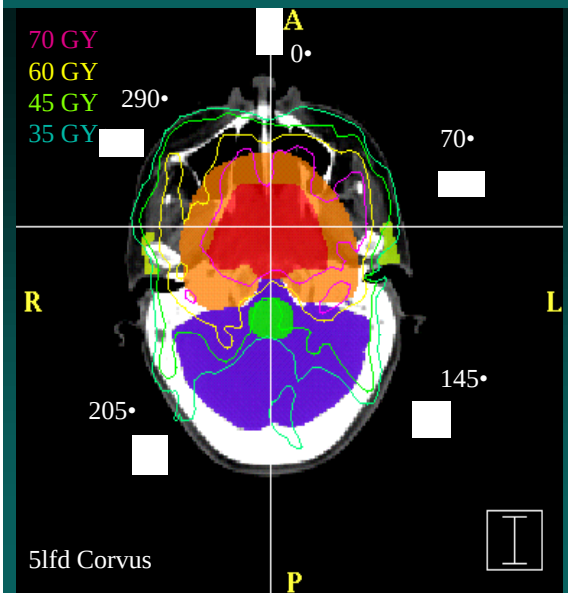


MIMiC
Slice #10

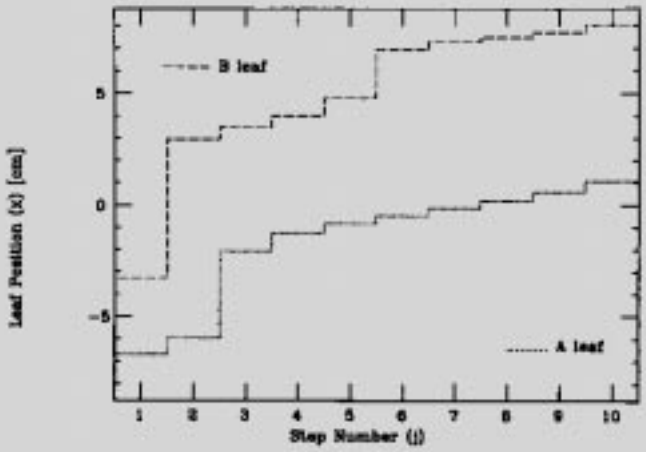
**Peacock MIMiC 55 beams inverse planned**

# Example of CORVUS Inverse-Planned IMRT treatment

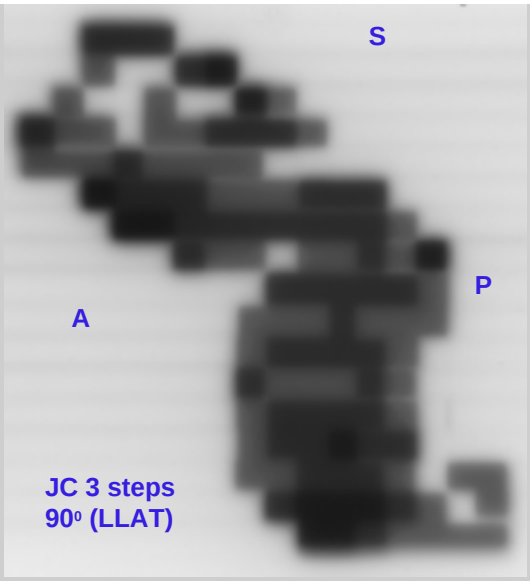
- Used 5 field directions similar to those used commonly for 3DCRT plans in clinic
- Found good plan with 5 levels of intensity
- Total of 92 segments used which would require about 25 minute treatment time using Siemens Primeview control system




Example of 5-field inverse-planned nasopharynx treatment using 5 levels of intensity and 92 MLC segments




Sliding window showing changing separation between leaves in opposite banks at different positions




Example of 3-step intensity pattern for one of four fields used in inverse-planned nasopharynx treatment

## Dynamic IMRT Methods with Conventional MLC's

- Truly dynamic IMRT modulated leaf velocity with constant beam intensity (MSKCC)
  - Sliding window approach
- Dynamic "step-and-shoot" (Stanford and others - including UCSF )
  - Large numbers of discreet MLC shapes per field
  - Beam turned off between segments
- Intensity Modulated Arc Therapy (IMAT)
  - Use multiple arcs delivering single intensity level
  - Each arc consists of multiple MLC subfields - continuously changed while gantry rotates

## Dynamic DMLC-IMRT

- Advantages of this method of IMRT:
  - Faster beam delivery than static methods
  - Can yield more complex dose distributions
  - Can produce smoothly varying intensities
- Disadvantages of this method:
  - Leaf edge effects can produce dosimetric errors when field sizes are small
  - Difficult to verify leaf patterns
  - Potentially more difficult to recover from interruption
  - Complex MLC control system required
  - Inverse planning required

## Treatments Done to Date (6/1/99) at UCSF

- Multi-segment forward planned IMRT
  - Prostate 7 field, 18 segment (50 cases)
  - Nasopharynx 5 field, 10 segment (40 cases)
- Inverse planned SMLC-IMRT
  - 16 cases typically 4-7 fields, 40 or more segments (lung, mesothelioma, paraspinal, prostate)
- Inverse planned DMLC-IMRT
  - Only single case to date (Mesothelioma 700 segments in 7 fields)
- Peacock MIMiC tomotherapy
  - 50 cases primarily nasopharynx

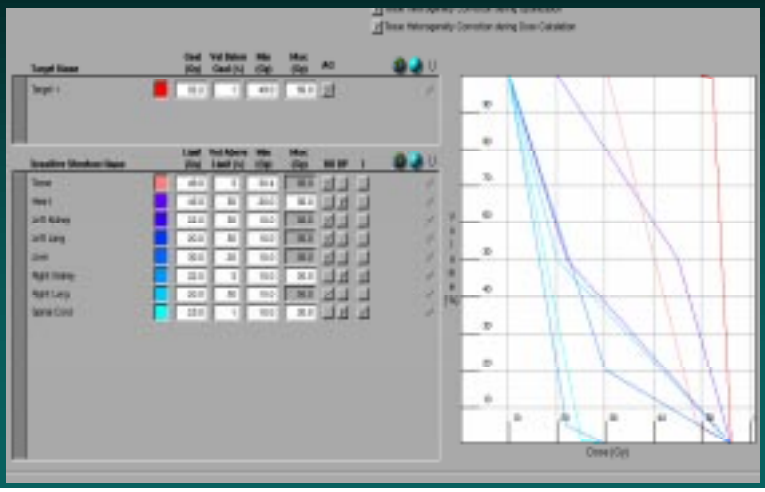
## Treatment Planning Considerations for IMRT

- Forward planning leads to increase in number of fields compared to 3DCRT
  - Can increase treatment time
  - Optimization may require many iterations
  - Verification more time-consuming
- Inverse planning requires complete change in thought processes
  - Results non-intuitive
  - Optimization can be impossible if prescription unrealistic
  - Effects of prescription change difficult to predict

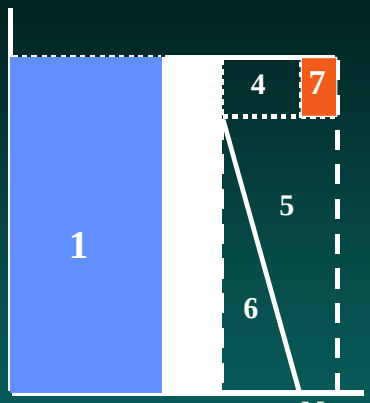
## Inverse Treatment Planning Example

- CORVUS treatment planning system by NOMOS used by many groups
- Prescription page requires dose goals for target and normal tissues input as 3-point DVH's
- Opportunity to place margins between CTV and PTV
- Objective function minimized using simulated annealing
- Penalties based on clinical input

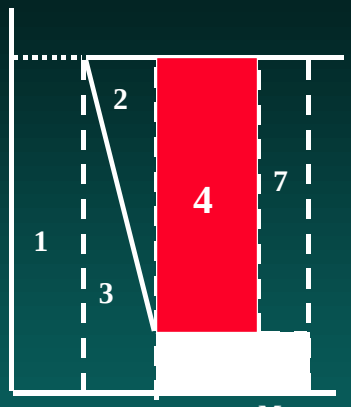
# Dose distribution Objective



**Zone 8 = Min / Rx Min** **Zone 9 = ( Max-Rx Max) / (1-Rx Max)**



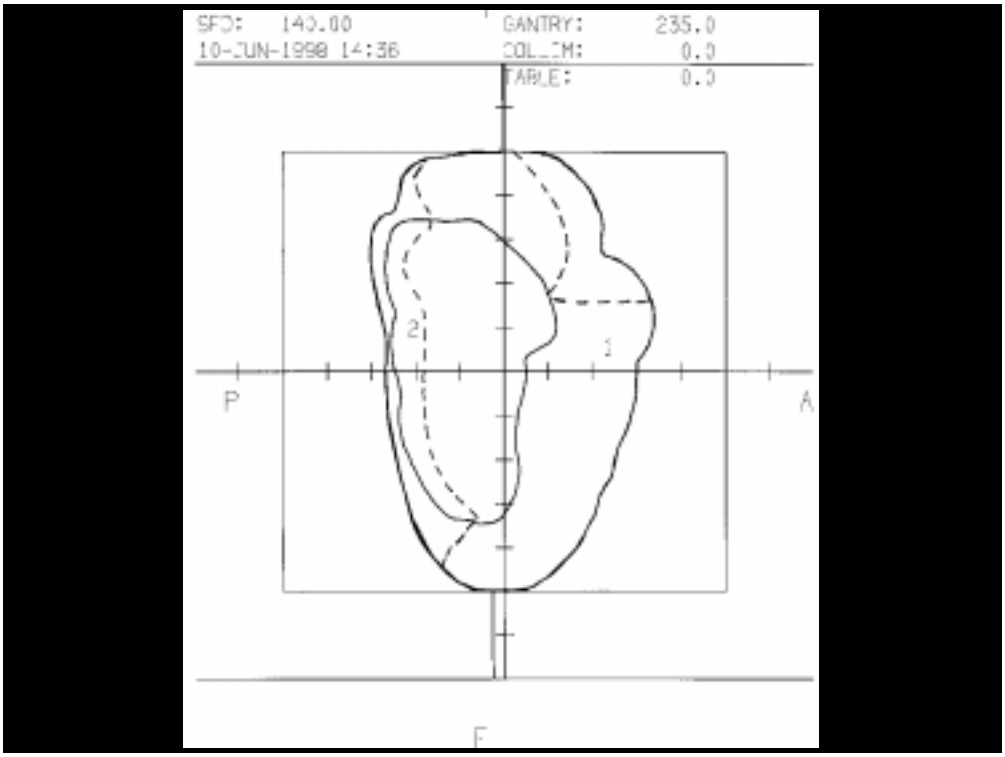

**Target Zones**

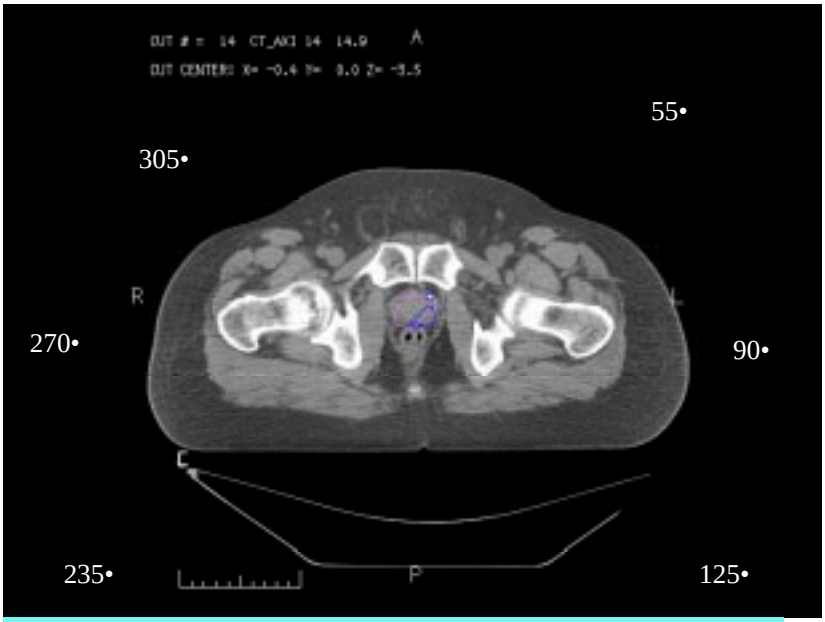



**Structure Zones**

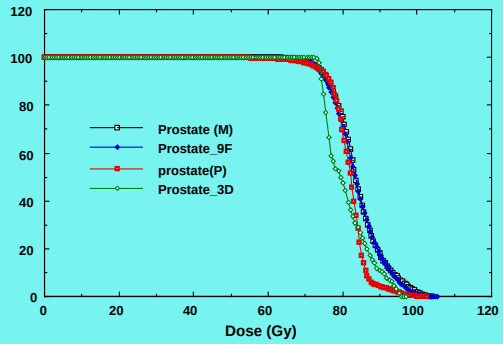
| Target Name | | Goal (Gy) | Vol Below Goal (%) | Min (Gy) | Max (Gy) | AG |
|---|---|---|---|---|---|---|
| Target 1 | | 52.2 | 1 | 49.0 | 56.0 | ☑ |

| Sensitive Structure Name | | Limit (Gy) | Vol Above Limit (%) | Min (Gy) | Max (Gy) | BU | BP | I |
|---|---|---|---|---|---|---|---|---|
| Tissue | | 49.0 | 5 | 30.4 | 56.0 | ☑ | ☐ | ☐ |
| Heart | | 45.0 | 50 | 20.0 | 56.0 | ☐ | ☑ | ☐ |
| Left Kidney | | 22.0 | 50 | 10.0 | 56.0 | ☑ | ☐ | ☐ |
| Left Lung | | 20.0 | 50 | 10.0 | 56.0 | ☑ | ☐ | ☐ |
| Liver | | 30.0 | 20 | 10.0 | 56.0 | ☑ | ☐ | ☐ |
| Right Kidney | | 22.0 | 5 | 10.0 | 30.0 | ☐ | ☑ | ☑ |
| Right Lung | | 20.0 | 50 | 10.0 | 56.0 | ☑ | ☐ | ☐ |
| Spinal Cord | | 25.0 | 1 | 10.0 | 30.0 | ☐ | ☑ | ☑ |






## Comparison of DVH's for IMRT Treatments

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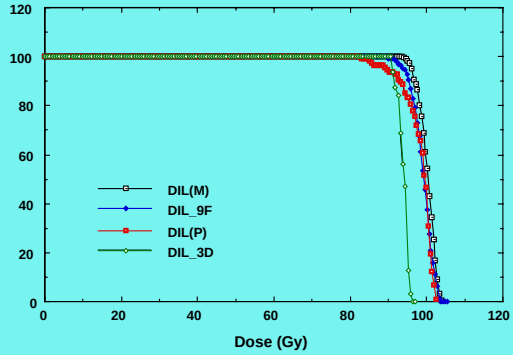

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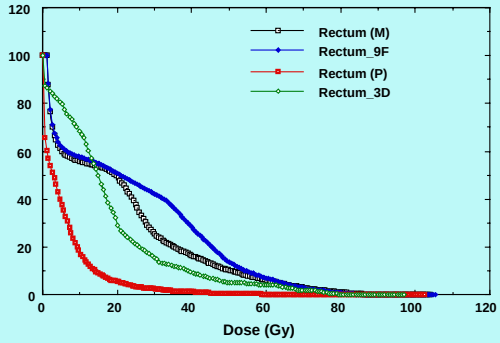
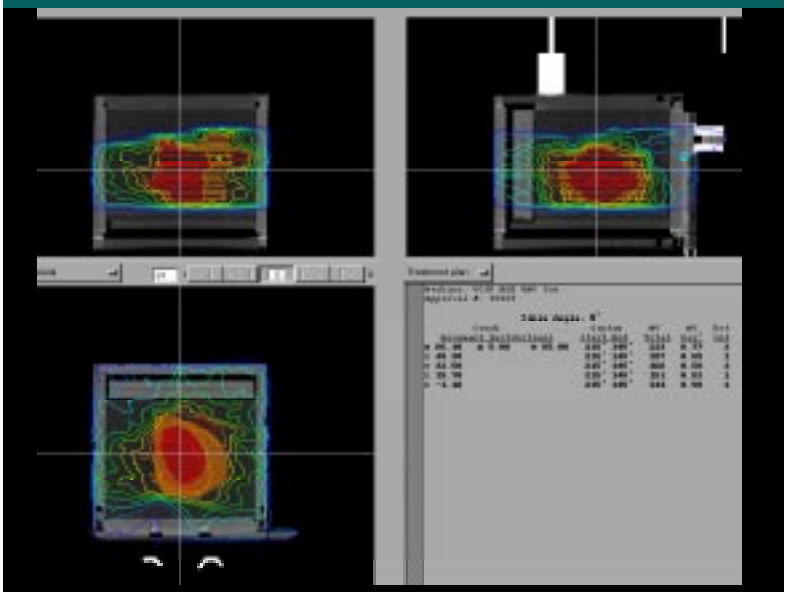



## Treatment Verification

- For forward planned cases
  - No special dosimetry required
  - Increase in number of fields
  - Worry more about position verification than for 3DCRT
- For inverse planned cases
  - Dose calculation algorithm not sophisticated
  - Requires dose calculation and dose measurement in one or more points in a phantom
  - Relative dose comparisons in film also advised



## Conclusions

- “Conventional” 3DCRT plans are adequate for a majority of curative radiotherapy patients
- Some patients can benefit from addition of simple IMRT or complex IMRT for at least a portion of treatment
- Need for IMRT should be demonstrated on a patient-by-patient basis
- At this time, more resources needed for IMRT treatment planning and execution than for 3DCRT

## Conclusions

- Not every patient is appropriate for IMRT
- Immobilization and position verification more important for IMRT than for 3DCRT since only a portion of target being irradiated at a time
- Different IMRT delivery methods range from simple to very complex in nature
- As a rule of thumb, use IMRT only when 3DCRT plans not adequate, and use complex IMRT only when simple IMRT not adequate

## Conclusions

- Accelerator vendors and treatment planning companies are providing us with the tools to do IMRT treatments (maybe before most of us are ready)
- The planning systems and control systems are evolving rapidly so that the time required to create a plan and to deliver that plan will soon be similar to 3DCRT
- Quality assurance issues will eventually be the limiting considerations as to when IMRT is appropriate