Intensity Modulated Radiotherapy (IMRT) with Conventional MLC’s

Lynn J. Verhey, Ph.D.
Dept. of Radiation Oncology
University of California, San Francisco

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

Table 240

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 Intrasprostatic Lesion - “DIL”)
    - 7 axial field directions
    - Simultaneously boost DIL to 90 Gy and remainder of prostate gland to 73.8 Gy
**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
Proposed IMRT delivery methods include:
- “Stop-and-shoot” static IMRT 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
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
3D-CRT
Slice #10

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

7/10
Slice #10

7 beam directions with 10 levels of intensity, inverse planned

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
Target Zones

Structure Zones

Zone 8 = Min / Rx Min

Zone 9 = (Max-Rx Max) / (1-Rx Max)
<table>
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<th>Sensitive Structure Name</th>
<th>Limit (Gy)</th>
<th>Vol Above Limit (%)</th>
<th>Min (Gy)</th>
<th>Max (Gy)</th>
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<th>BP</th>
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Target 1

Goal (Gy) | Vol Below Goal (%) | Min (Gy) | Max (Gy) | AG |
---------|--------------------|----------|----------|----|
52.2     | 1                  | 49.0     | 56.0     | ✓  |
Comparison of DVH's for IMRT Treatments

Comparison of DVH's for IMRT Treatments
Comparison of DVH’s for IMRT Treatments

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