Knowledge Based Treatment Planning in Eclipse

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FLAAPM Meeting
April 29th, 2016
Disclosure

- Research Funding – NIH and Varian Medical Medical Systems
Typical Inverse Planning Workflow

1. Physician prescribes treatment goals
2. Dosimetrist Designs Plan Setup and Translates Goals into Cost Function
3. Dosimetrist Reviews Optimization Result vs. Treatment Goals

- Add Ring Structure
- Add “Hotspot” Structure
- Tweak Cost Function
- etc....
Critical Impact of Radiotherapy Protocol Compliance and Quality in the Treatment of Advanced Head and Neck Cancer: Results From TROG 02.02

Reasons for Suboptimal Treatment Planning

• Lack of treatment team experience
  – Not sure how “good” the plan could be
• Lack of time to reach “best” plan
• Too many OARs – Hard to focus on everything without sacrificing high priority objectives
Tools to Improve
Plan Quality & Efficiency

• Priority based (in-house systems) and multi-criteria optimization techniques (RayStation)
• Automated planning techniques that mimic dosimetrist interaction with planning system (Pinnacle)
• Knowledge based planning (in-house systems and Eclipse Rapidplan)
What is Knowledge-Based Planning?

• Treatment planning that utilizes knowledge gained from prior cases when planning current cases

• Source of knowledge
  – Prior dose distribution features
  – Prior DVH metrics and features
  – Physician-prescribed metrics
Knowledge Based DVH Estimation

Estimated DVH achievable for bladder

Objective set for inverse planning
Building a Knowledge Based Model for Treatment Planning & QA

Database of High Quality Plans

- Distance-Based
- Volume-Based
- Dose-Based

Feature Extraction

Model Training

Predictive Model

Prospective
- New Cases
- Planning Guidance

Retrospective
- Plan Databases
- Quality Analysis

Adapted from Jackie Wu, Duke
Example Model Building

Case Preparation

- Data Transfer (if needed)

Model Definition

- Model Description
- Anatomic Site
- Structures to Include in Model
Example Model Building

Data Extraction
Example Model Building

Data Extraction

Model Structures
- PTV
- Cord
- Cord PRV
- Esophagus

Patient Structures
- Cord
- Cord+2mm
- Esoph
- PTV1
## Example Model Building

### Model Training

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<th>Patient ID/Course ID/Plan ID</th>
<th>Plan Prescription</th>
<th>Structure Matching</th>
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<th>Extracted</th>
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Example Model Building

Model Verification & Validation

Use Tools to Add/Remove Outlier Cases from the Model

Test how the Model Works Compared to Clinical Plans
Motivation

• Building a knowledge based model can be time-consuming and complicated

• Is it worth it??
  – Plan Quality
  – Plan Efficiency
  – Automation
Suboptimal Plans Lead to Increased Risk

UM Custom Rapidplan Model Goals

• **Prostate**
  – TPS commissioning and quality control across hospital network

• **Spine SBRT**
  – Improved standardization and efficiency for a potentially emergent, but complex treatment

• **Liver SBRT**
  – Aid in planning a very complex site for less experienced planners
  – Test the limits of knowledge based planning in areas of PTV/OAR overlap

• **HN & Pancreas**
  – Newer models that haven’t been fully refined or clinically tested yet
Prostate Model: Can Knowledge-Based Planning help with a Planning System Transition?

- Transitioning from in-house TPS to Eclipse for prostate IMRT was a challenge
- Struggled to get the same plan quality and efficiency in Eclipse vs. in-house TPC
  - A lot of iterative planning
- Created a knowledge based model from in-house TPS cases to compare performance with Eclipse cases planned early and late in the transition
Prostate Model Description

• 60 plans, prostate and prostate bed
• Prescription range: 68.4-79.2 Gy
• All plans had to be exported from in-house system and then imported into Eclipse
• Structure and plan QA done and unacceptable geometries and plans were not included in the final 60 plan model
Prostate Model Plan Quality

Clinical Plan – Early in Transition

Model Generated Plan

- 73.7 Gy
- 70.2 Gy (Rx)
- 60 Gy
- 45 Gy
- 30 Gy
Prostate Model Plan Quality

Clinical Plan – Later in Transition

- 81.6 Gy
- 77.7 Gy (Rx)
- 73.8 Gy
- 45 Gy
- 30 Gy

Model Generated Plan
Prostate Model Plan Efficiency

Range of Planning Times
(Not including Physician Review)

Planning Time (minutes)

Eclipse - First 10 Cases
Eclipse-Recent 10 Cases
Model Generated Cases
Prostate Model Automation

• Using the custom model
  – 4/20 plans met all clinical objectives with no iterations of the objective function
  – 15/20 plans required 1 iteration of the cost function (likely due the rectum and therefore a model tweak could also be done to improve automation)
  – 1/20 plans required 2 additional iterations of the cost function
Quality Control of Treatment Plans

Variation in external beam treatment plan quality: An inter-institutional study of planners and planning systems

Benjamin E. Nelms PhD\textsuperscript{a,b,*}, Greg Robinson CMD\textsuperscript{c}, Jay Markham CMD\textsuperscript{c}, Kyle Velasco CMD\textsuperscript{c}, Steve Boyd CMD\textsuperscript{c}, Sharath Narayan CMD\textsuperscript{c}, James Wheeler MD, PhD\textsuperscript{d}, Mark L. Sobczak MD\textsuperscript{e}

Conclusions

There is a large inter-planner variation in plan quality as defined by a quantitative PQM score that measures the ability of the planner to meet very specific plan objectives. Plan quality was not statistically different between different TPS or delivery techniques and was not correlated to metrics of plan complexity. Certification and education demographics, experience, and confidence level of the planner were not good predictors of plan quality.
Quality Control of Treatment Plans

• How does the plan quality of prostate patients compare across a system of hospitals?
• Ran the model on cases that came from 4 different community clinics in the same network
• Generated DVH estimations for OARs defined by the model for each patient
• Optimized a new plan based on the DVH-estimations (field parameters were copied from the original plan)
Clinic I: DVHs

- ▲ = KBP-generated Plan
- □ = Clinically-Used Plan
Clinic I: Plan Quality

Clinical Plan

Model Generated Plan

- 82 Gy
- 77.7 Gy (Rx)
- 60 Gy
- 45 Gy
- 30 Gy
Clinic II: DVHs

- ▲ = KBP-generated Plan
- □ = Clinically-Used Plan
Clinic II: Plan Quality

Clinical Plan

Model Generated Plan

72 Gy
68.4 Gy (Rx)
60 Gy
45 Gy
30 Gy
Clinic III: DVHs

- ▲ = KBP-generated Plan
- □ = Clinically-Used Plan
Clinic III: Plan Quality

Clinical Plan

Model Generated Plan

- 72 Gy
- 68.4 Gy (Rx)
- 60 Gy
- 45 Gy
- 30 Gy
Quality Control

- Disseminating the model throughout our system was a great educational/collaborative experience
- Identified differences in planning priorities
- Easily identified and corrected an outlier
- As models get updated, they are easily transported and loaded on different systems so long-term quality control (and improvements in plan efficiency) are possible
RapidPlan for Liver SBRT

- Large liver SBRT service
- Variation in plan quality between dosimetrists as well as physicians
- Things to consider:
  - Non-standard geometry
  - PTV overlap with various structures
RapidPlan Model for Liver SBRT

- 60+ plans to create model
- Tested with 20 plans, made tweaks to the model
- Validated the model with 16 new cases
- 13 of 16 met all priority 1 planning objectives with the push of a single button
KBP: Liver SBRT

Model Plan – ‘Easy Button’

- 1 Iteration
- All OAR constraints met
- Planning time: 9 minutes

Manually optimized plan

- 1 Iteration
- All OAR constraints met
- Planning time:
  - 10 minutes - experienced dosimetrist
  - 17 minutes - novice dosimetrist
KBP: A tool for Novice Planners?

Manually Optimized Plan

Rapidplan Model Plan

Red = GTV
Pink = PTV
Orange = Colon
Blue = Liver

= Manual Plan
= Model Plan
Rapidplan Liver SBRT Model

- Performs well even in PTV/OAR overlap
- Time savings of 50% for novice dosimetrist w/ quality improvements

Note steep dose gradient and excellent sparing of colon
Another Complex Geometry

- Model reduced planning time from 1 hour to 20 minutes
Rapidplan for Liver

• A great tool for dosimetrist
  – Especially for novice users
• Very useful in implementing planning for a new or less common body site
• Impressive performance in areas of PTV/OAR overlap
• Excellent first pass for both simple and complex geometries: some ‘tweaking’ may be necessary to achieve ‘ideal’ plan
Knowledge Based Planning to improve standardization and efficiency in spine SBRT

- Spine SBRT can be used as an emergent technique to treat cord compression.
- Spine SBRT planning can be iterative and time-consuming.
  - Geometrical variation
  - Importance of OAR sparing (Reduced acceptability of tradeoffs)

Can KBP be effective in spine SBRT, where there are important variations in the gradient regions and strong prioritization of normal tissues?

Example Targets from RTOG 0631 (PI S. Ryu)
Knowledge Based Planning for Spine SBRT

- 6/10 model-generated cases were acceptable with no tweaking
- 4/10 model-generated cases were acceptable after 1 or 2 iterations of tweaking
- Without sacrificing cord and cord_prv objectives, target coverage improved by approximately 5% in the model-generated plans
Confidence in quick plan turn-around may allow us to offer same day spine SBRT for emergent cases.
Do we still need dosimetrists? (Yes!)

• Is it possible to create a fully automated plan with a push of a button?
  – Perhaps, but you still need a dosimetrist!

• Limitations include:
  – There are evaluation criteria that can’t be put in the objective function (NTCP, conformity, etc...)
  – There may still be improvements that can be gained on top of the default objectives
  – Not every patient is going to be represented by a model – leaving more time for planners to tackle complex non-standard cases
What do our dosimetrists think about RapidPlan?

• Depends on:
  – Dosimetrist seniority
  – Dosimetrist experience with using Rapidplan
  – Dosimetrist engagement in the model creation
Clinical Benefits of Rapidplan Rollout

• Standardization throughout system and between planners on common cases

• Ability to more confidently roll out complex planning to additional planners and clinics

• General confidence and quality assurance
  – Currently testing physician acceptance of rapidplan and any increases in novice planner confidence as a result of their use of a model as guidance
Summary

• There is a variation in plan quality within and between centers – regardless of size or volume
  – This can lead to increased risk for patients
• Inverse planning, especially for complex cases, is iterative and time consuming
  – It is difficult to ensure each structure is always the “best it can be”
• Knowledge-based and other automated planning techniques may be able to improve both quality and efficiency for a variety of treatment sites
Acknowledgements

• Thank you to the FL-AAPM & Twyla for the invitation

• UM Knowledge Based Planning Teams
  – Spine: Joseph Foy, Robin Marsh, Dawn Owen, Kelly Younge
  – Prostate: Kathryn Masi, Paul Archer, Will Jackson, Dan Hamstra, Maria Ditman + Community Practice Teams
  – Liver: Janell Dow, Hunter Gits, Mary Feng, Dawn Owen

• Lindsey Olsen, Washington University
• Ping Xia, Cleveland Clinic
• Jackie Wu, Duke University
• Kevin Moore, University of California - San Diego