Clinical Implementation of IMRT Treatment Planning

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Goals for this discussion

- Describe the inverse planning process
- Illustrate some problems and pitfalls
- Suggest a method for learning how an (your) inverse system behaves
- Discuss broader elements of clinical implementation

Inverse planning flowchart

Why is the process iterative?

- Differentiate between three things sometimes called "prescription"
  - Statement of clinician’s goals
  - Planning parameters given to the RTP system
  - Final dose distribution accepted for treatment
- These usually differ from each other because we do not get what we ask for

Why is the process iterative?

- Clinical goals may not be achievable
- Results may differ from the goals as presented to the planning system
- Goals may not be explicitly described
  - e.g. avoid hotspots outside of target

Modeling the clinical problem

- All treatment planning is numerical modeling
- Patient, beams, interactions, dose
- With inverse planning, also include model of “what we want to achieve”
  - Goals, limits, value judgments
  - Some is hidden from the user in the details of the “objective function” and search process
Defining targets

- All targets need to be explicitly defined
  - not too small (geographic miss)
  - not too large (nowhere to throw low dose shadows)
- May need
  - contrast (consequence for CTsim?)
  - fusion with pre-op studies

How generous to make the target?

With ultrasound localization of prostate, defining the base is critical!

May need contrast in the bladder to identify the base on CT.
Over-contouring the prostate can lead to misalignment on US

Careful of automatic CTV expansions

- Automatic CTV expansions may cross tissue boundaries unrealistically
- Human planners trim beams accordingly, inverse planners to not.

Human planners sometimes have to trim IMRT beams ....

This row might be used by the IMRT plan if the target is drawn too close to the isocenter plane

Defining normal tissues

- Tissues to be spared need to be explicitly defined; e.g. oral mucosa when changing from parallel-opposed to IMRT

Oral mucosa - avoid
Defining normal tissues

- Consistent definitions of structures must be used if dose-volume criteria are taken from the literature

Mayo Scottsdale: Prostate Criteria for acceptability

- **Rectum** (contents, 1.5 below to sigmoid flexure)
  - $D_{40} \leq 65$ Gy
  - $D_{30} \leq 70$ Gy
  - $D_{10} \leq 75$ Gy
  - $D_{\text{max}}^* \leq 81$ Gy
- **Bladder**
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*$D_{\text{max}} = \text{dose to clinically significant volume}$

Margins

- IMRT does not inherently demand or permit tight margins
- CTV and PTV margins are independent of beam delivery technique - depend on patient and immobilization/localization techniques
- To achieve tight margins, may need to improve imaging for planning, immobilization, imaging for verification

Margins (other issues)

- Distance to block edge $\neq$ PTV expansion
  
  \[
  \text{GTV} \rightarrow \text{CTV} \rightarrow \text{PTV} \rightarrow \text{penumbra} \rightarrow \text{block edge}
  \]

Block edge to PTV expansion

- Suggestion: compare to 3D conformal alternative planned with specified block margins
- Determine the distance from the CTV to the 95\% isodose line
- Call that the PTV expansion
Target volumes in buildup regions

- Inverse planner will try to compensate for the low doses by increasing intensities of some beamlets
- Especially watch for PTV expansions that encroach on the buildup region
- May cause excessive skin reactions and compromise the plan quality in general

PTV in buildup region

Buildup

- Expand PTV by 2-10 mm
- Evaluate dose uniformity
  - CTV max/min
  - Volume max/CTV mean

Breast treatments and “Flash”

- Most inverse planning systems do not allow the user to expand a field outside the skin
- How to do breast IMRT without a forward planning component?
  - Somehow need to expand the target outside the original skin
  - Somehow need to avoid buildup region problems
Radiobiological issues

- More dose inhomogeneity in targets than with previous clinical experience
  - may get more acute reactions, especially in H&N treatments
- Targets given different doses get different doses/fraction
  - may need to adjust total doses accordingly

Plan evaluation

- Plan evaluation cannot just be based on DVHs, since all positional information is lost
  - Target: cold spot inside vs at edge
  - Normal tissues: hot spots near target vs unexpectedly elsewhere

Choosing beam directions

- Choice of beam directions still matters
  - Don’t modulate any more than necessary

Spatial quantization effects

- Shift isocenter to provide best separation between target and tissues

Developing a planning strategy
General principles (1)

• Don’t ask for the impossible
  - If you ask for NO dose to the cord, 60 Gy may appear just as bad as 40 Gy to the optimizer
  - Look at a good 3D conformal alternative to get a starting point

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  - Define what needs to be treated
  - Define what needs to be avoided
  - The system is going to choose the beam shapes according to the structures defined

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  - What is desirable
  - Where you are able to compromise

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General principles (4)

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  - What you want and tell the human planner to get
  - What the planner tells the system to try for
  - What you eventually get and treat with

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Example: H&N treatment with Corvus

• Physician wants 45 Gy to target, 50% of parotid below 25 Gy

Results - DVH

82% > 25 Gy, no good!
General principles (5)
• Learn what “knobs” there are
  - DVH criteria for targets and structures
  - Relative weights or tissue types
  - Number of intensity levels
  - Number and direction of beams
  - ...
• Try each individually and systematically
  - on idealized and actual patients

General principles (6)
• Dose uniformity vs Conformality
• Target dose uniformity can be expected to decrease with
  - increasing concavity
  - increasing dose gradient
  - decreasing number of beams

General principles (7)
• Don’t assume IMRT is the way to go
• 3D conformal, judged by the same criteria, may be better
  - parallel-opposed beam pairs are often best
  - IMRT system may have limitations
    - 1x1 beamlets
    - insufficient weight to dose uniformity

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Building experience with artificial problems
• Designed to illustrate performance for certain types of situations
• Observe how changing various planning parameters affects plan quality and delivery efficiency
• For each, decide on relevant measures of plan quality

Simple cylindrical geometry
• Single target with 1 cm PTV expansion (PTV is 8 cm diam, 8 cm long)
• Goal: target dose uniformity
  - PTV max/min
  - PTV D2/D98
• Compare to:
  - 3 open fields
  - evenly weighted

Target dose uniformity
• As you vary the requested degree of target dose uniformity, how do the results change?

Corvus V5 “Prescription Panel”
Goal: target uniformity (Corvus V5)

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<thead>
<tr>
<th>Inverse plans</th>
<th>Forward plans</th>
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<tr>
<td>Goal 100 100 100 100</td>
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<td>Min 95 98 99 100</td>
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<td>Max 105 102 101 100</td>
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<td>Rx Max/Min 1.11 1.04 1.02 1.00</td>
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<td># MU 302 301 318 291</td>
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Goal: target uniformity

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Goal: target uniformity

- Effect of Corvus’ “efficiency” control

<table>
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<th>Efficiency %</th>
<th>PTV D2/D98</th>
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<th># MU</th>
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Simple cylinder with 4 structures PipesEasy

- Goal: structure sparing vs target uniformity
  - PTV D2/D98
  - Structure mean/PTV mean
- 15 fields equispaced
- Try different structure goals
  - 50, 20, 10, 2% of target dose

PipesEasy: Effect of changing structure goals

- Asking for too much sparing degrades target uniformity with little improvement

PipesEasy: comments

- Asking for too much sparing degrades target uniformity with little improvement

90% and 20% isodoses
### What is achievable?

**Limiting dose gradient**

![Graph](image1.png)

- Goal: structure sparing vs target uniformity
  - PTV D2/D98
  - Structure D5/PTV 98
- 15 fields equispaced
- Try different structure goals
  - 60, 50, ..., 10% of target dose

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### C Shape

- Goal: structure sparing vs target uniformity
- PTV D2/D98
- Structure D5/PTV 98
- 15 fields equispaced
- Try different structure goals
  - 60, 50, ..., 10% of target dose

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### Corvus: C Shaped Target

- Structure at 10%
- Structure at 60%

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### Limiting dose gradient

- 6%/mm

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### Corvus

- C Shape Target Around Central Structure
- Structure Goal from 10 to 60 Gy

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### Uniformity and Sparing vs Structure Goal

- Dose ratio
- Structure Goal (Gy)

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**Graphs**

- PTV D2/D98
- Structure D5/PTV 98
Comparing planning systems

Reverse the structure and target

Try for different PTV expansions
- Gap between structure and PTV of 3, 5, 7 mm
- Look at
  - uniformity vs sparing
  - limiting dose gradients

Other parameters, e.g. “weights”
Comments on these artificial problems

• Good for gaining some feel
  - for the “knobs”
  - for the limiting conditions (e.g. maximum dose gradients)
  - for the consequences of being unrealistic in the problem statement

Dealing with real clinical plans

• Determine method/conventions for defining structures and targets
• Determine margins (CTV and PTV)

These do not change whether IMRT or 3D conformal

Dealing with real clinical plans

• Decide on criteria for an acceptable plan
  - e.g. PTV dose must be sufficiently uniform: PTV D2/D98 ≤ 1.15
• Decide on parameter to be optimized
  - e.g. minimize mean parotid dose

These will often be competing and cannot both be “optimized”

Dealing with real clinical plans

• Start with a 3D conformal plan to get a sense of what is achievable
• Look at requested dose gradients to see if achievable
• Use these results as a starting point for DVH goals for the inverse planner
• Start with relaxed goals and gradually tighten them

Overall clinical implementation

• Many aspects
  - immobilization
  - imaging for planning
  - imaging for verification
  - information transfer
  - quality assurance needs
  - training
  - maintenance

Overall clinical implementation

• Establish an implementation team
  - Physician
  - Physicist
  - Dosimetrist
  - Therapist
  - Scheduler
  - Nurse
Penumbra

- Measure with film, diode, or microchamber, conventional scanning chamber too wide
- Subtle effects make a difference in IMRT