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Automated Planning Techniques

The Dosimetrist's Perspective

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Disclosure

- Research Funding
  - NIH
  - Varian Medical Systems

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Typical Inverse Planning Workflow

Physician prescribes treatment goals

↓

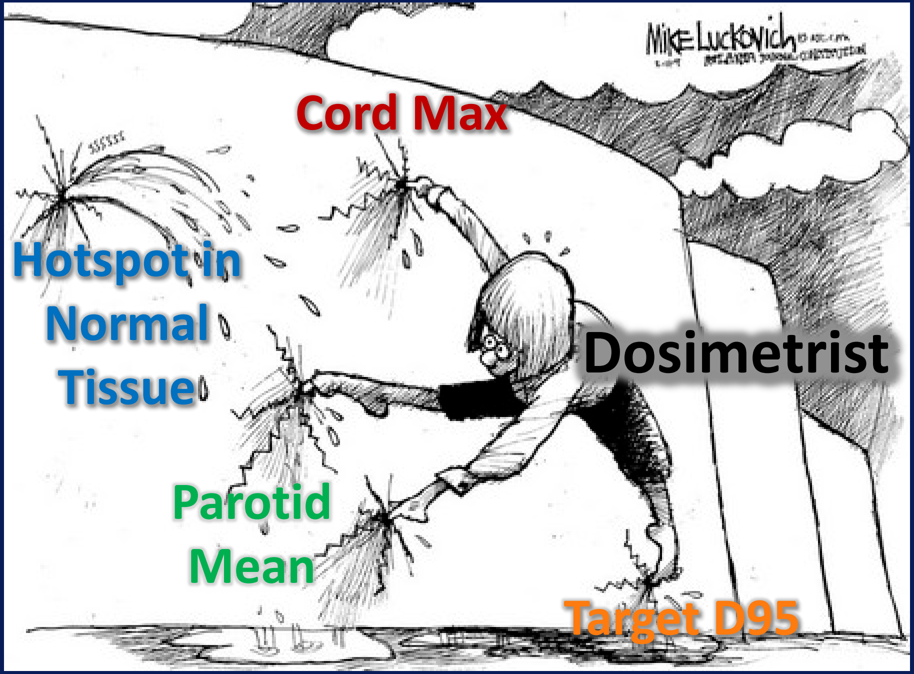
Dosimetrist Designs Plan Setup and Translates Goals into Cost Function

↓

Dosimetrist Reviews Optimization Result vs. Treatment Goals

- Add Ring Structure
- Add "Hotspot" Structure
- Tweak Cost Function
- etc....

(loop back to review)



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Tools to Improve Plan Quality and 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)

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What is Knowledge-Based Planning?

- Software tool that utilizes knowledge gained from prior cases when planning current cases
- Source of knowledge

  - prior dose distributions

  - prior DVH metrics and features

  - Physician-prescribed metrics
- Commercially available TPS offer some pre-loaded models as well as the ability to create your own institution specific model (Eclipse Rapidplan)

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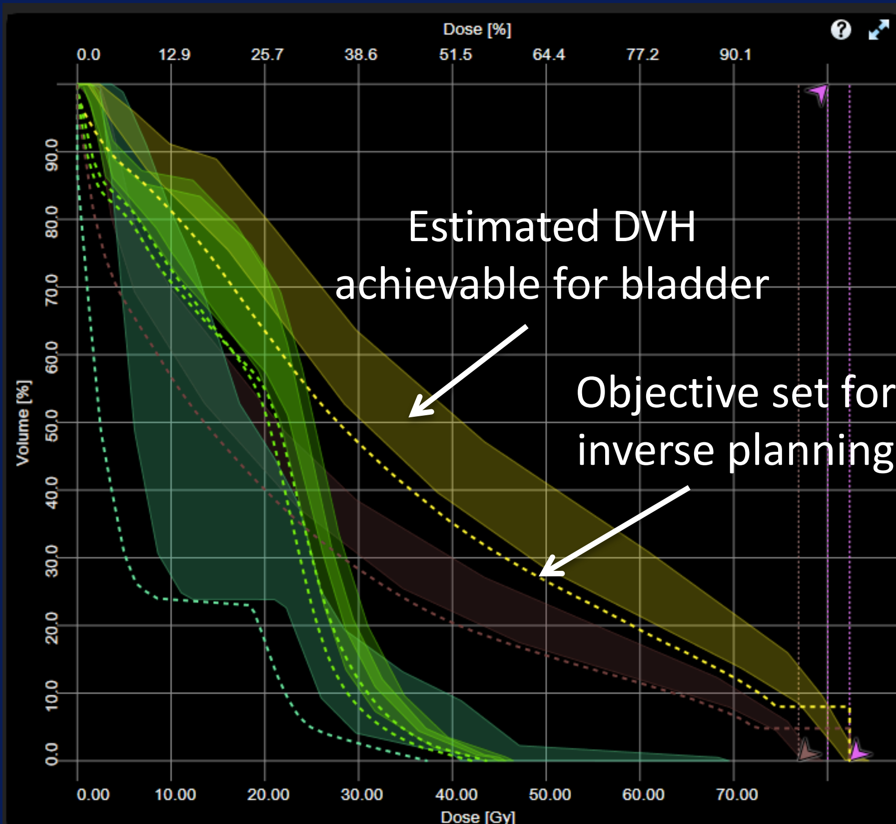
Knowledge Based DVH Estimation



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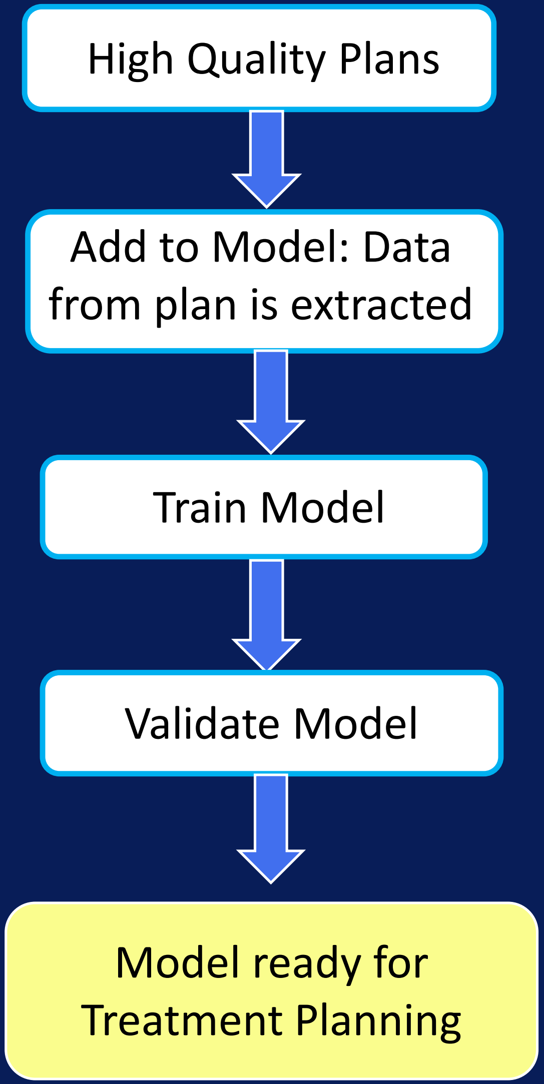
Creating a Knowledge Based Model for Treatment Planning



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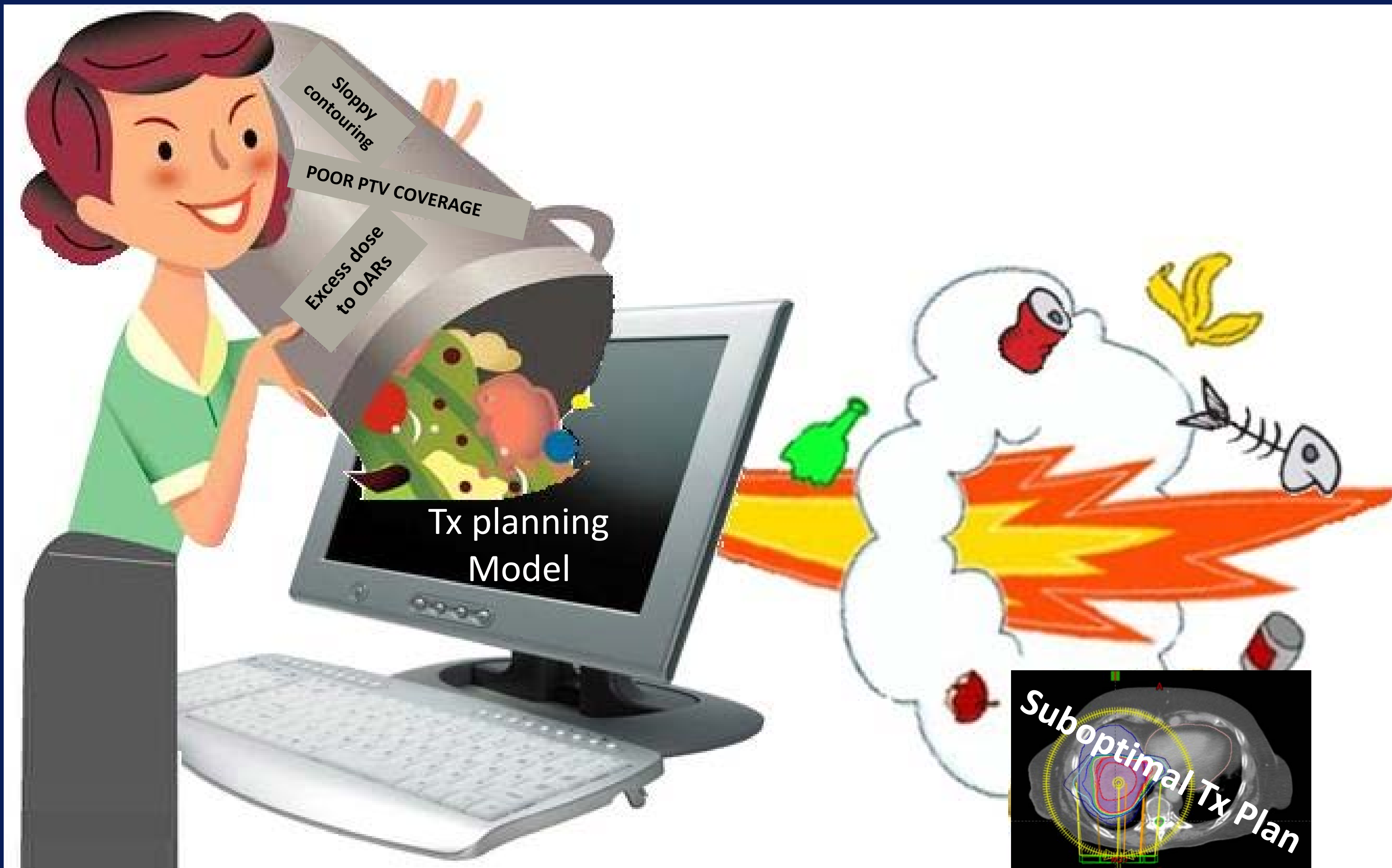
Quality Matters!



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KBP: Creating a model

- Developing a model requires a minimum number of cases
- All plans must be high quality i.e. meeting OAR dose limits and PTV coverage goals etc.
- Use same naming convention for targets and OARs

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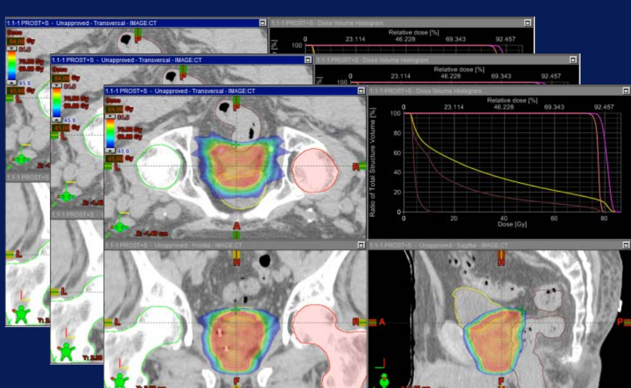
Example Model Building

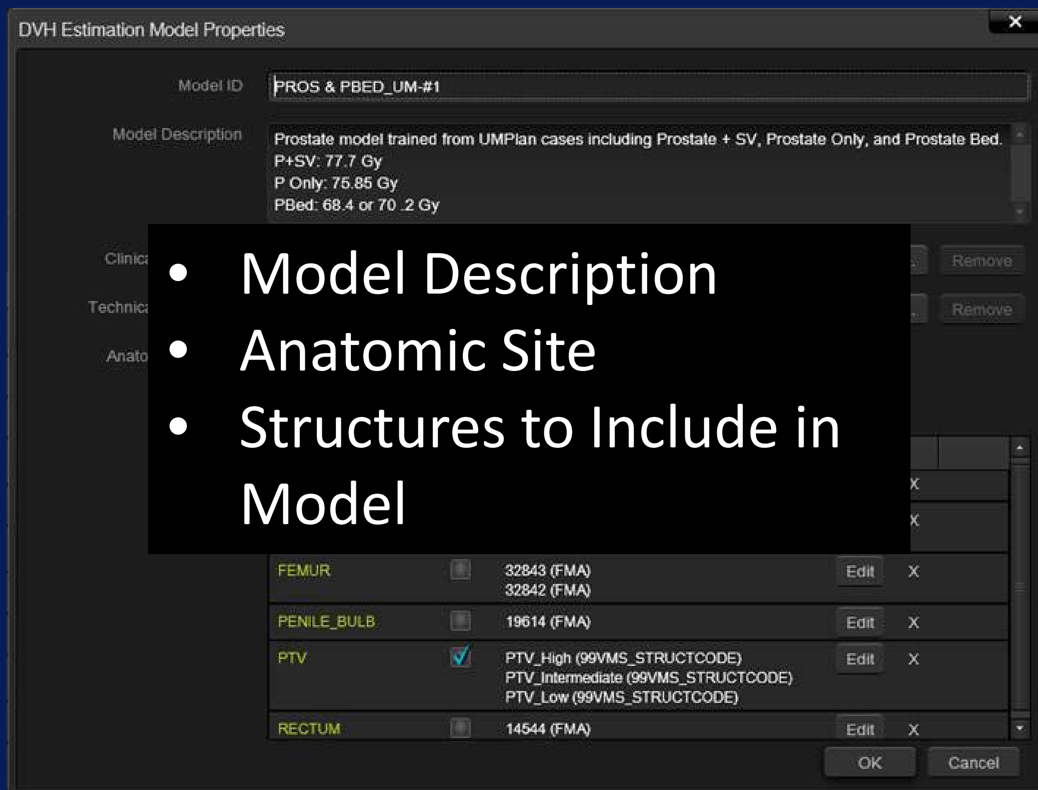
Case Preparation

Data Transfer (if needed)

Contouring & Plan QA



Model Definition



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

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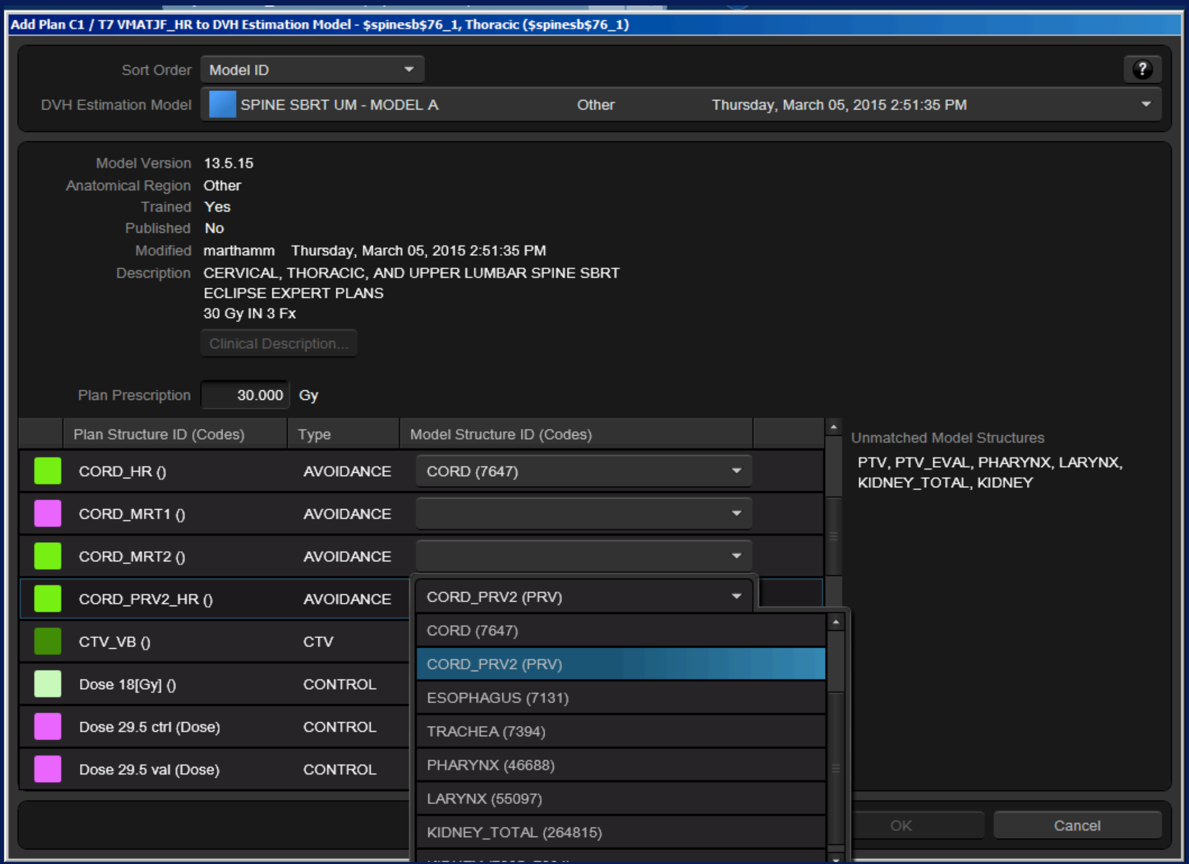
Example Model Building

Data Extraction



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Example Model Building

Data Extraction

Model Structures

- PTV
- Cord
- Cord PRV
- Esophagus

Patient Structures

- Cord
- Cord+2mm
- Esoph
- PTV1

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Example Model Building

Plans of the DVH Estimation Model

#	Patient ID/Course ID/Plan ID	Plan Prescription		Structure Matching	Include	Extracted	In Mod		
1	$pros002/C1/1.1-1 PROST+S	79.200	Gy	... Target: 1/1 Other: 4/5	✓	Yes	13.5.15		
2	$pros003/C1/1.1-1 PROSTAT	75.850	Gy	... Target: 1/1 Other: 4/5	✓	Yes	13.5.15		
3	$pros004/C1/1.1-1 IMRT PR	70.200	Gy	... Target: 1/1 Other: 5/5	✓	Yes	13.5.15		
4	$pros005/C1/1.1-1 PROST B	70.200	Gy	... Target: 1/1 Other: 4/5	✓	Yes	13.5.15		
5	$pros006/C1/1.1-1 PROSTAT	75.850	Gy	... Target: 1/1 Other: 4/5	✓	Yes	13.5.15		
6	$pros007/C1/1.1-1 PROSTAT	75.850	Gy	... Target: 1/1 Other: 4/5	✓	Yes	13.5.15	5.0	X
8	$pros009/C1/1.1-1 IMRT PR	77.700	Gy	... Target: 1/1 Other: 5/5	✓	Yes	13.5.15	3.7	X
9	$pros010/C1/1.1-1 PROST+S	77.700	Gy	... Target: 1/1 Other: 5/5	✓	Yes	13.5.15	1.5	X
10	$pros011/C1/1.1-8 PROST+S	77.700	Gy	... Target: 1/1 Other: 5/5	✓	Yes	13.5.15	1.5	X
11	$pros012/C1/1.1-1 PROST+S	77.700	Gy	... Target: 1/1 Other: 4/5	✓	Yes	13.5.15	1.6	X
13	$pros014/C1/1.1-3 IMRT PR	77.700	Gy	... Target: 1/1 Other: 4/5	✓	Yes	13.5.15	3.3	X
14	$pros015/C1/1.1-1 PROST+S	77.700	Gy	... Target: 1/1 Other: 4/5	✓	Yes	13.5.15	3.8	X
15	$pros016/C1/1.1-1 PROST+S	77.700	Gy	... Target: 1/1 Other: 4/5	✓	Yes	13.5.15	4.2	X
16	$pros018/C1/1.1-1 PROST B	70.200	Gy	... Target: 1/1 Other: 4/5	✓	Yes	13.5.15	17	X
17	$pros019/C1/1.1-1 PROST+S	77.700	Gy	... Target: 1/1 Other: 5/5	✓	Yes	13.5.15	35	X
18	$pros023/C1/1.1-1 PROST+S	77.700	Gy	... Target: 1/1 Other: 4/5	✓	Yes	13.5.15	5.2	X

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Example Model Building

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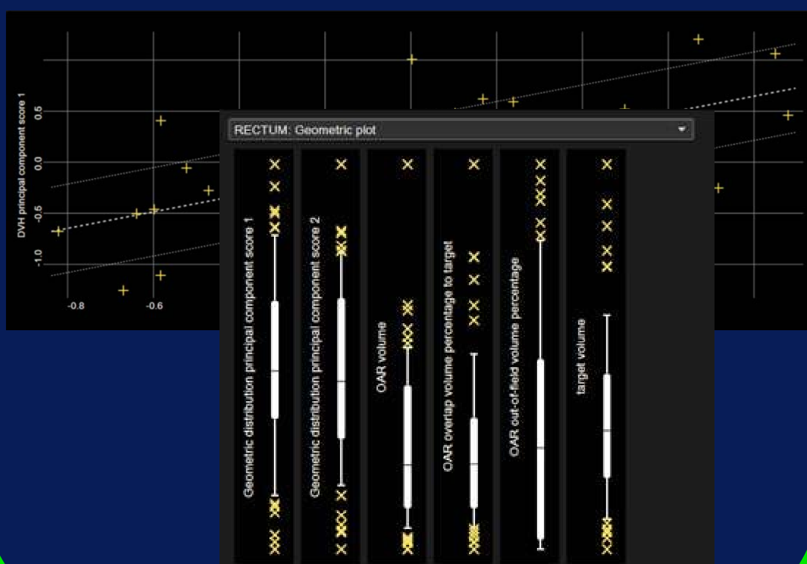
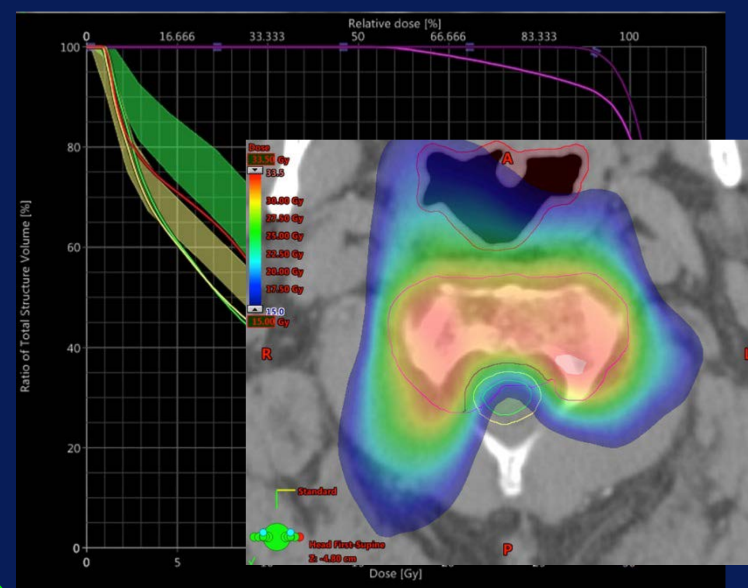
Model Verification & Validation

Use Tools to Add/Remove Outlier Cases from the Model



Test how the Model Works Compared to Clinical Plans



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KBP: Validating a model

How do you know if you have a 'good' model?

- Somewhat subjective…
- Plans should meet all planning objectives for OARs and targets
- Normal tissue DVHs should fall within the estimated regions
- Consistent results

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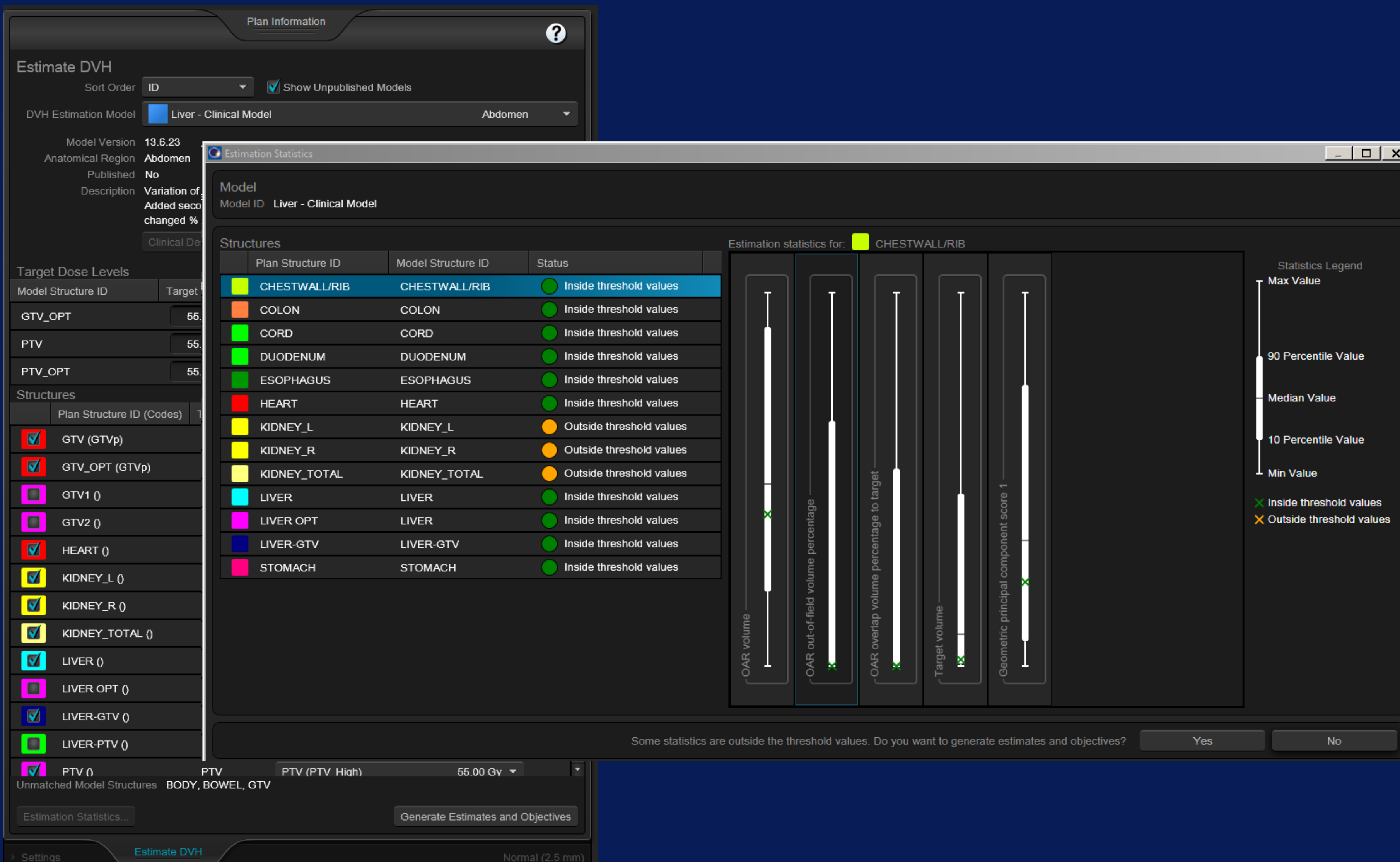
KBP: Using the model



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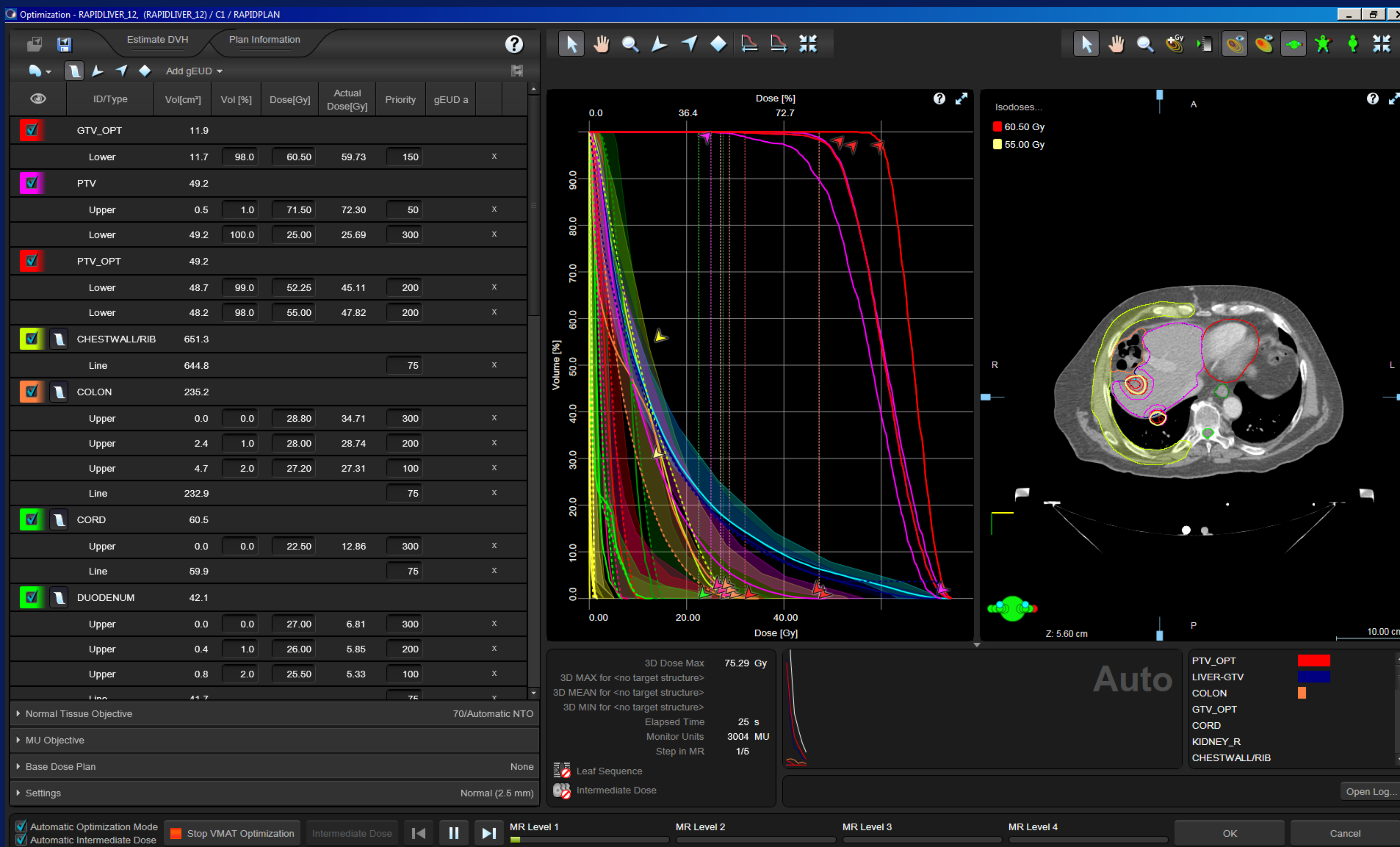
KBP: Optimization & 3D Calc



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Motivation

- Decrease planning time = increase in productivity
- Reduce variability in planning
- Potential to increase confidence of novice planners
- Aid in evaluating institution's treatment planning practices - which may result in improved tx planning protocols throughout the Rad Onc Community

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We would like to learn a little more about you & your department!

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KBP: Our Experience…

Started with an easier body-site….

Prostate

Then moved to more complex sites:

Spine SBRT

Liver SBRT

Head/Neck

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Prostate Model at UM

- 60 clinically treated patients
  - Prostate and Prostate Bed IMRT plans
  - Prescription range: 68.4 - 79.2 Gy
- Exported from in house TPS, UMPlan, and imported into Eclipse, v13.5
- Structure and plan QA performed; unacceptable geometries and plans were not included in the final 60-plan model

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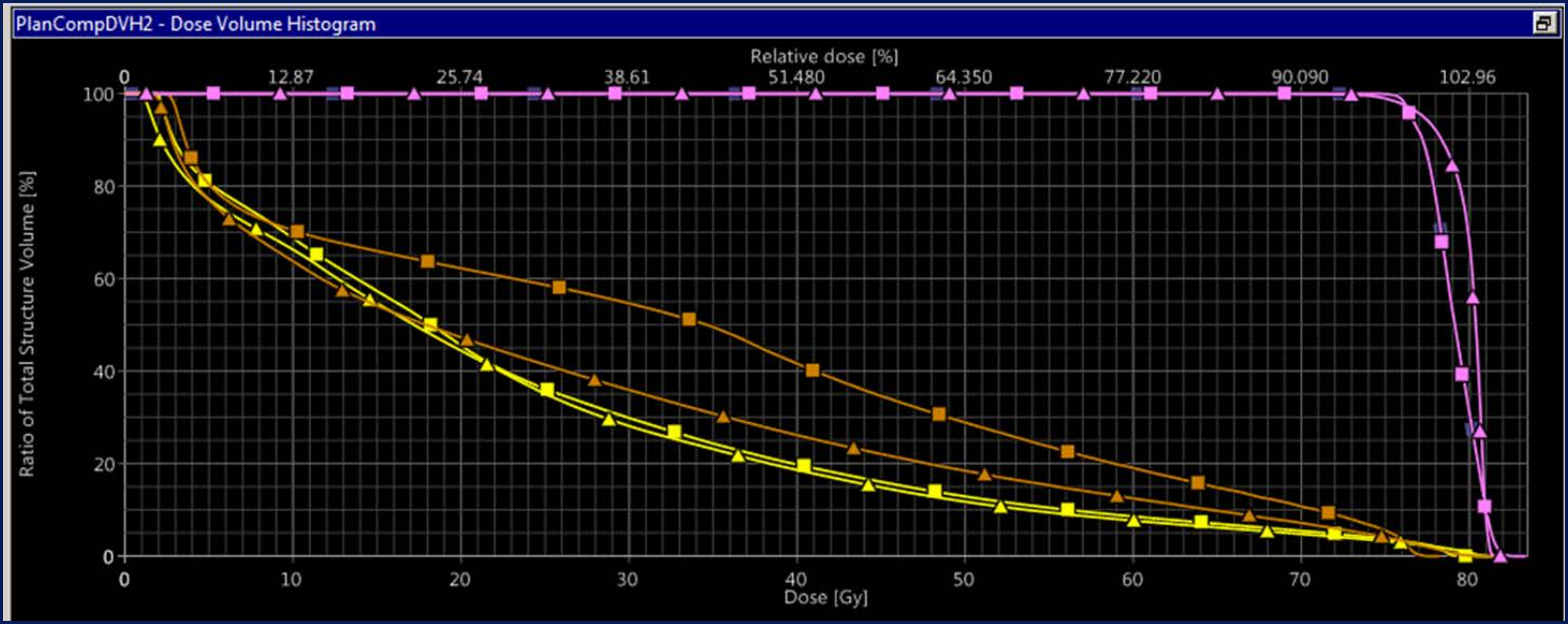
Initial Model Validation

- Used only the generated line objectives for normal structures



▲ = KBP-generated Plan ■ = Clinically- Used Plan

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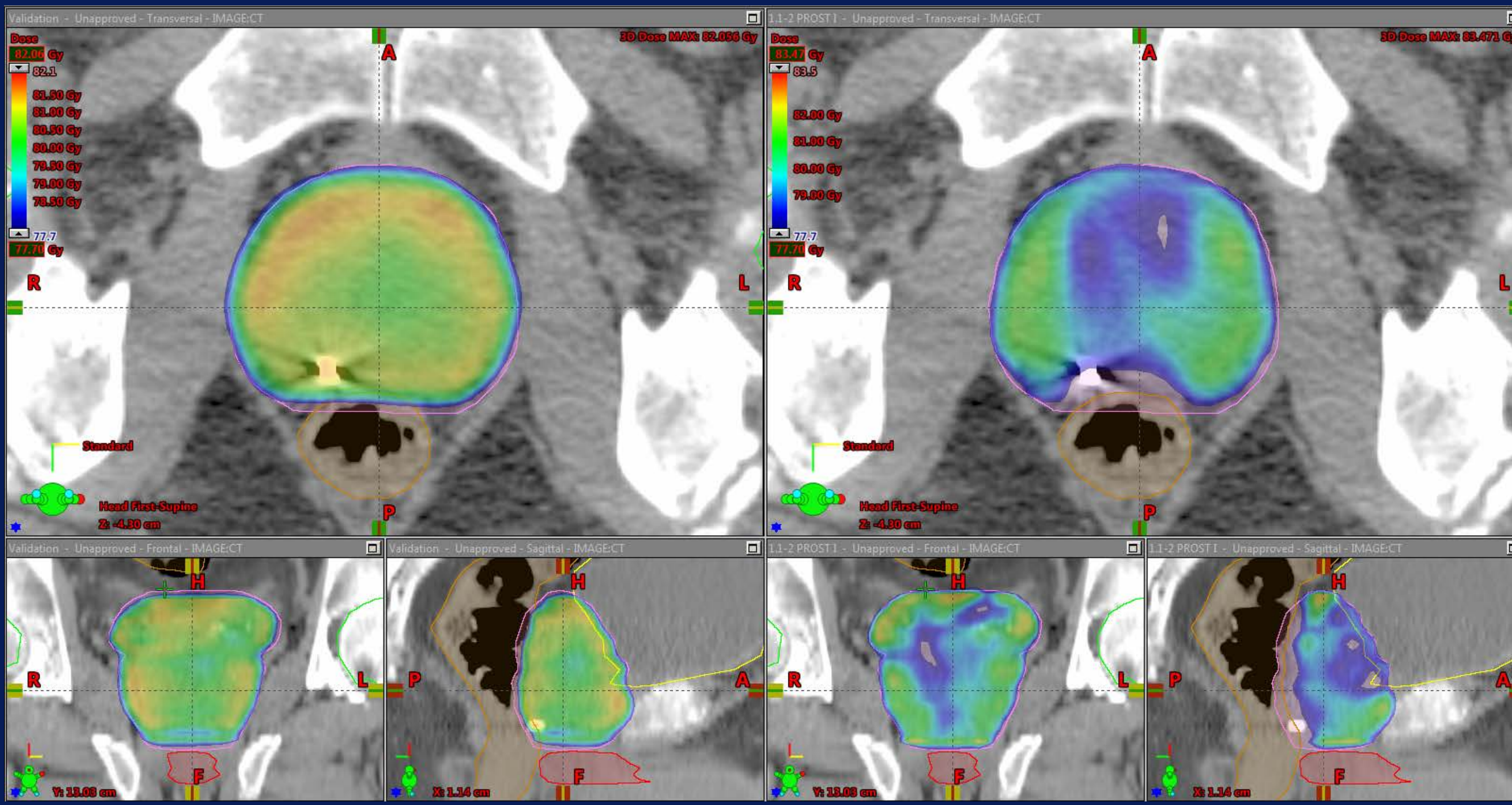
Initial Model Validation

Validation Plan	Clinically-Used Plan



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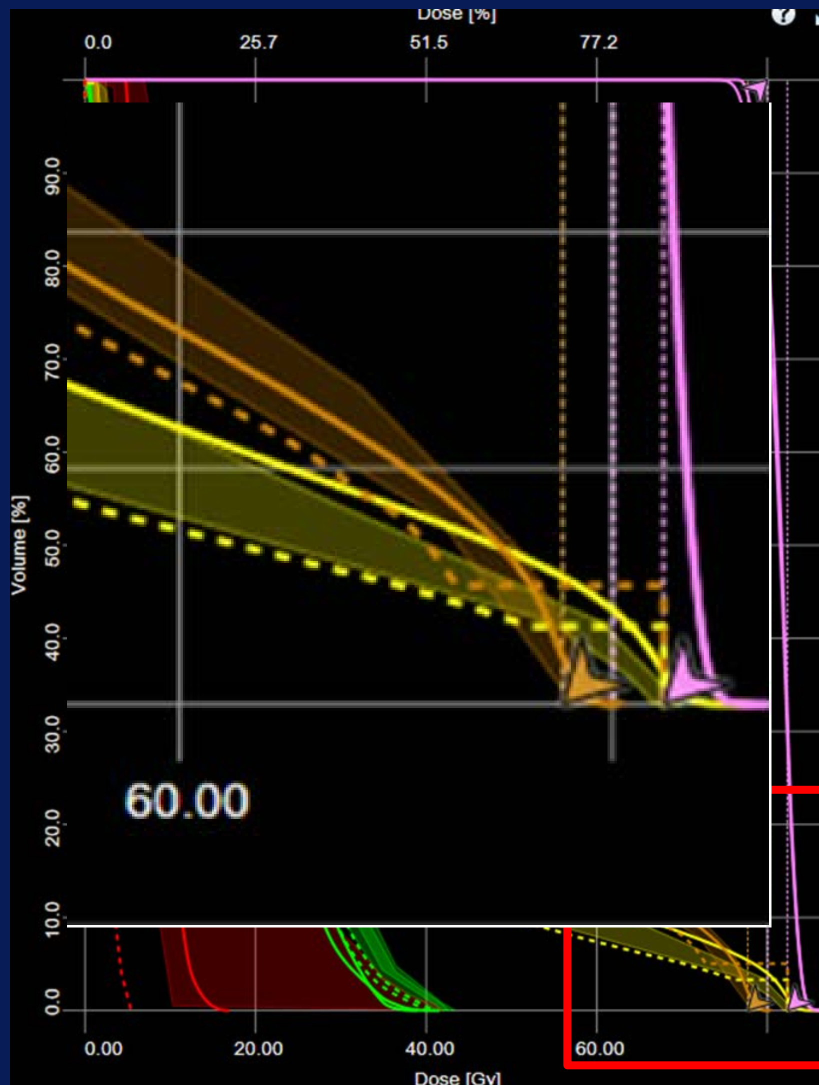
Target Coverage vs. OAR Sparing



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Model Application: Quality Control of Treatment Plans

- How does the plan quality of prostate patients compare across our system of hospitals?
- Ran the model on cases that came from 4 different community clinics
- 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

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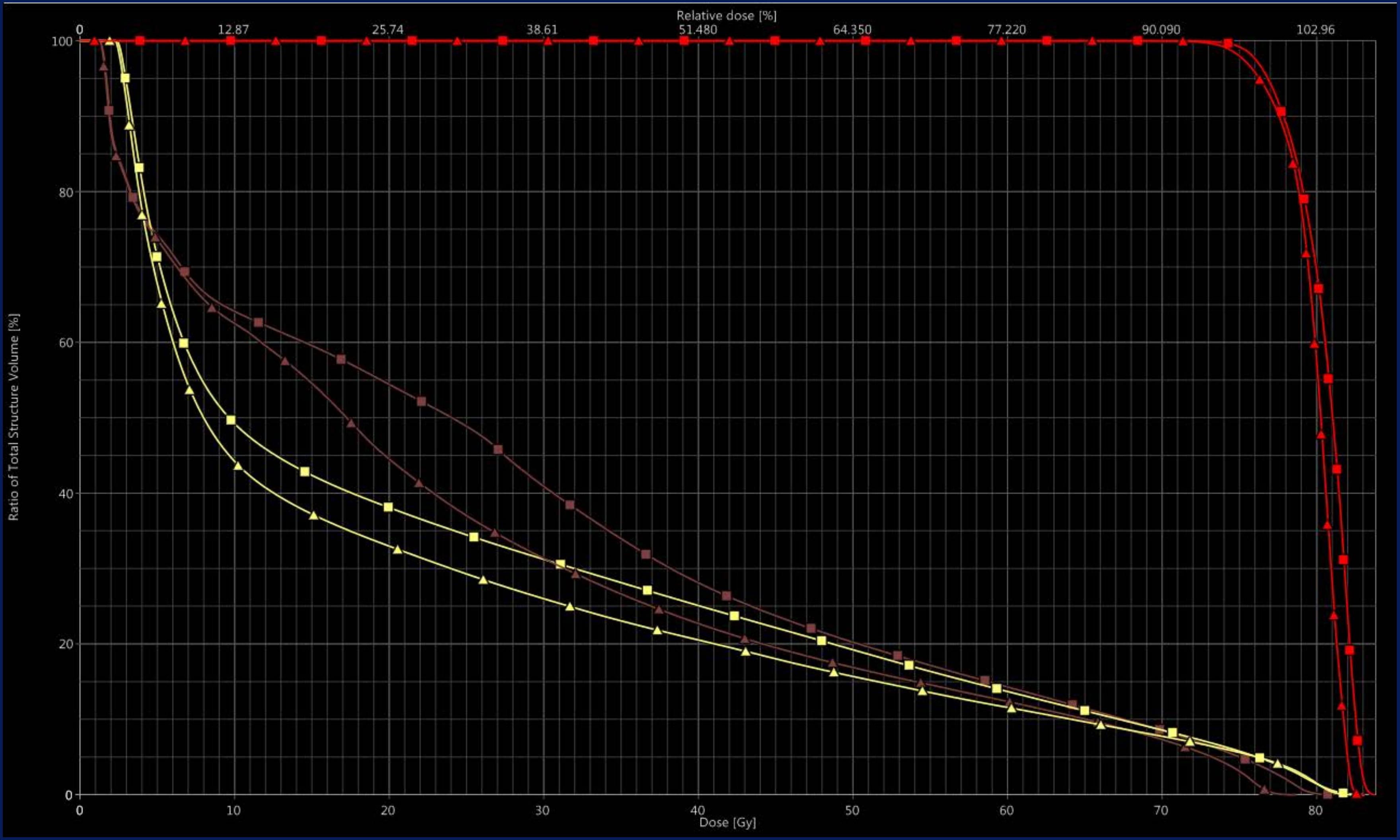
Clinic A: DVHs



▲ = KBP-generated Plan ■ = Clinically- Used Plan

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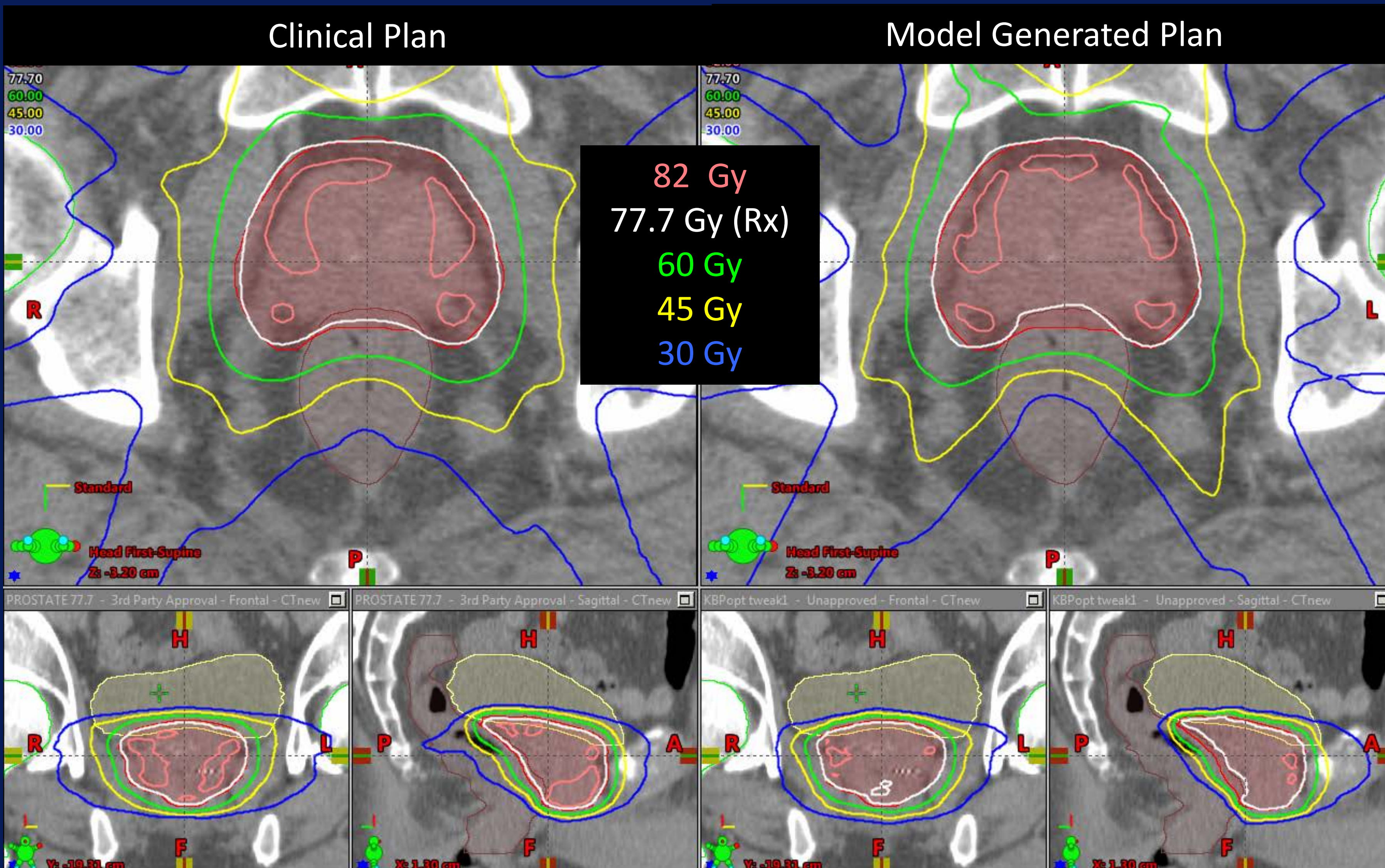
Clinic A: Plan Quality



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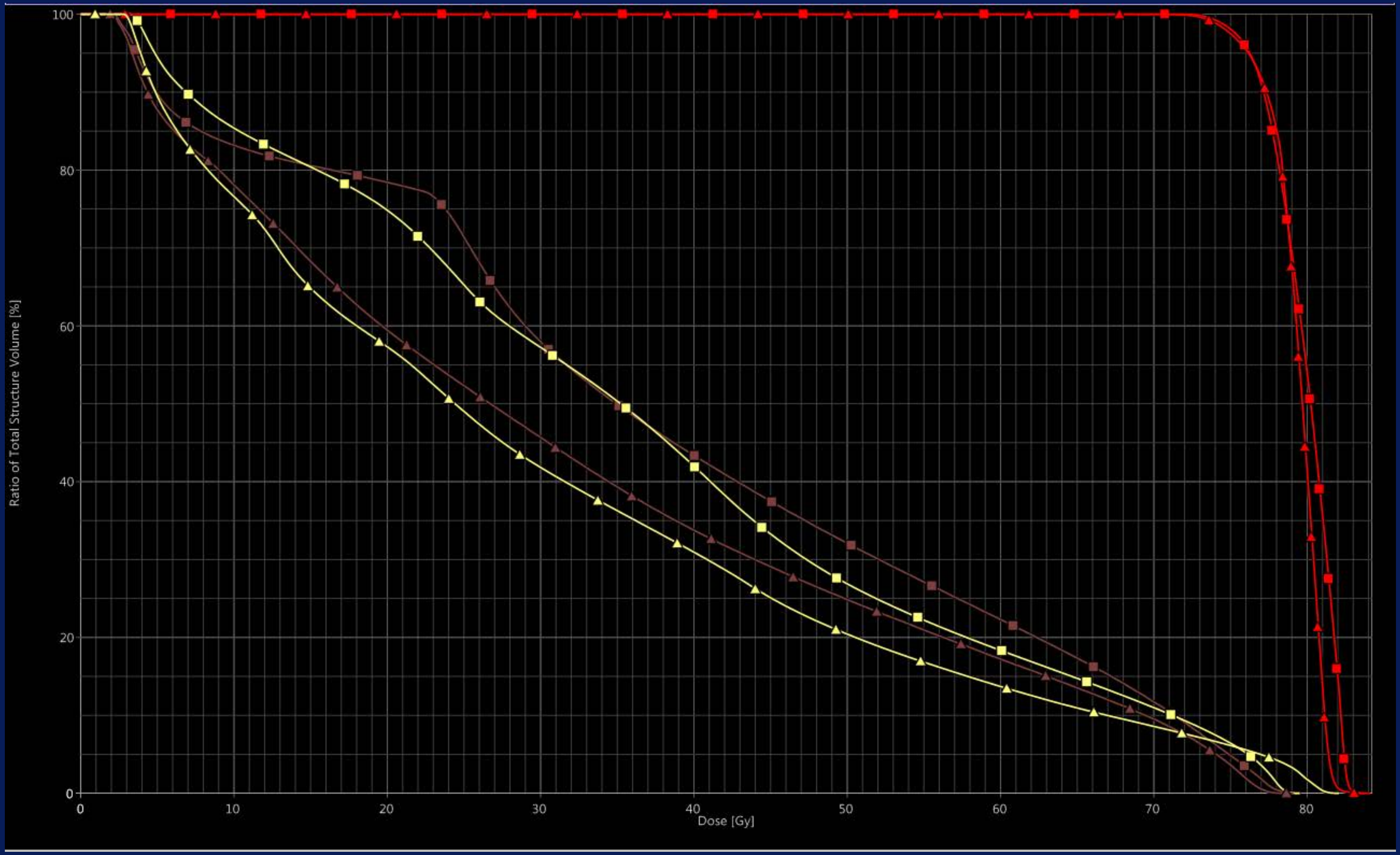
Clinic B: DVHs



▲ = KBP-generated Plan ■ = Clinically- Used Plan

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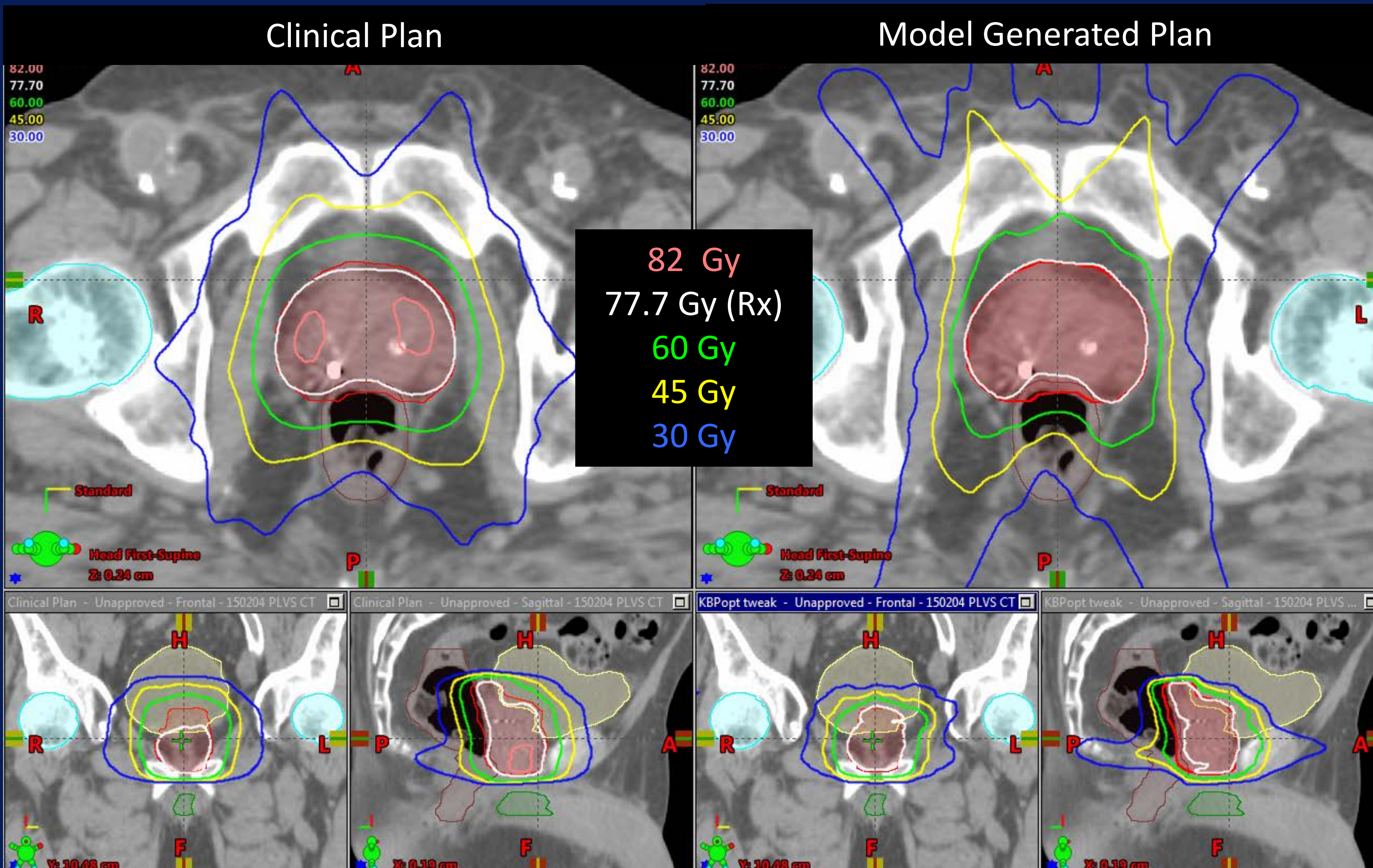
Clinic B: Plan Quality



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Clinic C: DVHs

▲ = KBP-generated Plan ■ = Clinically- Used Plan

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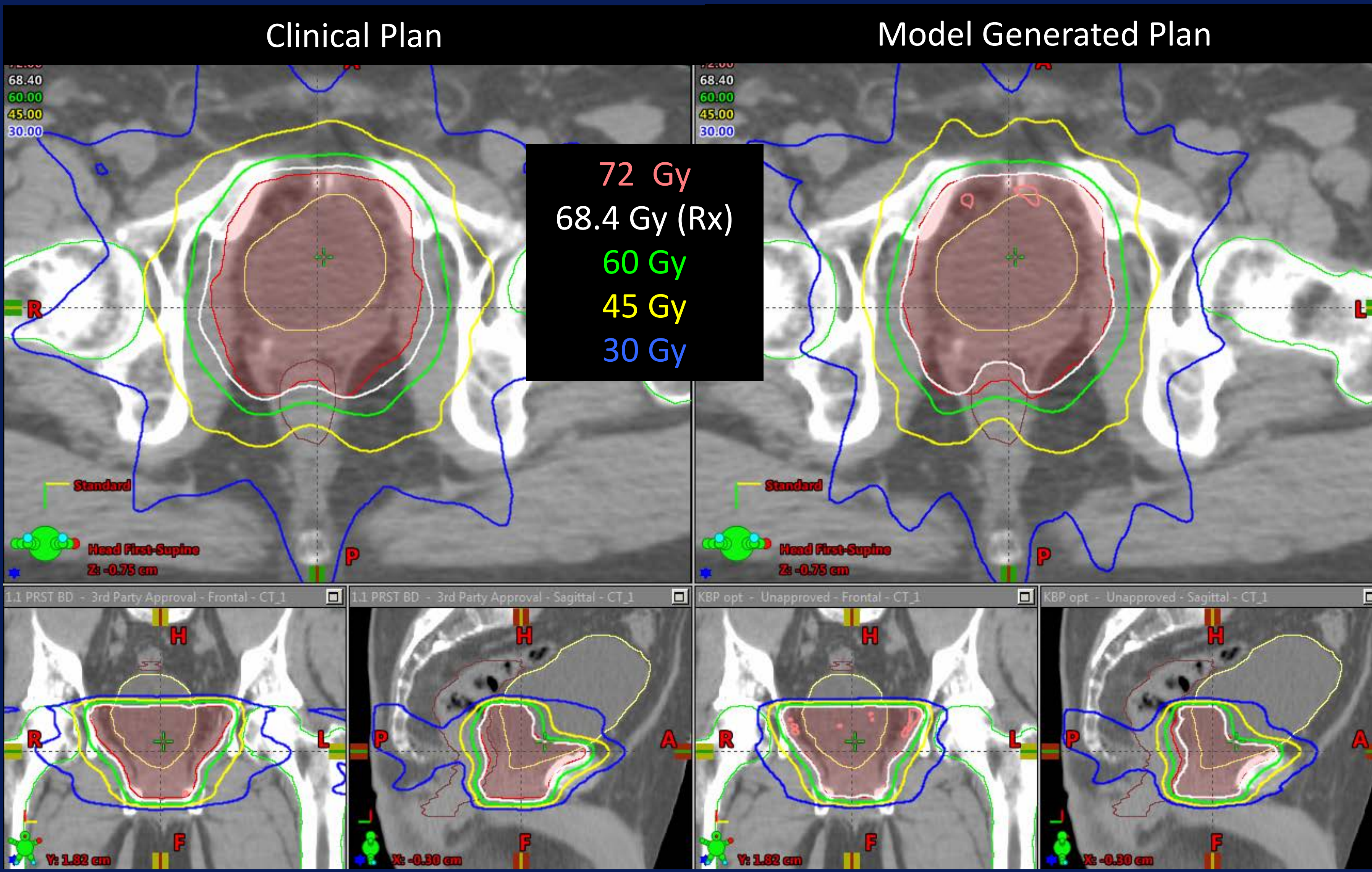
Clinic C: Plan Quality



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Clinic D: DVHs

▲ = KBP-generated Plan ■ = Clinically- Used Plan

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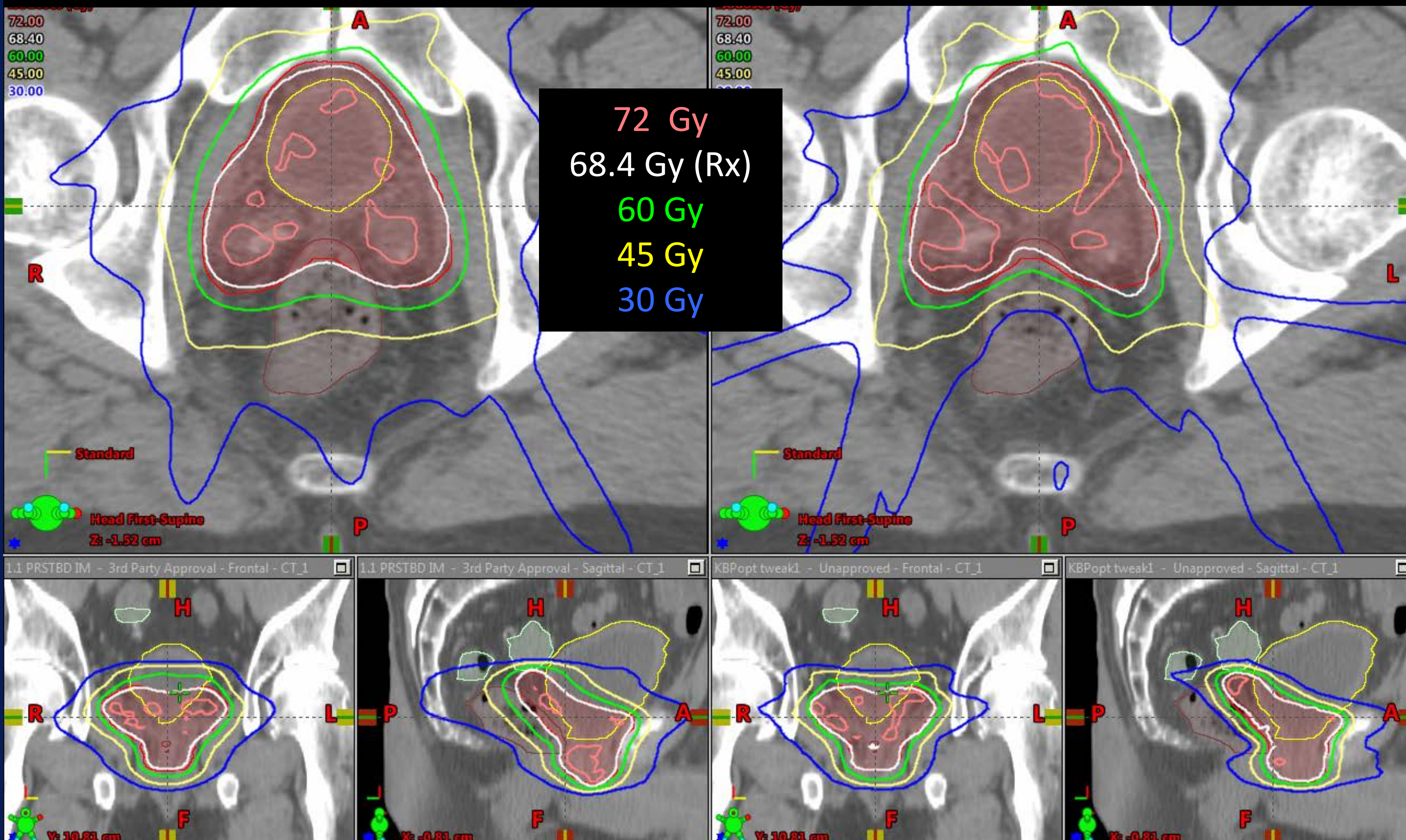
Clinic D: Plan Quality

Clinical Plan | Model Generated Plan



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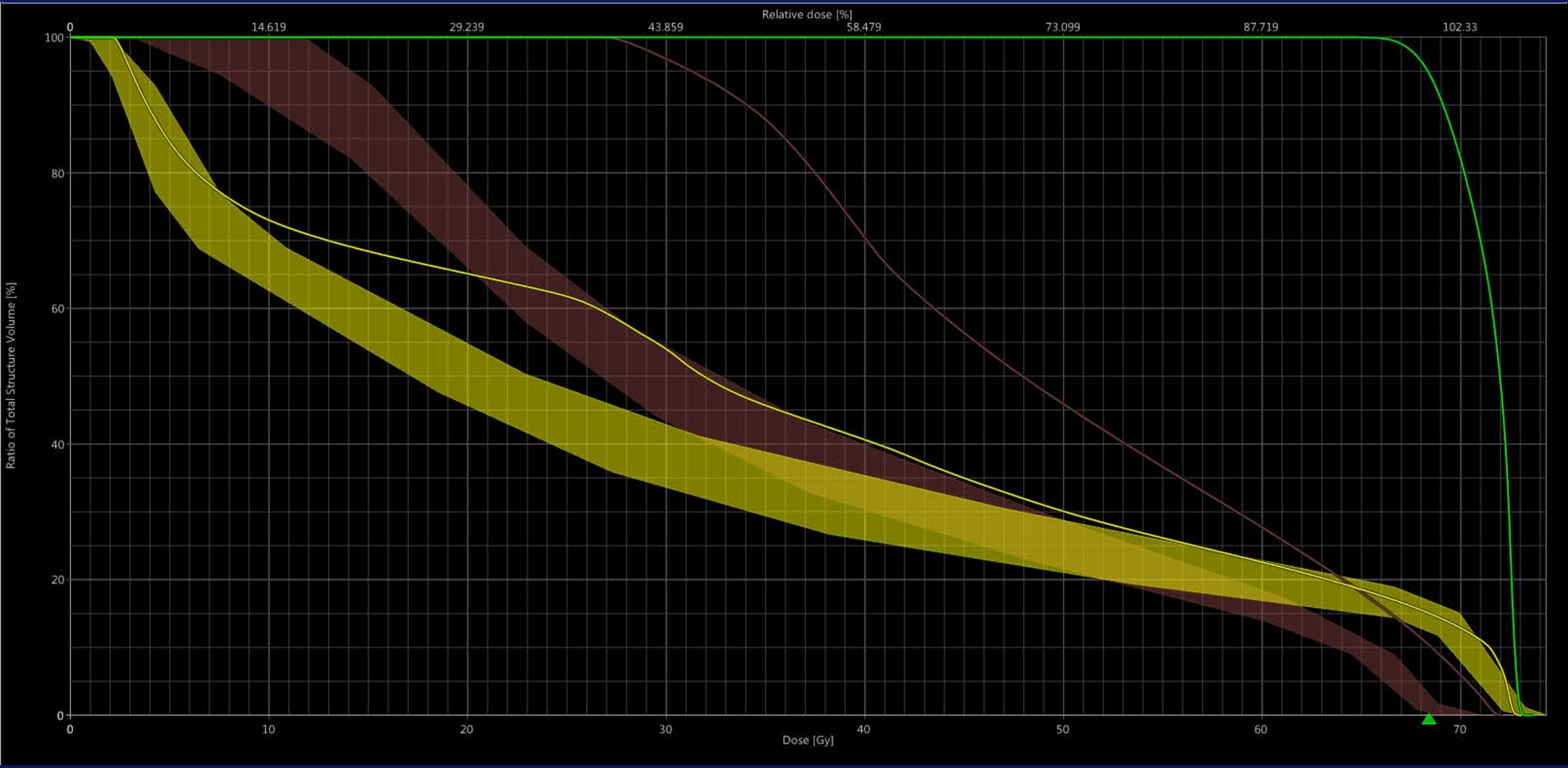
Clinic D



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KBP Prostate: Summary

- Inverse planning is an iterative process and time consuming
  - Difficult to ensure that all OAR structures, especially those of lower priority, are at an ALARA level
- Across our own system, there is a wide variation in plan quality for a simple site like prostate
- Knowledge-based planning can help improve both the quality and efficiency of the planning process

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Knowledge Based Planning to improve standardization and efficiency in spine SBRT

- Spine SBRT can be urgent and time sensitive used as a technique to treat
- Spine SBRT planning can be iterative and time-consuming
  - Geometrical variation
  - Importance of OAR sparing (Reduced acceptability of tradeoffs)

Example Targets from RTOG 0631 (PI S. Ryu)

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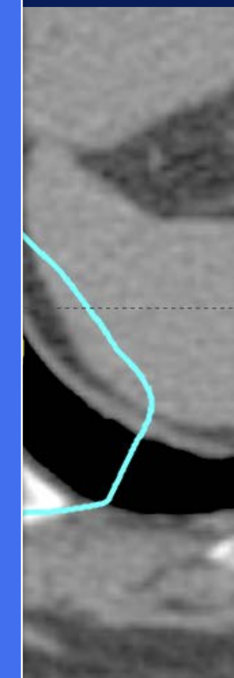
Knowledge Based Planning for Spine SBRT

- 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

Plan



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Spine Model Plan Efficiency
Range of Planning Times
(Not including Physician Review)

Confidence in quick plan turn-around may allow us to offer same day spine SBRT for emergent cases

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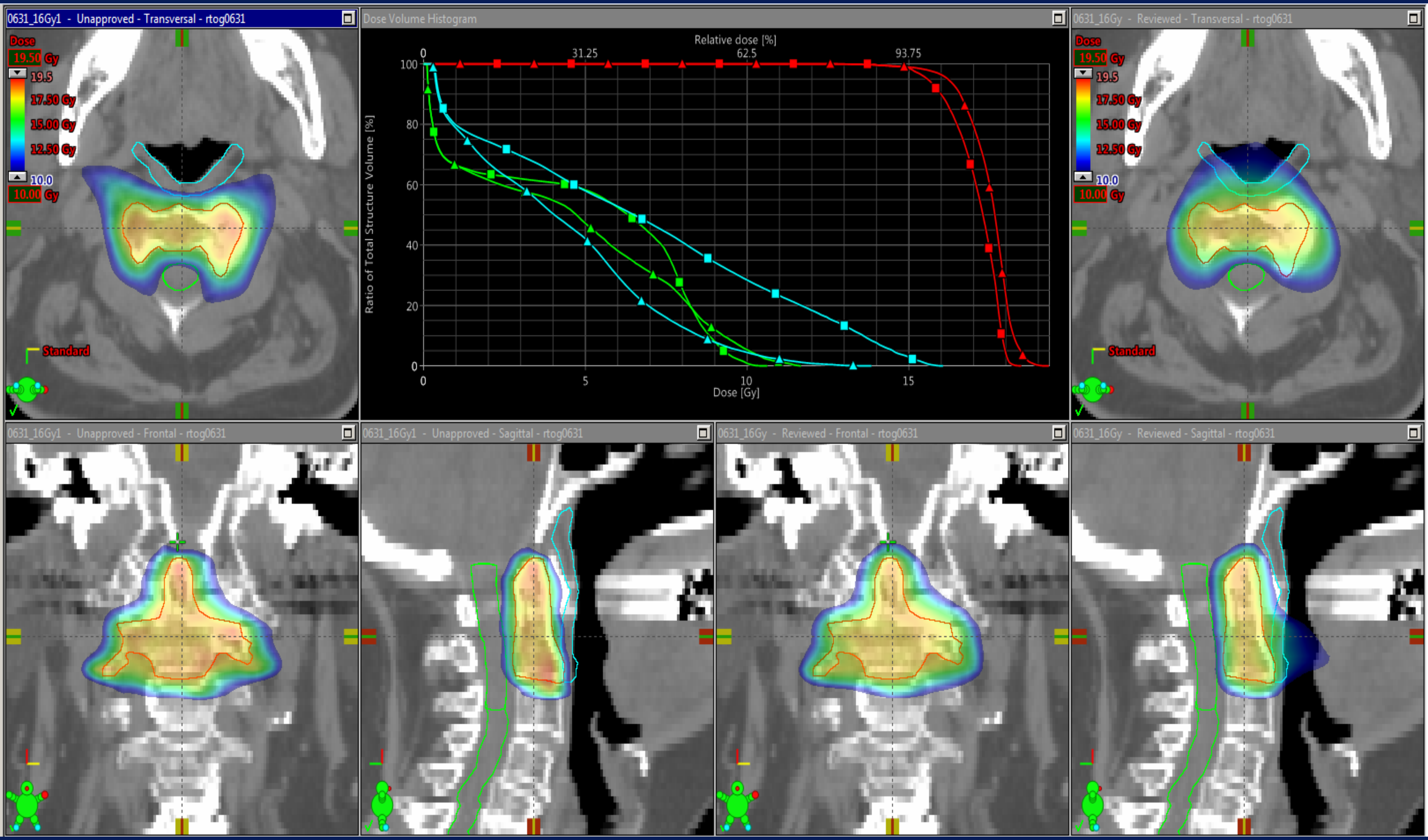
20 cases of specific oar's



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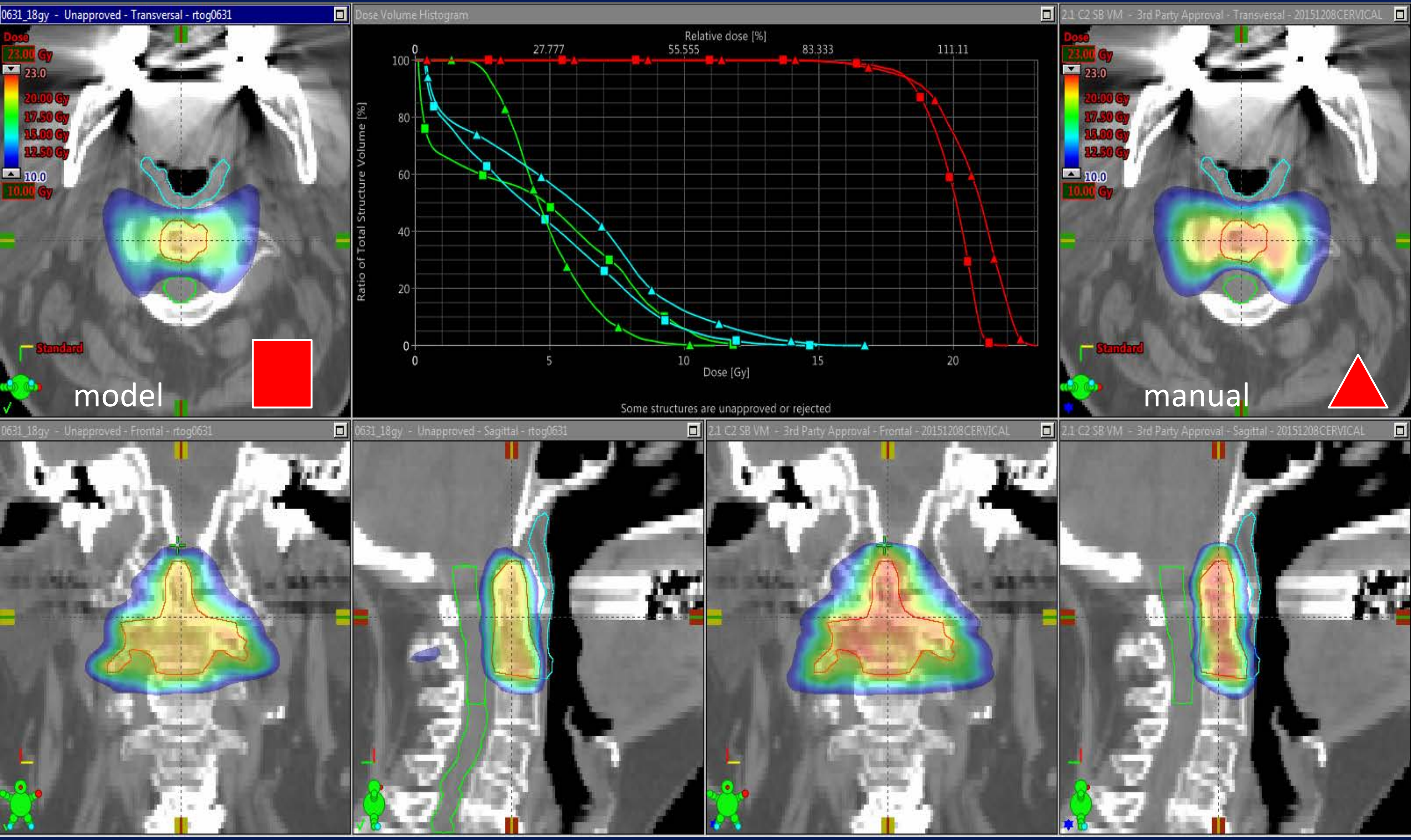
Model vs Manual C Spine



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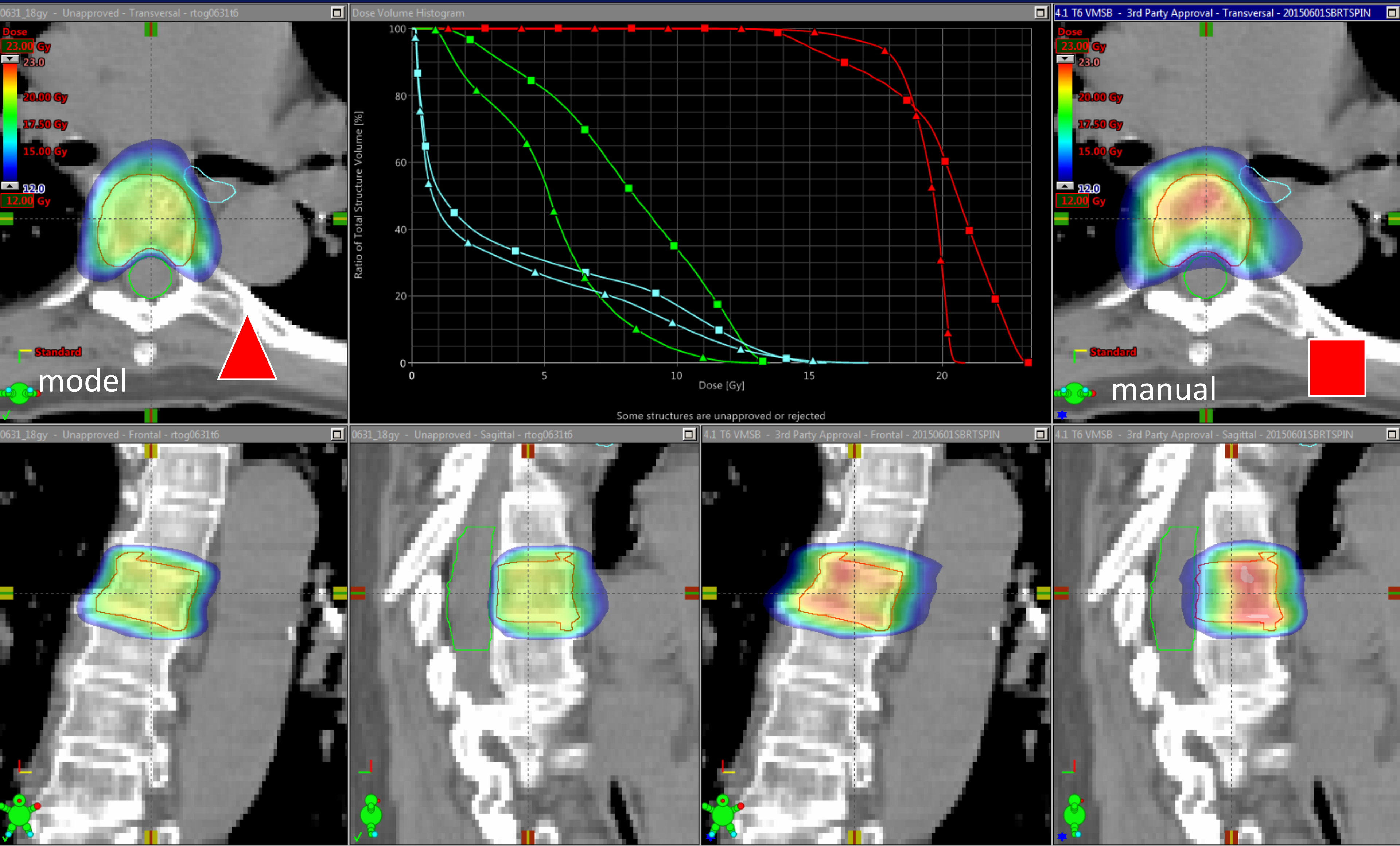
Model vs Manual T Spine



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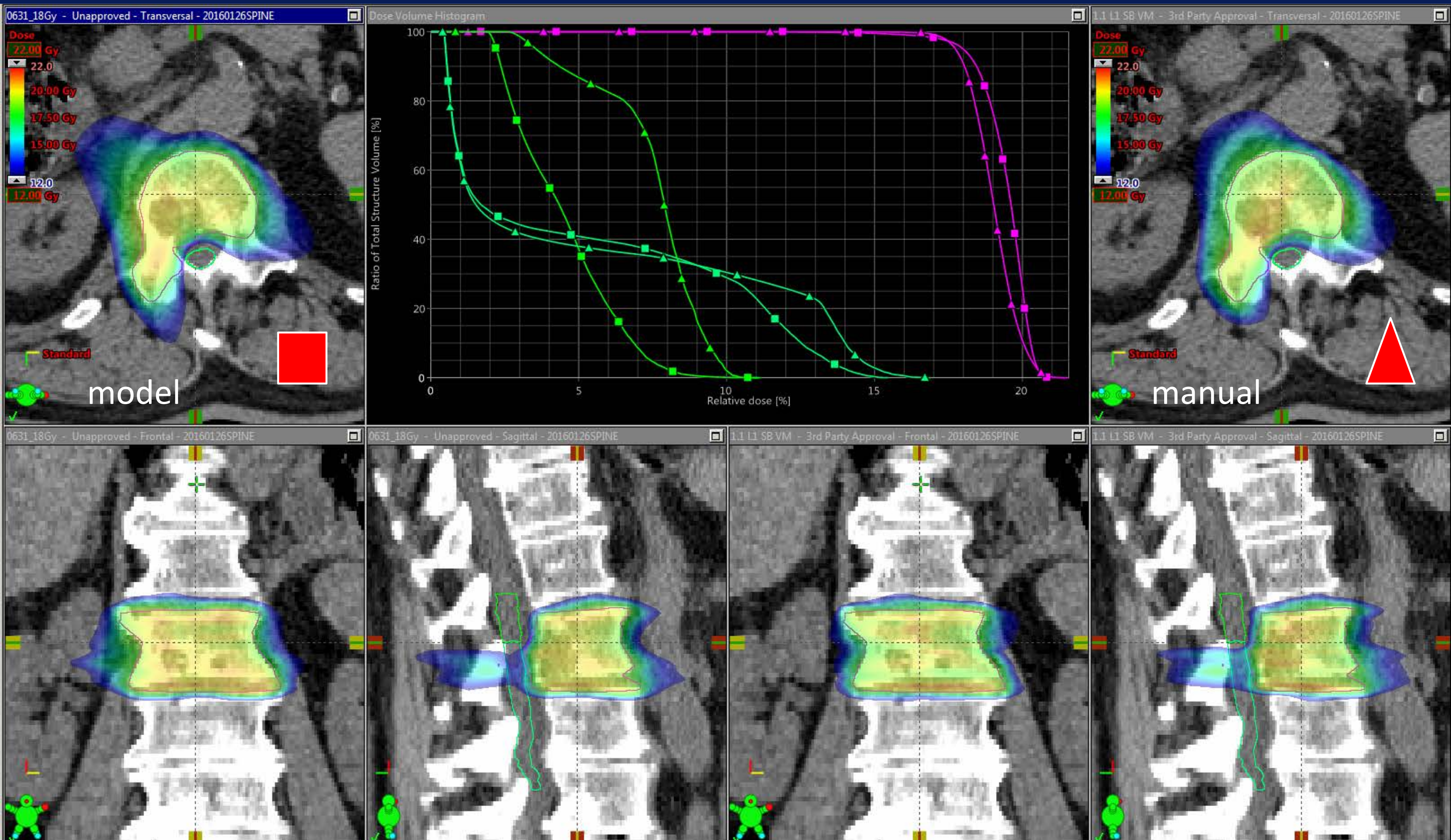
Model vs Manual L Spine



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Planning points of Spine sbrt

- Fractionation (1,3,5 etc.)
- Spine level (Cervical, thoracic, lumbar)
- Quantity of spines for modeling
- Reviewed by another dosimetrist or physics who may on you spine service.

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Kahoot!

Please join us for a few more questions!

KBP: Liver

- 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

We knew we would need a LOT of plans to create a 'good' model

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KBP: 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

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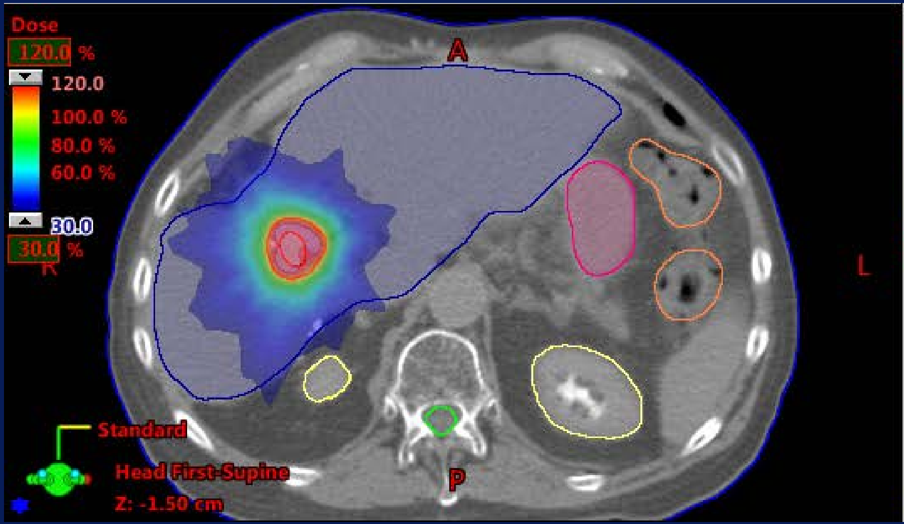
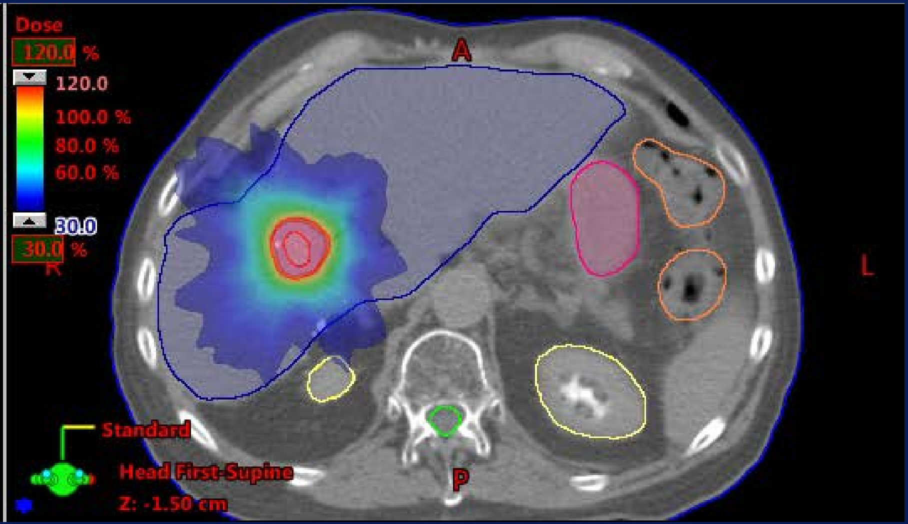
KBP: Liver SBRT

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

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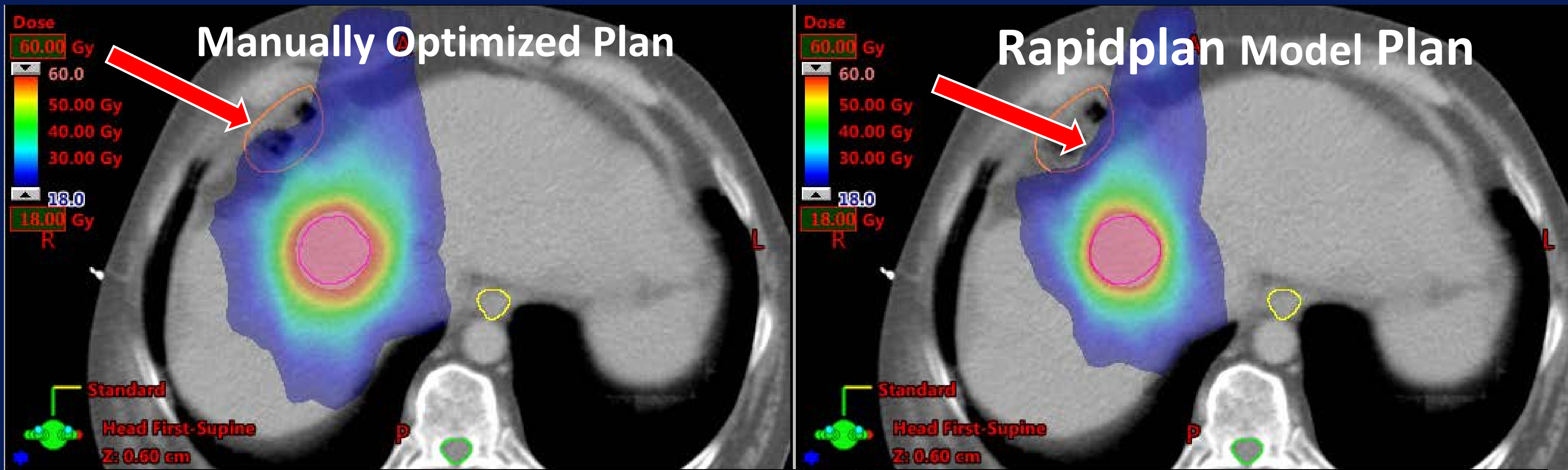
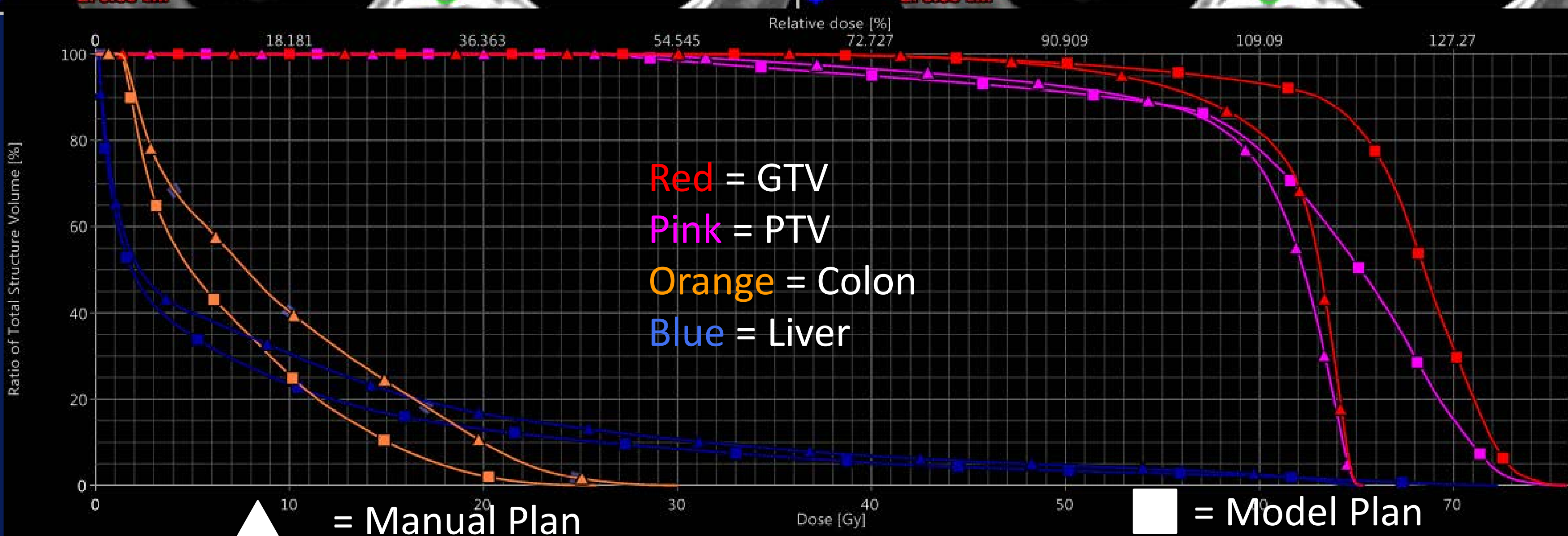
KBP: A tool for Novice Planners?





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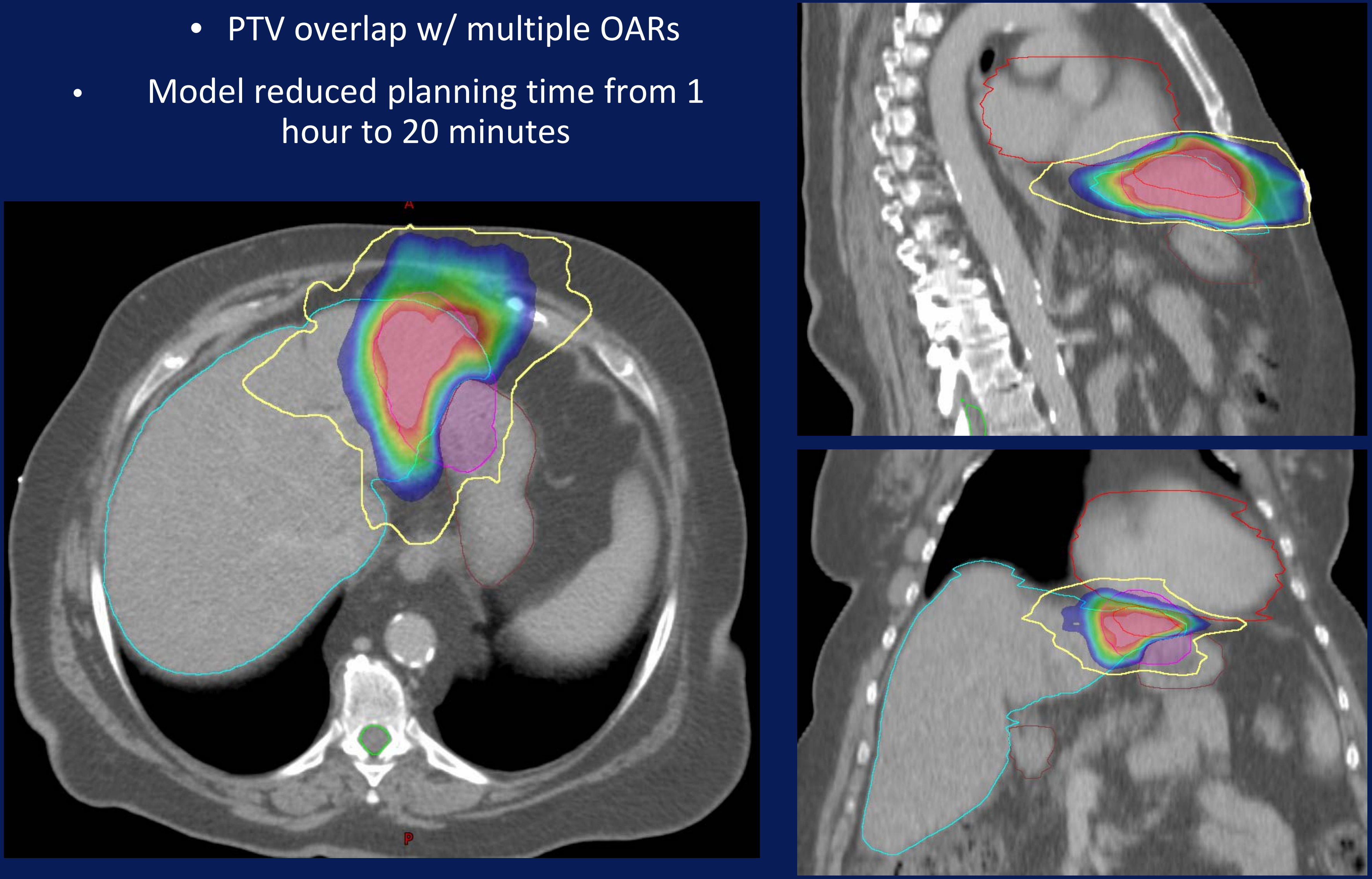
KBP: Liver SBRT

- PTV overlap w/ multiple OARs
- Model reduced planning time from 1 hour to 20 minutes



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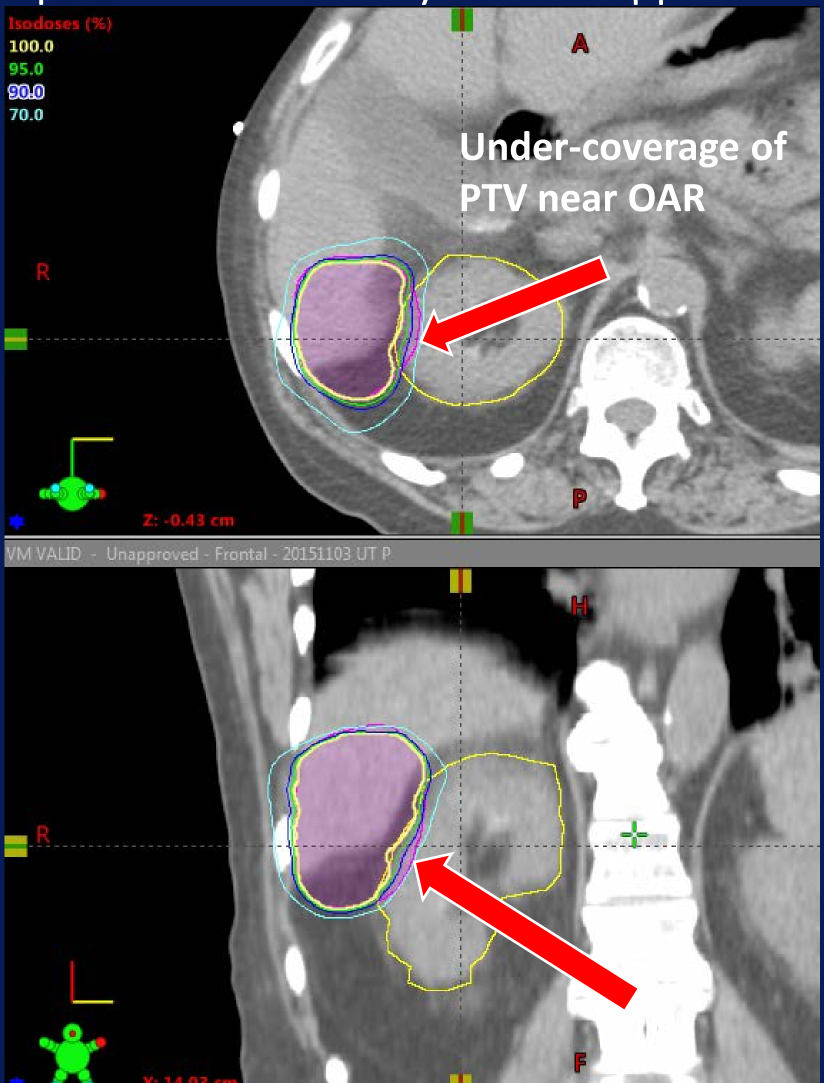
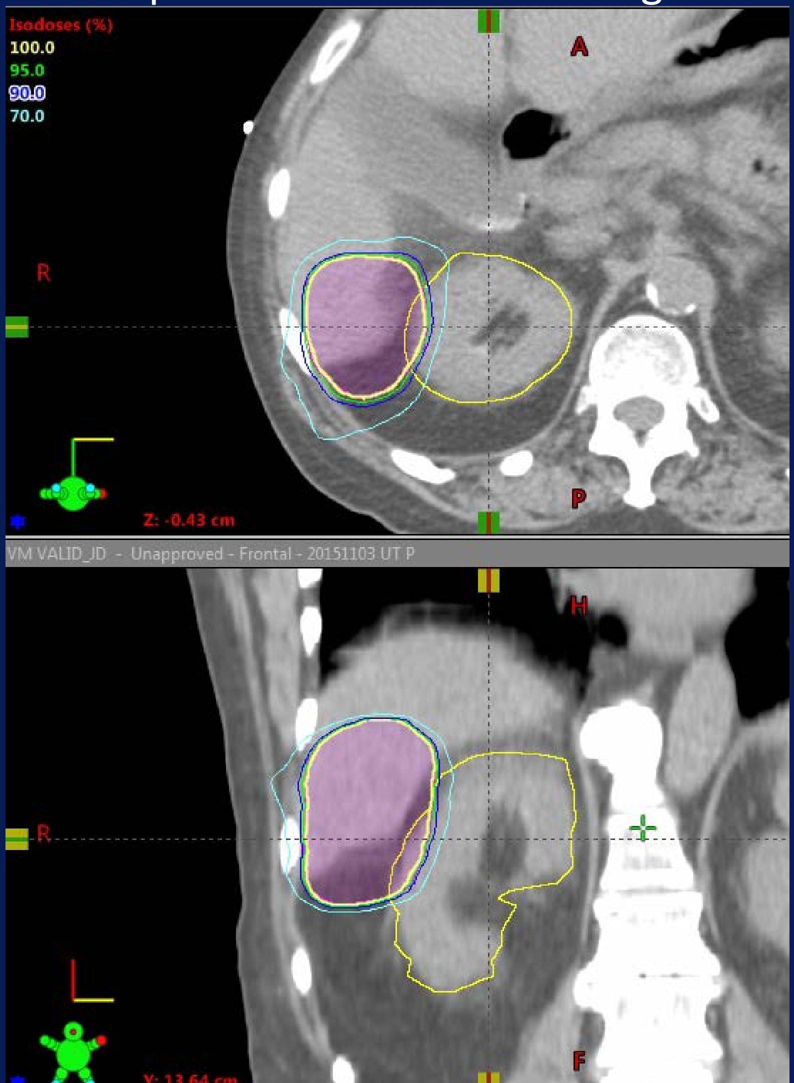
KBP: Liver SBRT

Rapid Plan Model ‘easy-button’ approach



Rapid Plan model + tweaking



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Rapidplan for Liver SBRT

- Great tool for dosimetrist's – especially 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

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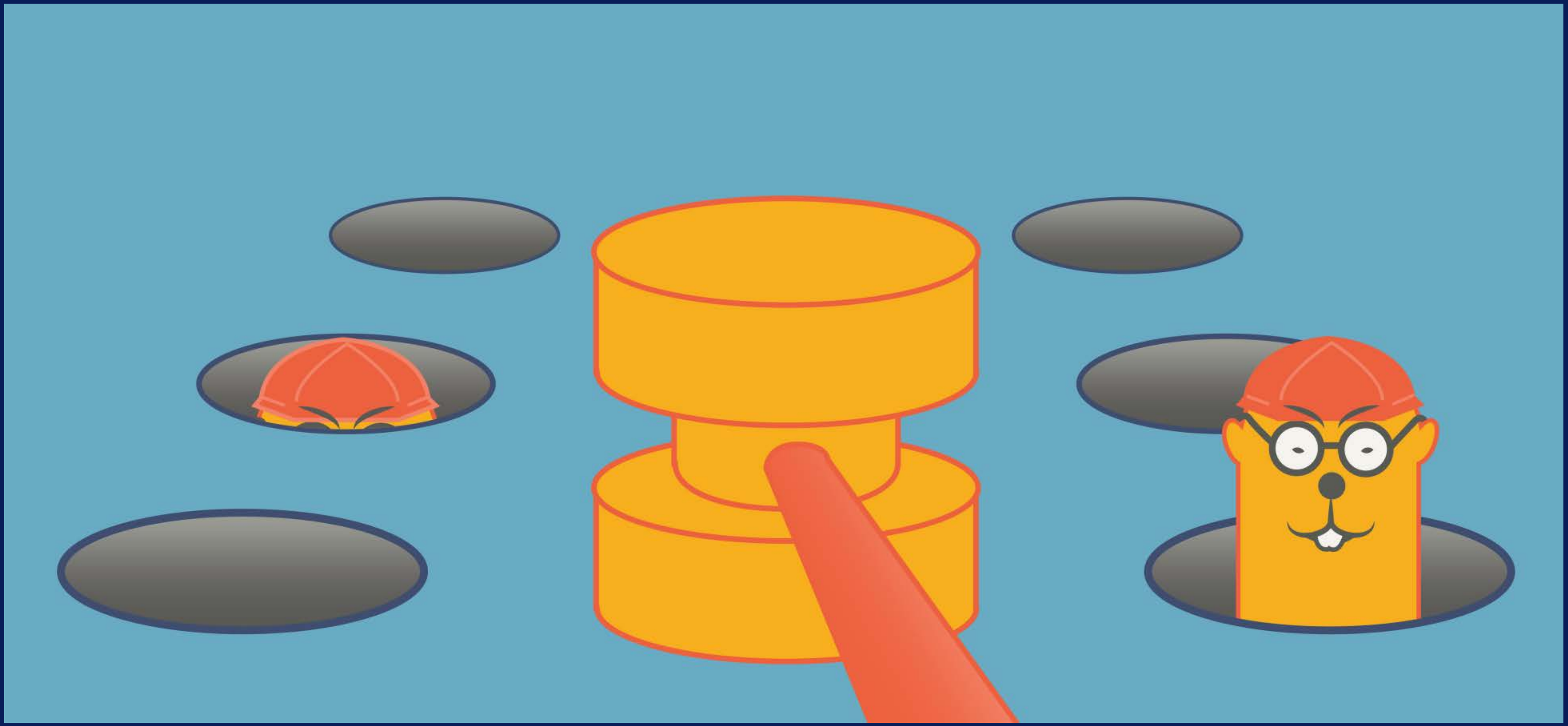
Inverse Planning for HN



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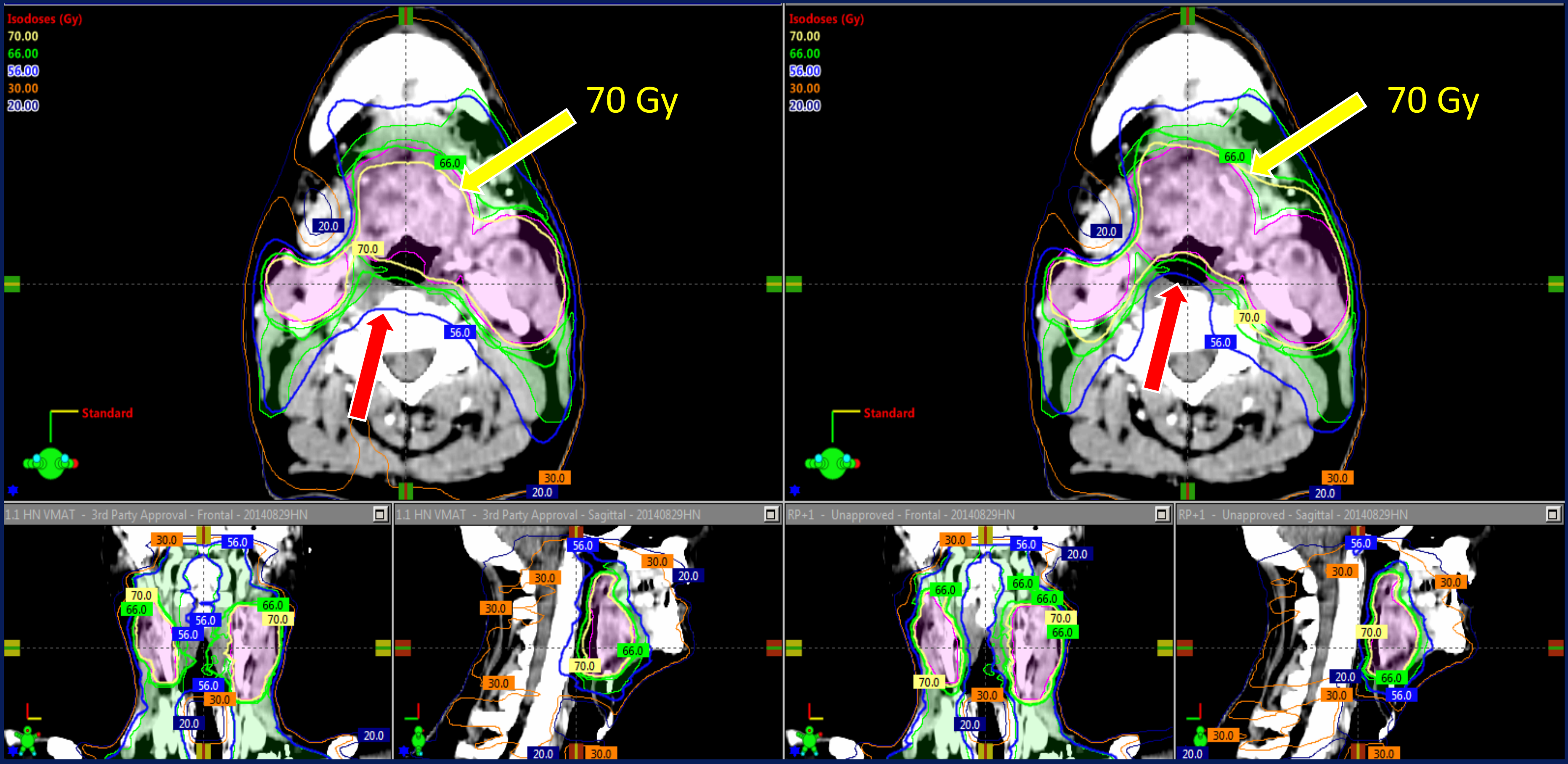
KBP: Head and Neck

Manually Optimized Plan | Rapidplan



Example #1

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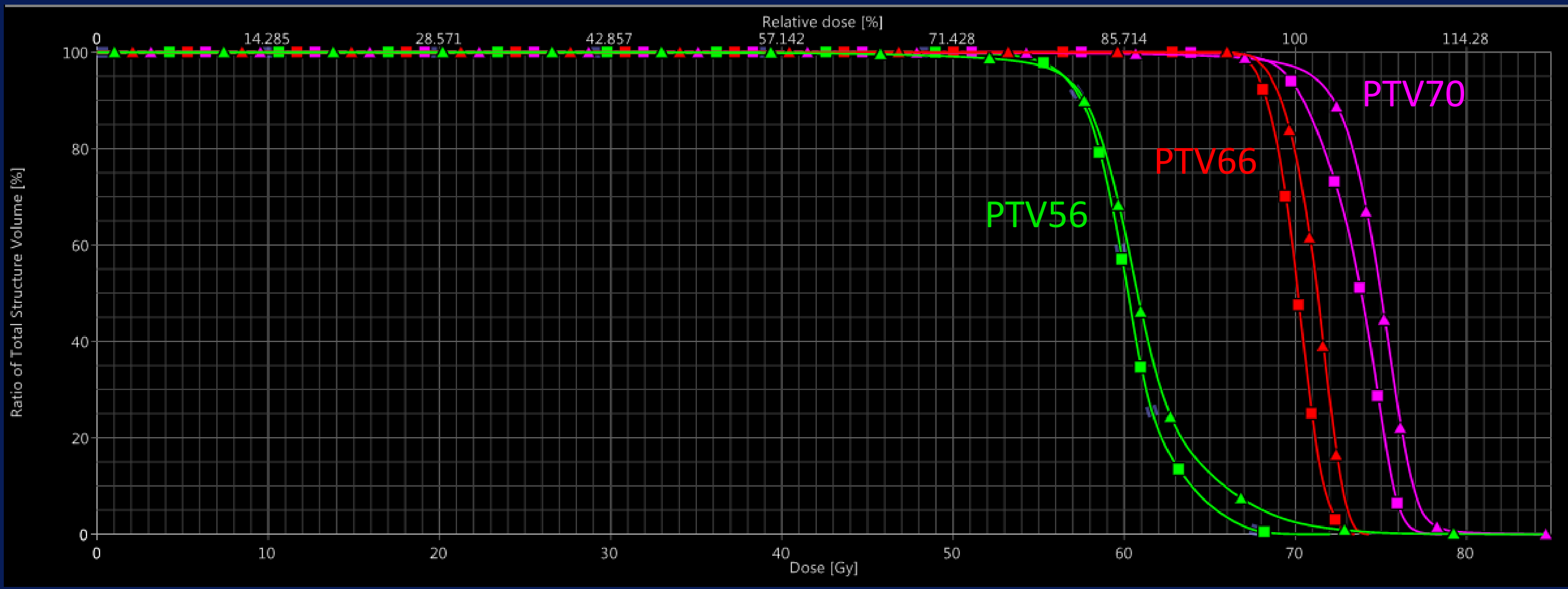
KBP: HN Target Coverage



= Manually Optimized Plan

= Rapidplan Optimization

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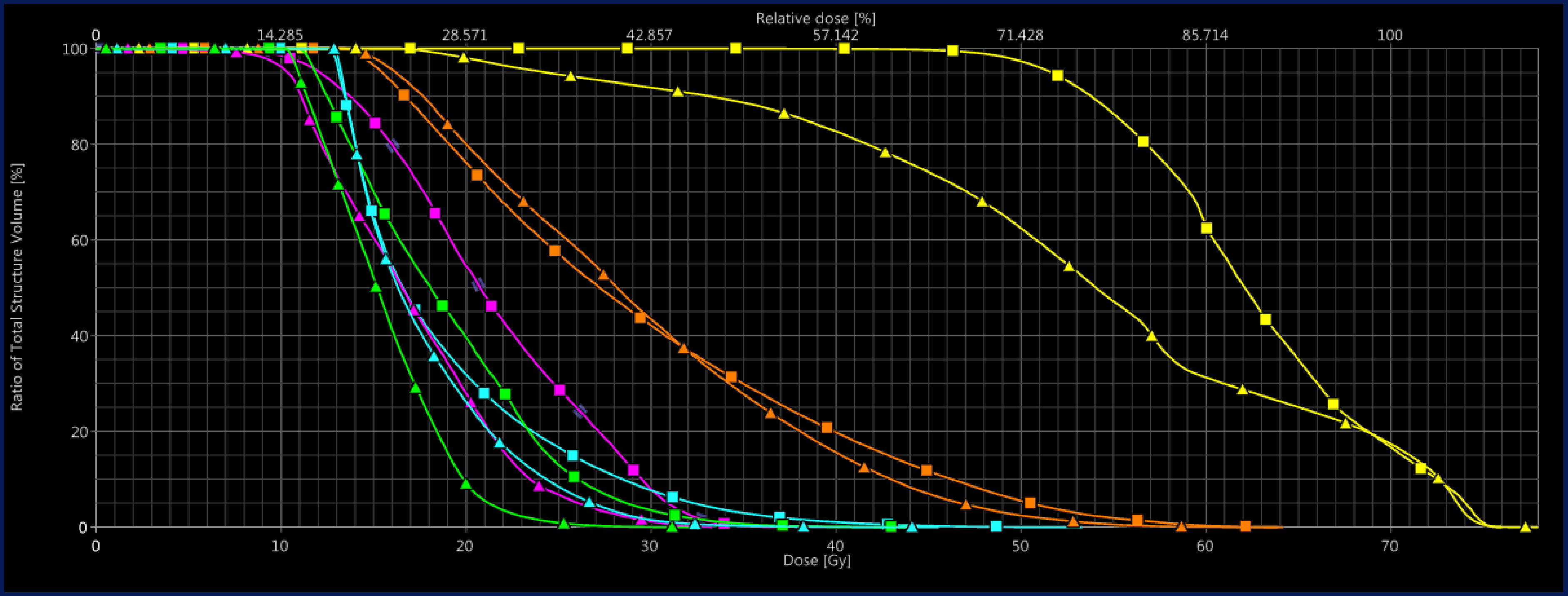
KBP: HN OAR sparing



OAR	Mean: Manual Optimization	Mean: RapidPlan	Difference
Lips	21.3	16.9	4.4
Superior Constrictors	62.5	53.3	9.2
Esophagus	18.9	15.5	3.4
Larynx	19	17.8	1.2
RT Submandibular	29.3	29.5	-0.2

■ = Manually Optimized Plan

▲ = RapidPlan Optimization

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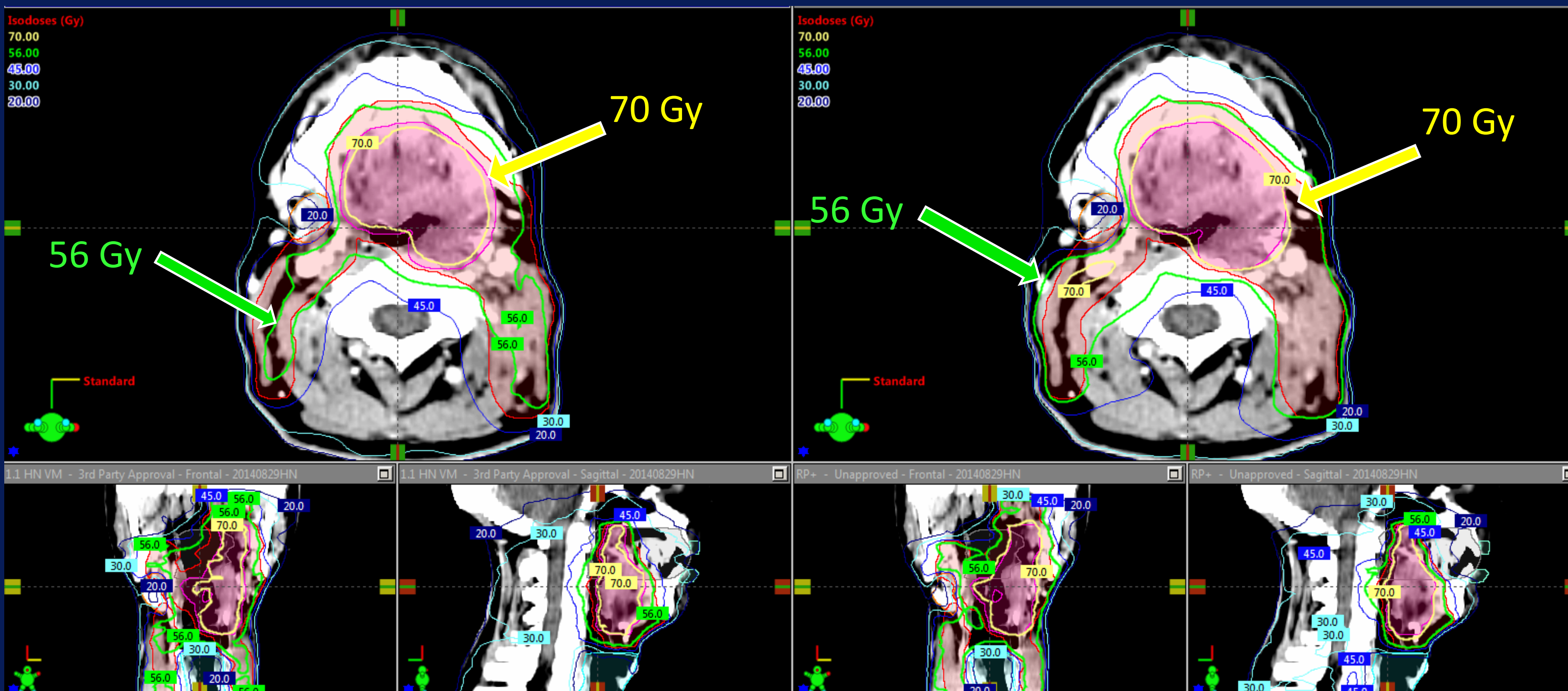
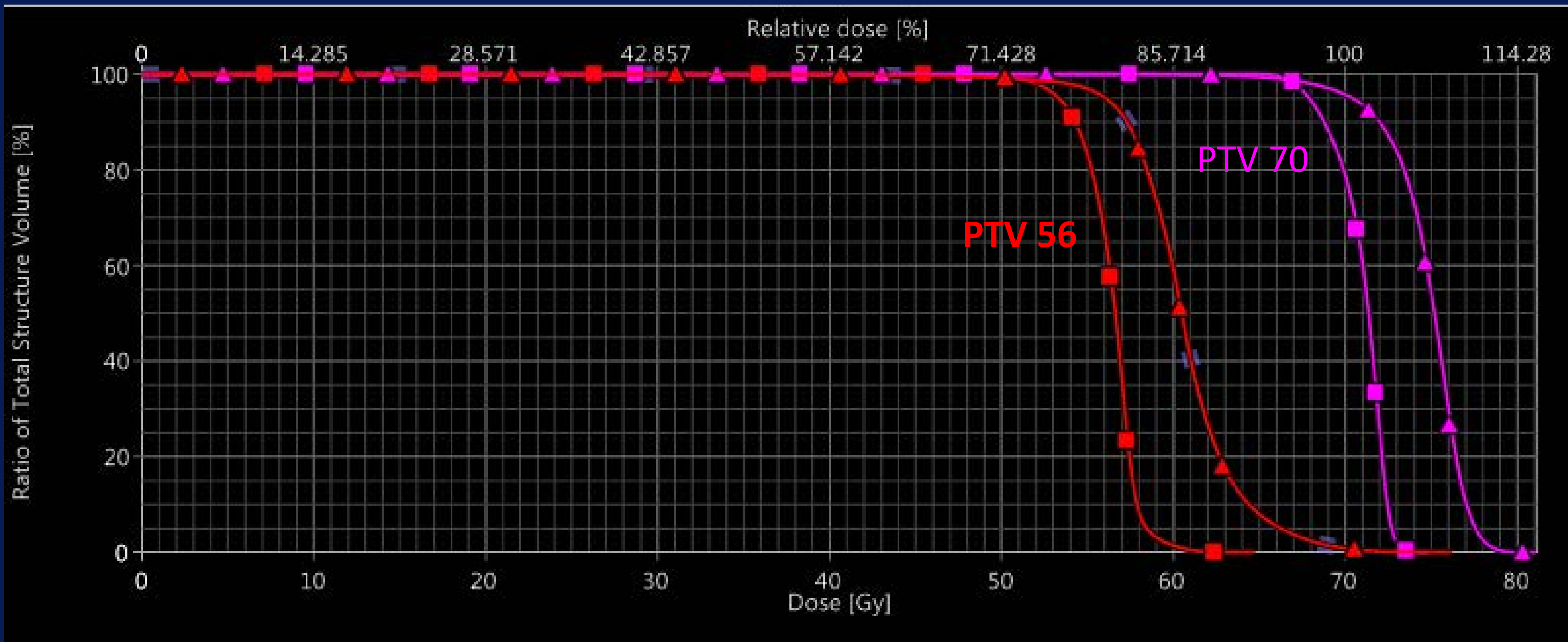
KBP: Head and Neck

Manually Optimized Plan | RapidPlan



Example #2

KBP: HN Target Coverage



■ = **Manually Optimized Plan**

▲ = **Rapidplan Optimization**

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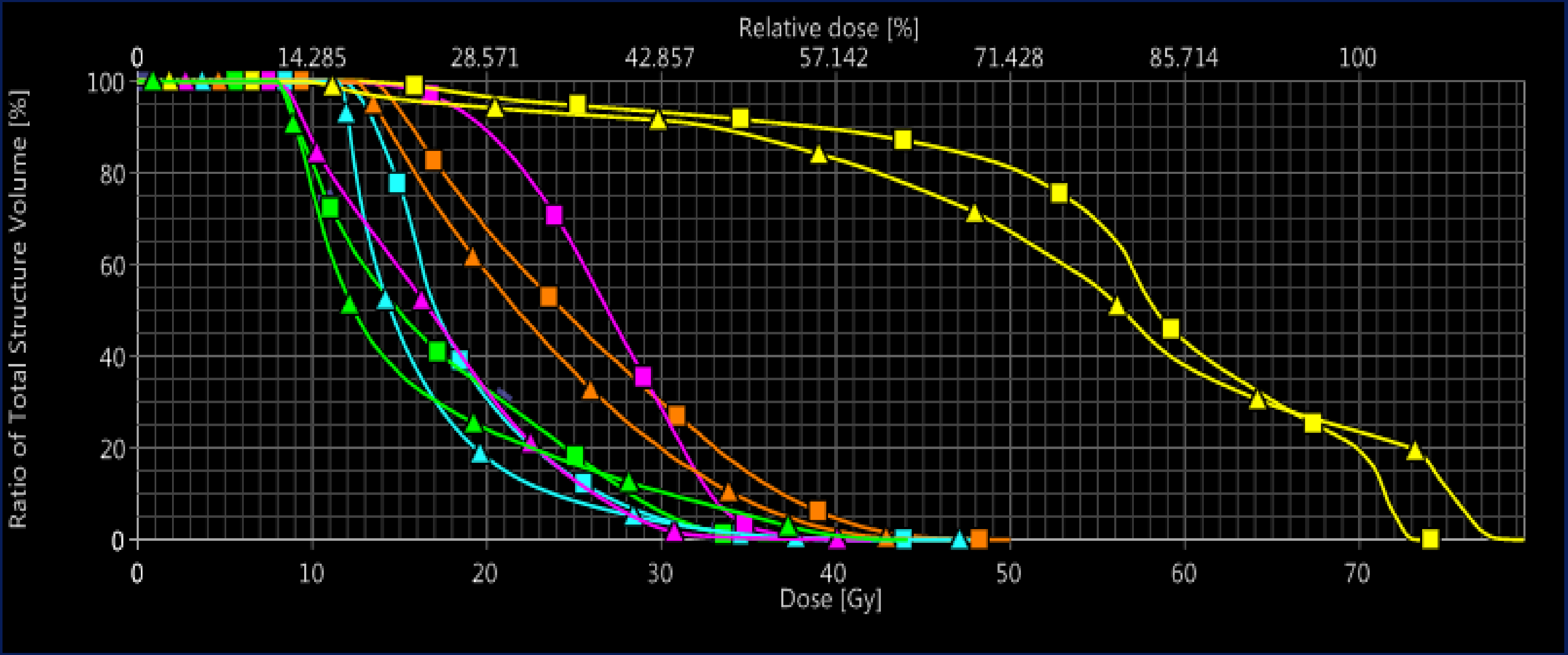
KBP: HN OAR Sparing



OAR	Mean: Manual Optimization	Mean: RapidPlan	Difference
Lips	26.6	17.3	9.3
Superior Constrictors	57.1	54.8	2.3
Esophagus	17	16	1
Larynx	18.8	16.4	2.4
RT submandibular	25.4	23.1	2.3

■ = Manually Optimized Plan

▲ = RapidPlan Optimization

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KBP: Head and Neck

- Time Savings
- Excellent start - individualization still necessary
- Line Objectives – helps reduce dose to OARs

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Kahoot!

Please take out your phone / tablet and join us for a few final questions….

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Summary

- Model building is time consuming – Is it worth it?
- Multiple body-sites that are great candidates for KBP
- Variation in plan quality from dosimetrist to dosimetrist – as well as from clinic to clinic

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What do our dosimetrists think about RapidPlan?

- Depends on:
  - Dosimetrist seniority
  - Dosimetrist experience with using Rapidplan
  - Dosimetrist engagement in the model creation

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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

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Acknowledgements

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