Taking Knowledge Based Planning to the Next Level - Modern Tools to Build Better Models Faster

Ryan Clark, MS, CMD. R.T.(T)

AAMD Annual Meeting 2023

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Disclosure

- I am employed by Varian
- The views expressed in this presentation are mine and mine alone and do not represent those of Varian.

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Outline

- Review of basic Knowledge Based Planning concepts
  - Challenges of the H&N treatment site
- Background for this H&N model
  - AI clustering by parotid involvement
  - Specific model for “Cluster 0” (both parotids partially involved)
  - Case selection for training set cases within cluster 0 (3 targets)
- Process overview
  - Scorecard development and refinement
  - Selecting starting “candidate KBP model”
  - Comparing “candidate model” scores, “manual plan” scores, and “final model”
- Automation tools
  - PlanScoreCard batch scoring
  - Structure generation
- Future Developments

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Knowledge Based Planning Concepts

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What is Knowledge Based Planning?

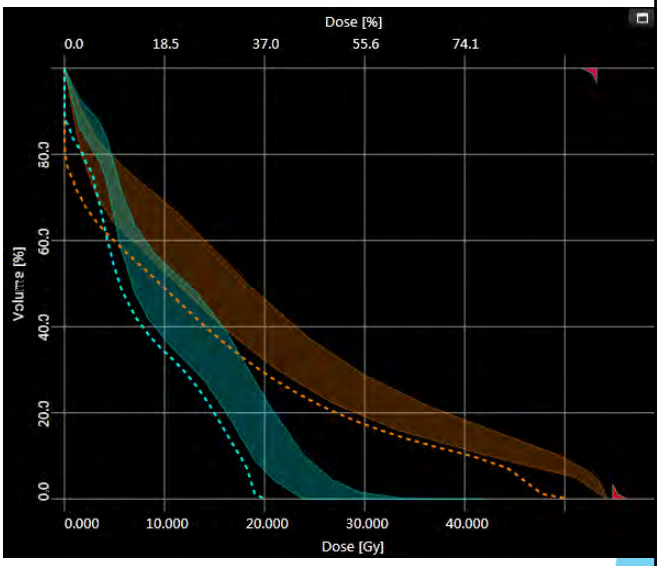
RapidPlan is a KBP product

A method for predicting DVH's which utilizes Machine Learning

- Based on patient geometry
- Previous knowledge contained in a set of existing patient "training set" cases

Optimization objectives are automatically populated at the lower level of estimated DVH bands

What relative weight/priority should be used?



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Objective Priorities

Setting the priorities for auto-created optimization objectives is not a straightforward process

Traditionally start with a "good guess" for auto-created optimization objectives for the model to act as "a starting point"

- With careful tuning of the optimization objectives, RapidPlan can create high quality plans -- with a single button press
- **Our method was to tune the auto-created optimization objectives via a ScoreCard**

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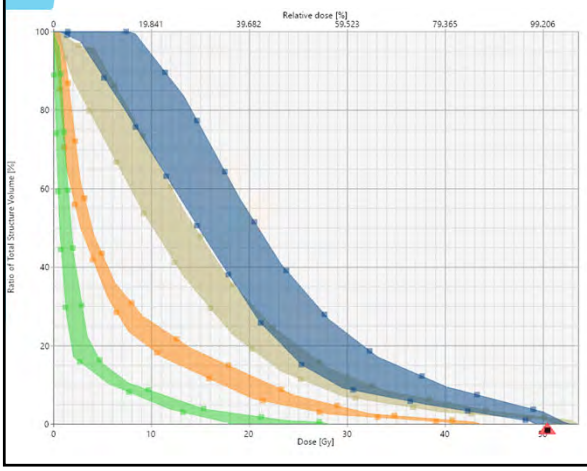
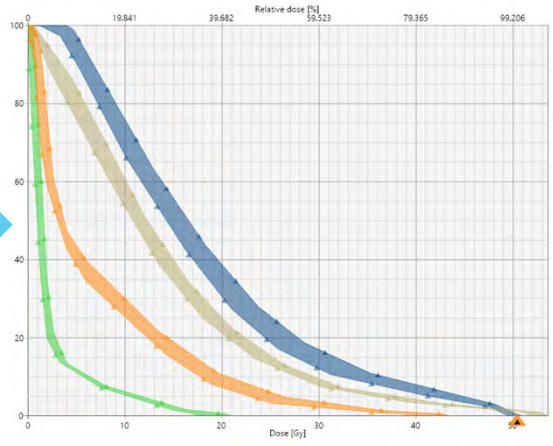
DVH estimation is straightforward

Consistently planned, high quality cases will help eliminate outliers

Initial Model DVHe (Clinical)



Final Model DVHe (KBP)



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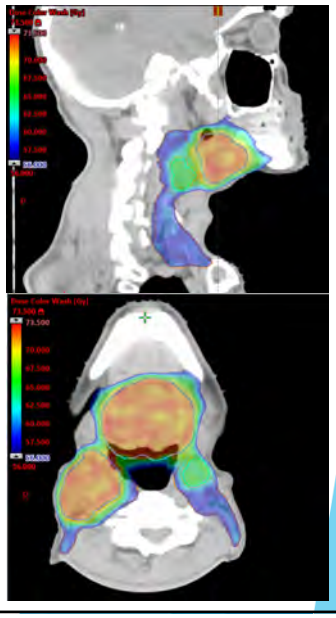
Head and Neck Cases are Heterogenous

Large variation in:

- The number of targets and prescription levels
- Target geometry (size and shape)
- Target location (proximity and overlap with OAR's)

- Variability requires different planning techniques and specific guidance to achieve desired plan quality

- Manual planning is time consuming and has a wide range of results based on the skill of the treatment planner



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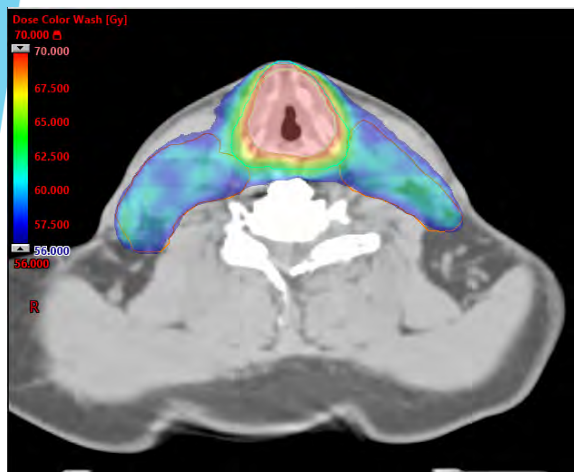
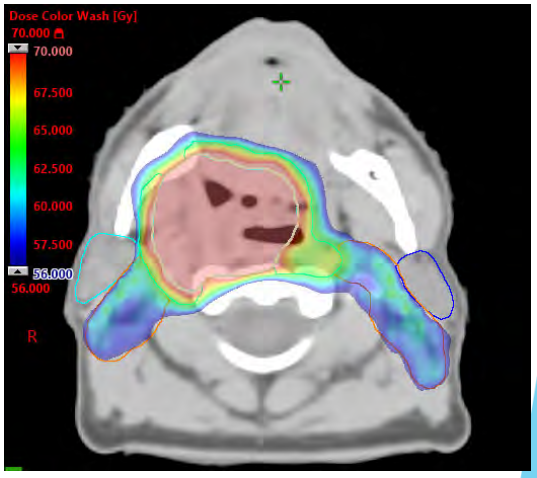
Head and Neck Cases are Heterogenous

Variation in high dose PTV size and location



Larynx



Oropharynx

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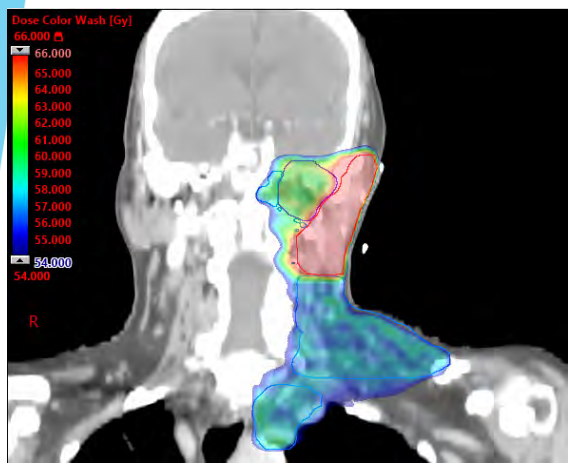
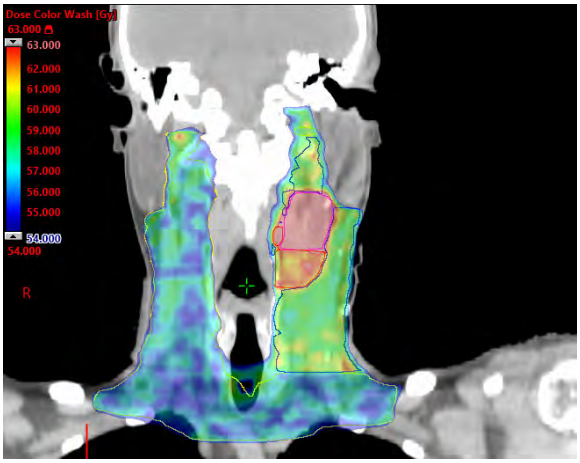
Head and Neck Cases are Heterogenous

Variation in laterality, number of PTV's, and prescription dose



Unilateral: SIB 66, 60, & 56Gy



Bilateral: SIB 63, 60, 57 & 54Gy

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Process

- **Theory**
  - Knowledge based planning models created with heterogenous cases can lead to wide range of DVH estimations
  - These wider DVH estimations can reduce plan quality
- **Goal**
  - Create a specific model for SIB (70, 63, & 56Gy) bilateral H&N with **both parotids** partially involved that requires minimal (if any) interaction from a dosimetrist
- **Method**
  - Test several existing models to select the best candidate for initial training set case generation

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Head and Neck Model Background

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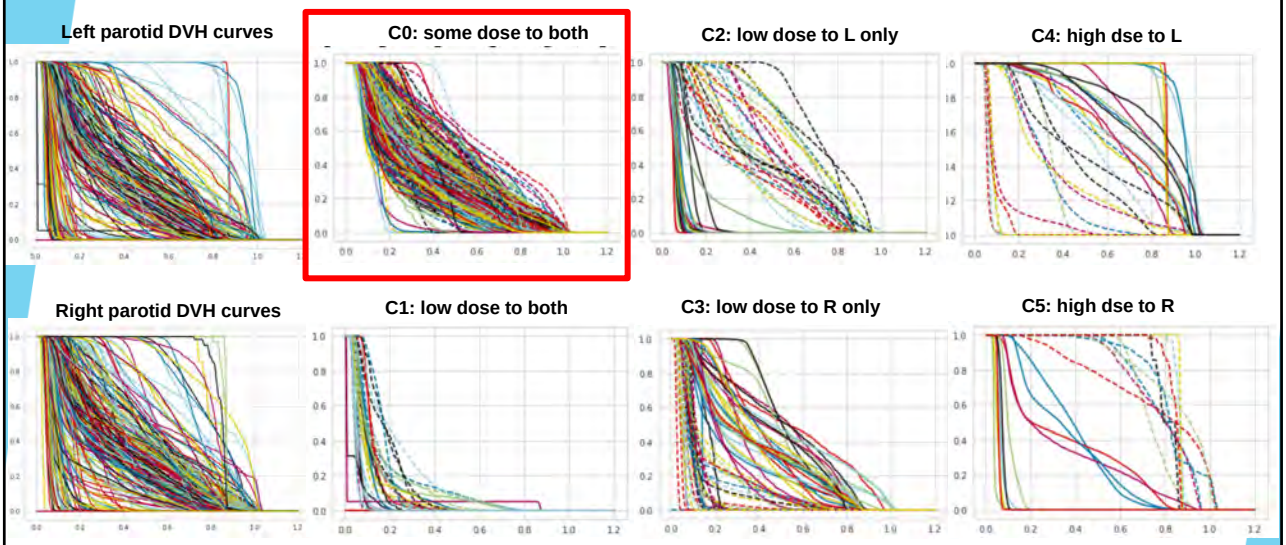
AI Clustered Plans by Parotid Dose



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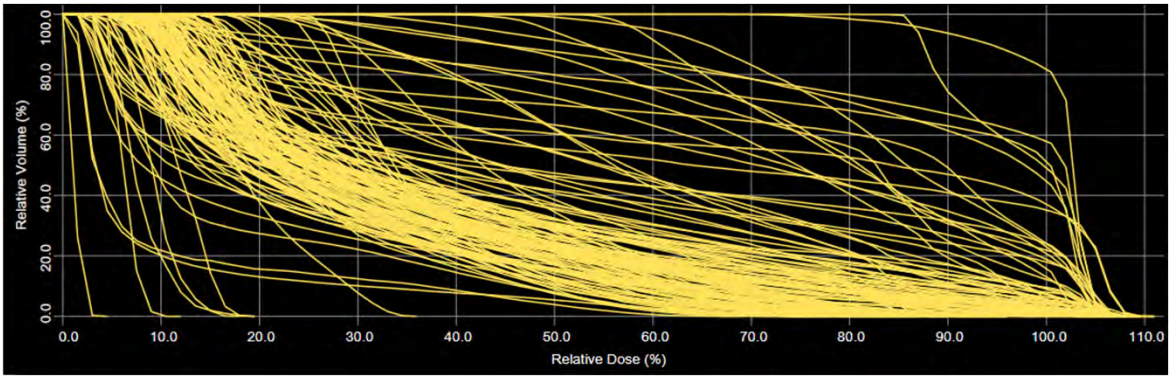
Plan Clustering



Parotid Gland DVH

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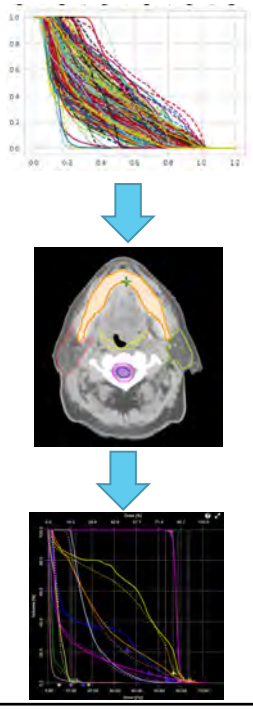
Data Collection Process

1. Import and evaluate the 118 cases that fall in C0 (dose to both parotids)
2. Keep cases that are bilateral with three targets (27 total)
3. Add any missing OAR contours and delineate the ipsilateral and contralateral parotids
4. Use an existing KBP model as a starting point for optimization **(clinical doses are not used)**
5. Design scorecard for evaluation and C0 model tuning



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Scorecard Development

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Scorecards: Basic Principles

Between two different patients, scores should not be directly compared

Designed to analyze multiple plan options for **the same patient/case**

Scorecards can be created for a single patient, but better to be created **per protocol** or class of patients

Max score should not be achievable

- Scorecard total
- Per metric

Powerful tool for retrospective plan quality analysis

- Create dosimetric wish list to document best achievable today

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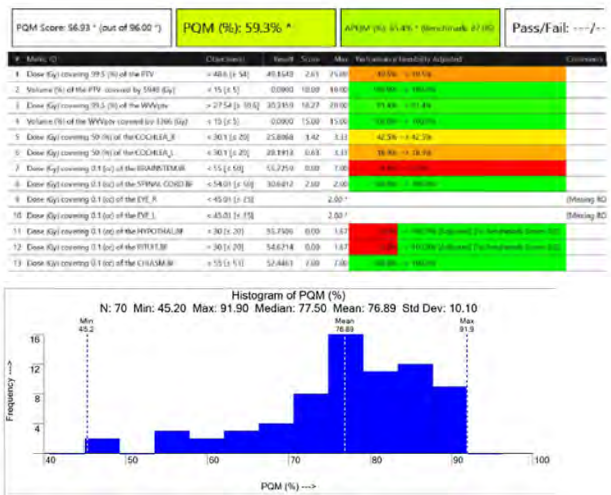
H&N Scorecard Development

Protocols lack specificity



Toward Systematic Assessment and Improvement of Radiation Therapy Plan Quality of Cooperative Group Trial Submissions: A Report From the Children's Oncology Group

Arthur J. Olch, PhD,[a,*] Mahesh Gopalakrishnan, MS,[b] Erin S. Murphy, MD,[c] Shannon M. MacDonald, MD,[d] and Chia-Ho Hua, PhD[e]

[a]Department of Radiation Oncology, University of Southern California and Children's Hospital Los Angeles, Los Angeles, California; [b]Department of Radiation Oncology, Northwestern Memorial Hospital, Chicago, Illinois; [c]Department of Radiation Oncology, Cleveland Clinic, Cleveland, Ohio; [d]Department of Radiation Oncology, Massachusetts General Hospital, Boston, Massachusetts; and [e]Department of Radiation Oncology, St. Jude Children's Research Hospital, Memphis, Tennessee

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Purpose: This study evaluates the quality of plans used for the treatment of patients in the Children's Oncology Group study ACNS1123. Plan quality is quantified based on a scoring system specific to the protocol. In this way, the distribution of plan quality scores is determined that can be used to identify plan quality issues for this study and for future plan quality improvement.
Methods and Materials: ACNS1123 stratum 1 patients (70) were evaluated. This included 50 photon and 20 proton plans. Digital Imaging and Communications in Medicine (DICOM) structure and dose data were obtained from the Children's Oncology Group. A commercially available plan quality scoring algorithm was used to create a scoring system we designed using the protocol dosimetric requirements. The whole ventricle and boost planning target volumes (PTVs) could earn a maximum of 70 points, whereas the organs at risk could earn 30 points (total maximum score of 100 points). The scoring algorithm adjusted scores based on the difficulty in achieving the structure dose requirements, which depended on the proximity of the PTVs and the dose gradients achieved relative to the organs at risk. The distribution of plan scores was used to determine the mean, median, and range of scores.
Results: The median adjusted plan quality scores for the 20 proton and 50 photon plans were 83.3 and 86.9, respectively. The range of adjusted scores (maximum to minimum) was 50 points. The average score adjustment was 7.4 points. Photon and proton plans performed almost equally. Average plan quality by individual structure revealed that the brain stem, PTV boost, and cochlea lost the most points.
Conclusions: This report is the first to systematically analyze overall radiation therapy plan quality scores for an entire cohort of patients treated in a cooperative group clinical trial. The methodology demonstrated a large variation in plan quality in this trial. Future clinical trials could potentially use this method to reduce plan quality variability, which may improve outcomes.

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H&N Scorecard Development

Protocols lack specificity

LBA 02

Radiotherapy with Durvalumab vs. Cetuximab in Patients with Locoregionally Advanced Head and Neck Cancer and a Contraindication to Cisplatin: Phase II Results of NRG-HN004

L.K. Mell [1 2], P. Torres-Saavedra [3], S. Wong [4], S. Chang [5], J.A. Kish [6], A.J. Minn III [7], R. Jordan [8], T. Liu [9], M.T. Truong [10], E. Winquist [11], T. Wise-Draper [12], C.P. Rodriguez [13], A. Musaddiq [14], B.M. Beadle [15], C. Henson [16], S. Narayan [17], S.A. Spencer [18], J. Harris [3], S.S. Yom [19]

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https://doi.org/10.1016/j.ijrobp.2022.09.003 Get rights and content

Purpose/Objective(s)

The optimal treatment for patients with locoregionally advanced head and neck squamous cell carcinoma (HNSCC) and contraindication to cisplatin is uncertain. This trial (NCT03258554) tested the primary hypothesis that radiation therapy (RT) with concurrent and adjuvant durvalumab, a PD-L1 inhibitor, improves progression-free survival (PFS) compared to standard RT with cetuximab.

	Objective	
Organ at Risk	D_{max} (cGy)	Dose-Volume Limit
SpinalCord_05	Myelopathy V(5000 cGy) < 0.03 cc	V(3000 cGy) < 45% V(4000 cGy) < 10% Lhermitte's < 2600
Brainstem_03	Neuropathy V(5400 cGy) < 0.03 cc	Or D(2.7 cc) < 5500 cGy D(0.9 cc) < 6000 cGy Nausea < 3600 cGy
PartialBrain		V(5000 cGy) ALARA
Chiasm	V(5400 cGy) < 0.03 cc	
Pituitary / Hypothalamus		Mean < 4500 cGy
Lacrimal Glands		Mean < 3500 cGy
OpticNerve_R	V(6000 cGy) < 0.03 cc	
OpticNerve_L	V(6000 cGy) < 0.03 cc	
Retina	V(5000 cGy) < 0.03cc	Mean < 4500 cGy
Cochlea		Nausea V(4000 cGy) < 80% Hearing loss < 4500 cGy
MiddleEar		Mean < 4600 cGy
Parotid_R		Mean < 2600 cGy
Parotid_L		Mean < 2600 cGy
Parotid_Stem_R		
Parotid_Stem_L		
Submandibula_R		Mean < 3900 cGy
Submandibula_L		Mean < 3900 cGy
OralCavity		Mean < 3200 cGy
Larynx		V(3500 cGy) < 79% V(4500 cGy) < 45% V(5500 cGy) < 32% V(6500 cGy) < 22% Aspiration < 4100 cGy PEG Dependence < 5100 cGy
Thyroid		10–15cc Gland – mean < 1000 cGy 20 cc Gland – mean < 2500 cGy 25 cc Gland – mean < 4000 cGy
SPC/MPC/IPC		Aspiration < 5400 cGy Stricture < 5400 cGy PEG Dependence < 5100 cGy
IPC		V(4000 cGy) < 65% V(5000 cGy) < 47%

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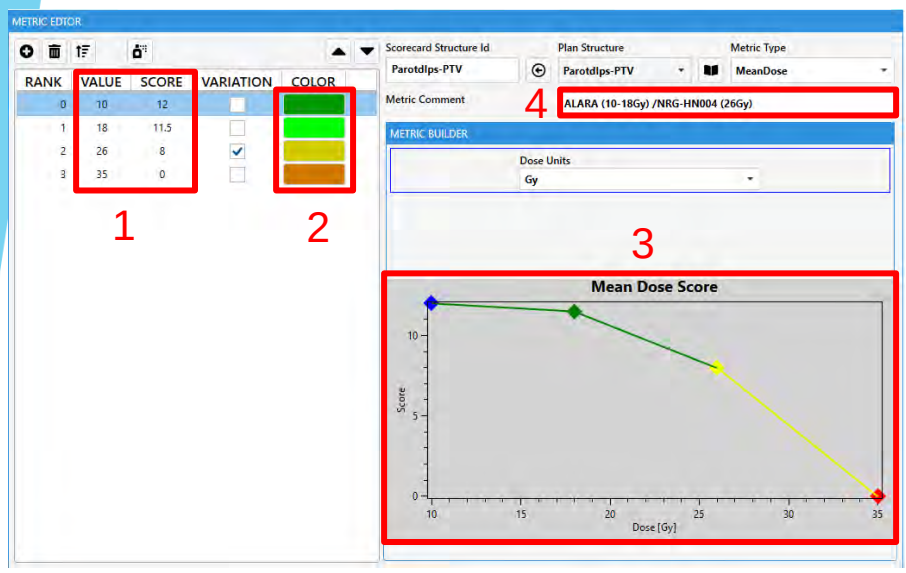
H&N Scorecard Development

Metric Editor



1. Points assigned for mean dose in Gy

2. Metric points scorecard expressed in qualitative colors
   - **Orange = 0-8 points**
   - **Dark Green = Full points**

3. Points plotted as a piecewise linear function
   - Yellow symbolizes variation range

4. Comment box used for referencing protocol

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H&N Scorecard Development

Contra and Ipsilateral Parotid Metrics

1. Parotid glands were designated as either ipsilateral or contralateral

2. More total points are awarded for contralateral parotid

3. Contralateral parotid has a steeper variation point slope

4. Ipsilateral parotid has a higher failing dose (0 points)

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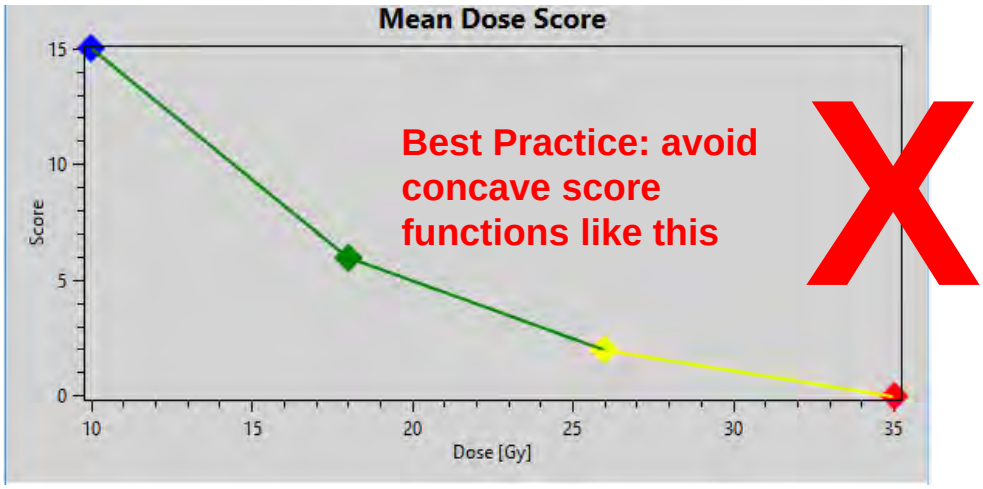
H&N Scorecard Development

Point Slopes



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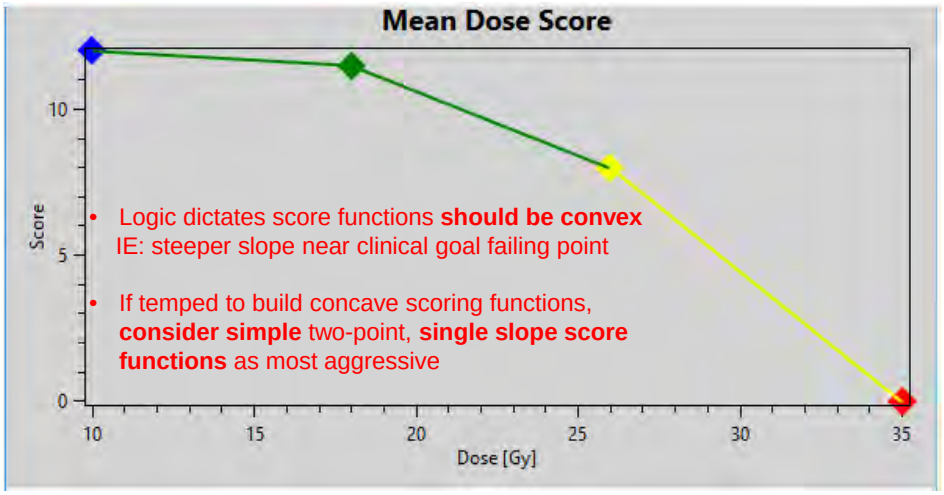
H&N Scorecard Development

Point Slopes



- Logic dictates score functions **should be convex**
  IE: steeper slope near clinical goal failing point
- If temped to build concave scoring functions, **consider simple** two-point, **single slope score functions** as most aggressive

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H&N Scorecard Development

Point Distribution

Balance Target metrics (up to 50%)
- Max/min dose
- % coverage
- Homogeneity
- Conformality

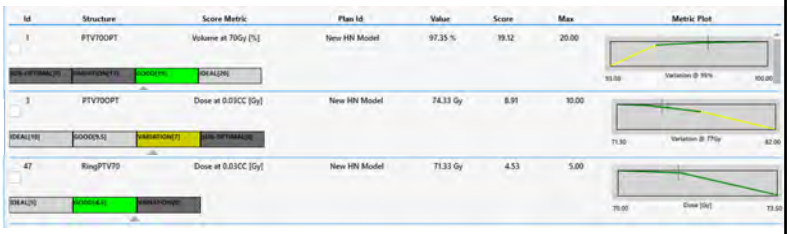
OAR metrics
- Volume at Dose
- Mean dose
- Dose at Volume (0.03cc)

Highest points to PTV coverage

Add multiple dose level rings
(PTV56, PTV63, & PTV70)

Max score should not be achievable
- Rarely: single metric (out of field)
- Never: total score card

Target metrics (37.5%)



OAR metrics (62.5%)

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H&N Scorecard Development

53 Metrics with 260 total points

Metric Id	Structure Id	Metric	Max Score
0	PTV70OPT	Volume at 70Gy [%]	20
1	PTV70OPT	Dose at 99.5% [Gy]	1.5
2	PTV70OPT	Dose at 0.03CC [Gy]	10
3	PTV63	Volume at 63Gy [%]	17
4	PTV63	Dose at 99.5% [Gy]	1.5
5	PTV63-PTV70	Volume at 66.15Gy [%]	8
6	PTV56	Volume at 56Gy [%]	15
7	PTV56	Dose at 99.5% [Gy]	1.5
8	PTV56-PTV63	Volume at 58.8Gy [%]	8
9	SpinalCord_05	Dose at 0.03CC [Gy]	6.5
10	SpinalCord_05	Volume at 40Gy [%]	2
11	SpinalCord_05	Volume at 30Gy [%]	2
12	Brainstem_03	Dose at 0.03CC [Gy]	4
13	Brain	Dose at 0.03CC [Gy]	2
14	Brain	Volume at 50Gy [CC]	3
15	Pituitary	MeanDose [Gy]	1
16	Chiasm	Dose at 0.03CC [Gy]	3
17	OpticNerve_L	Dose at 0.03CC [Gy]	3
18	OpticNerve_R	Dose at 0.03CC [Gy]	3
19	LacrimalGlands	MeanDose [Gy]	3
20	Cochlea_R	Volume at 40Gy [%]	3
21	Cochlea_L	Volume at 40Gy [%]	3
22	Lens_R	Dose at 0.03CC [Gy]	2.5
23	Lens_L	Dose at 0.03CC [Gy]	2.5
24	Eye_R	Dose at 0.03CC [Gy]	2
25	Eye_R	MeanDose [Gy]	2
26	Eye_L	Dose at 0.03CC [Gy]	2
27	Eye_L	MeanDose [Gy]	2

Metric Id	Structure Id	Metric	Max Score
28	Lips	MeanDose [Gy]	7
29	ParotdIps-PTV	MeanDose [Gy]	12
30	ParotdCon-PTV	MeanDose [Gy]	15
31	PharConst-PTV	MeanDose [Gy]	5
32	Mandible-PTV	Volume at 70Gy [%]	5
33	Mandible-PTV	Volume at 60Gy [%]	2
34	Mandible-PTV	Volume at 50Gy [%]	2
35	Esophagus	MeanDose [Gy]	4
36	Esophagus	Dose at 0.03CC [Gy]	3
37	OCavity-PTV	MeanDose [Gy]	6
38	OCavity-PTV	Dose at 0.03CC [Gy]	2
39	Larynx-PTV	MeanDose [Gy]	7
40	Thyroid-PTV	MeanDose [Gy]	2
41	BrachialPlexus_L	Dose at 0.1CC [Gy]	4
42	BrachialPlexus_R	Dose at 0.1CC [Gy]	4
43	SubmandL-PTV	MeanDose [Gy]	9.25
44	SubmandR-PTV	MeanDose [Gy]	9.25
45	TMJoint	Dose at 0.03CC [Gy]	2
46	RingPTV70	Dose at 0.03CC [Gy]	5
47	RingPTV63	Dose at 0.03CC [Gy]	5
48	RingPTV56	Dose at 0.03CC [Gy]	5
49	Posterior_Neck	Volume at 35Gy [%]	5
50	Trachea	MeanDose [Gy]	2.5
51	Lungs	Volume at 20Gy [CC]	2
52	Shoulders	MeanDose [Gy]	1

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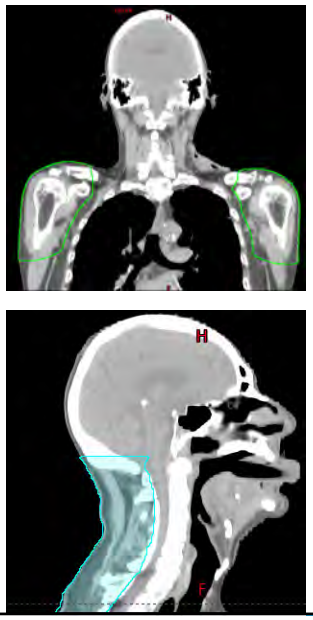
H&N Scorecard Development

Highlights

- PTV70_OPT (Cropped from the Brachial Plexus)
- Lower PTV's cropped from the higher PTV's (i.e. PTV63 – PTV70)
- OARs were evaluated by using substructures not overlapping with PTVs
- Unique ring structures were added for each PTV
- Shoulder and posterior neck structures were added



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Model Training Process

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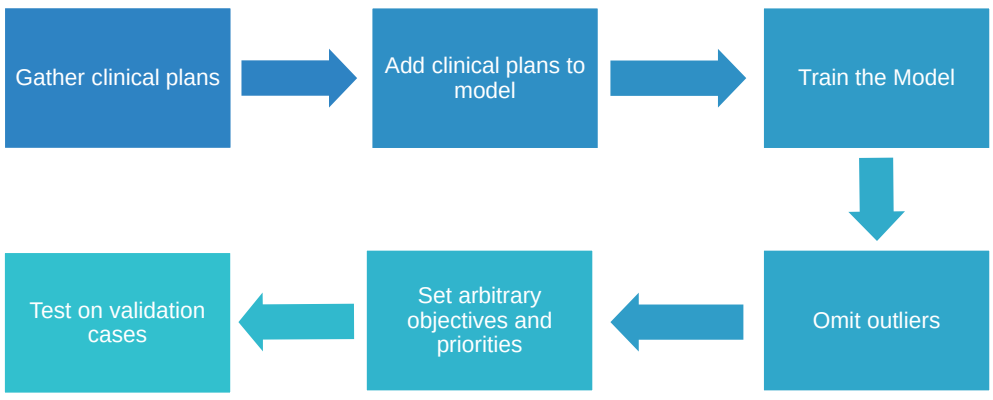
Traditional Model Training Process



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Non-Recursive Scorecard Model Training Process

Test existing KBP models

Gather feedback from original plans → Create scorecard that addresses feedback → Evaluate original plans using scorecard → Manually reoptimize KBP cases to maximize points

Check scorecard for min/max points and revise → Reoptimize +rescore plans → Create initial model from plans → Replan all cases using initial model

Retune: change model objectives and priorities → Add additional plans → Validate model on external cases → Finished Model

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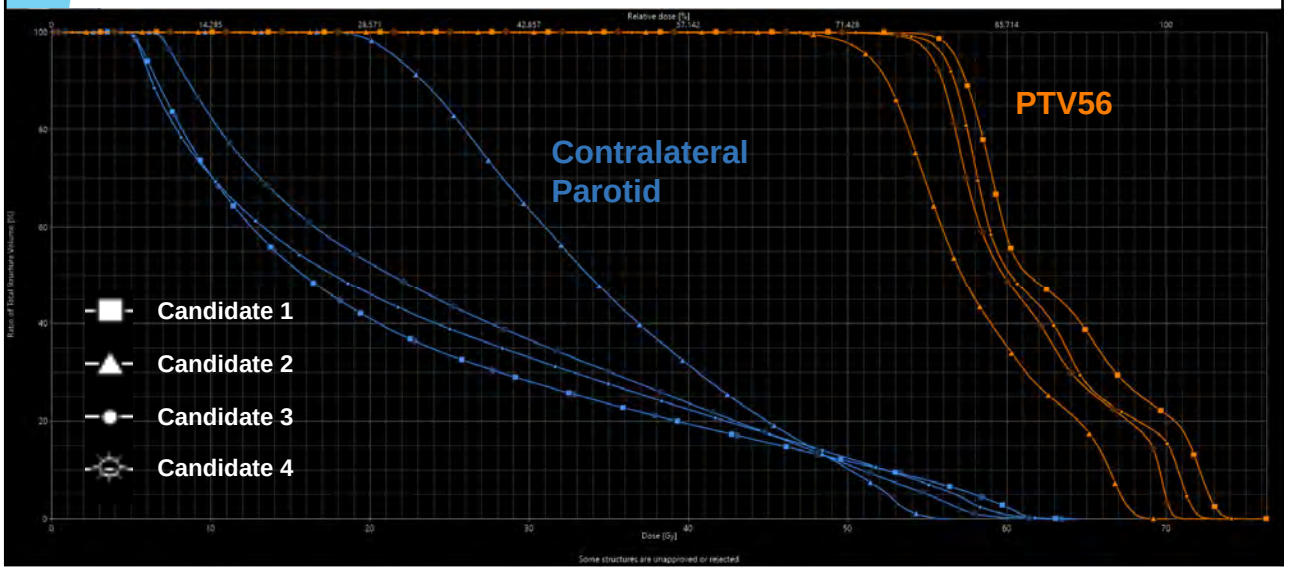
Testing candidate KBP models

DVH

Test existing KBP models



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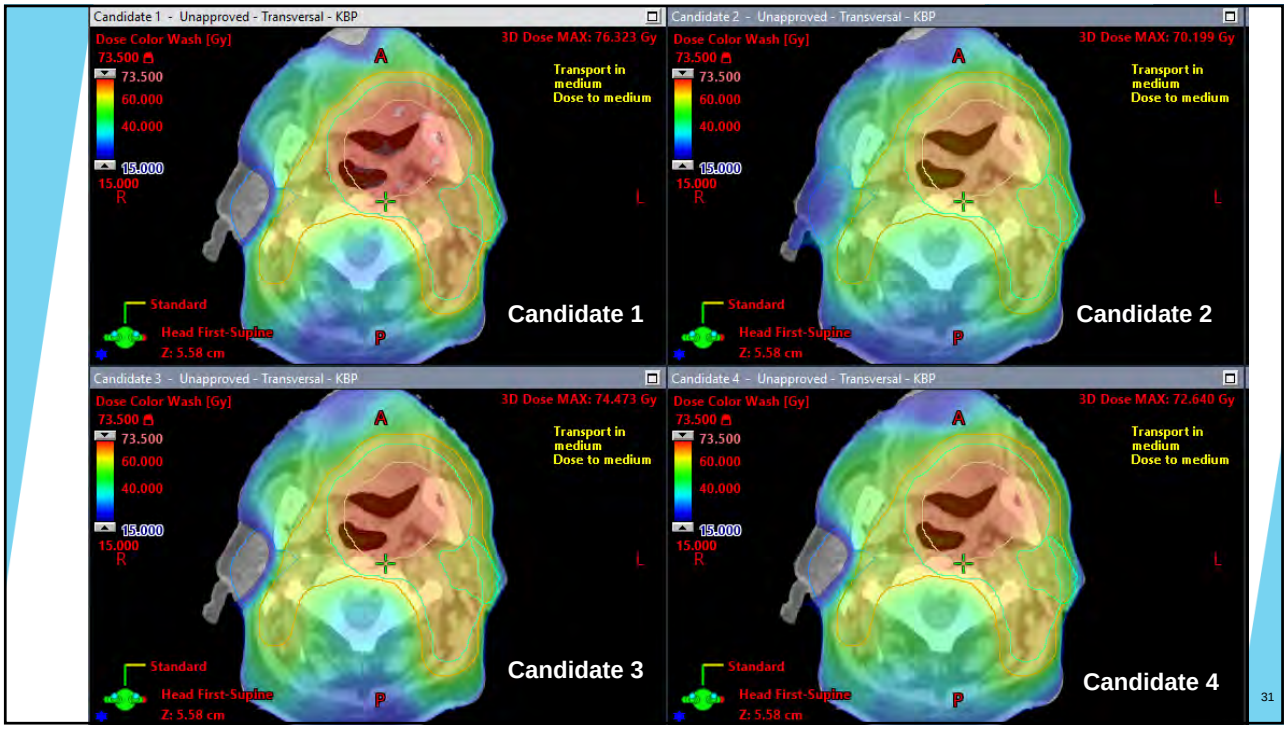

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Testing candidate KBP models

Scores

Test existing KBP models

Patient	Course	Plan	☑	Score (X/250
002445	RC	Candidate 1	■	181.82
002445	RC	Candidate 4	☑	144.00
002445	RC	Candidate 3	☑	161.09
002445	RC	Candidate 2	☑	138.51

Special thanks to Vanessa Magliari for providing Candidate 1 (top candidate model) used throughout the rest of this work!

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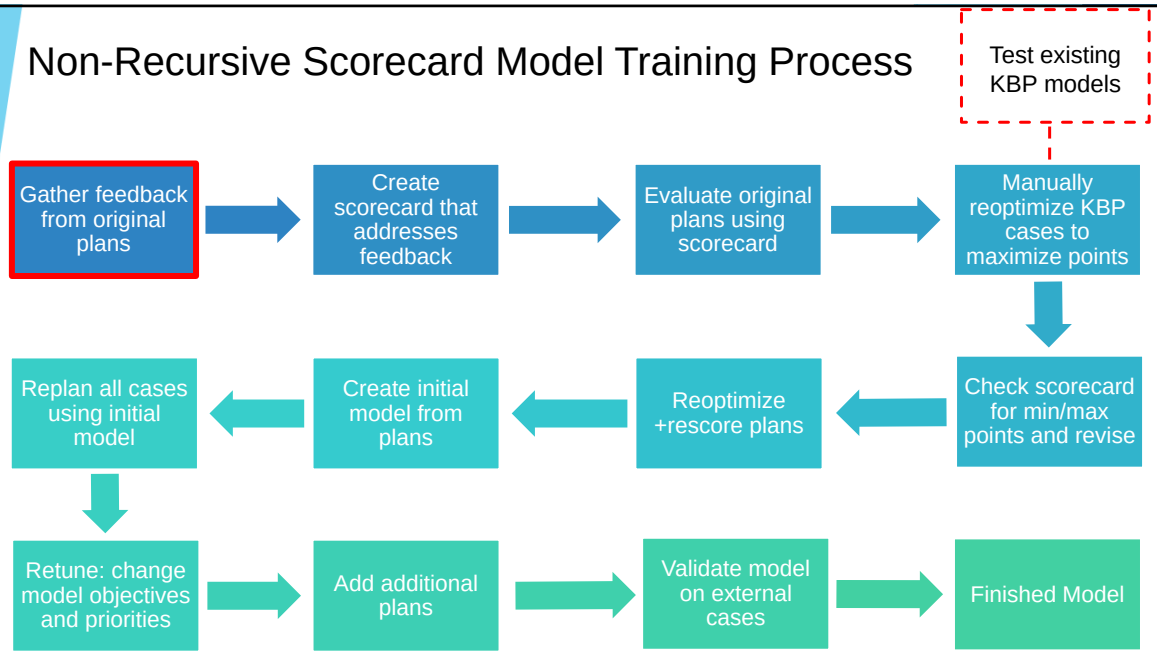
Non-Recursive Scorecard Model Training Process



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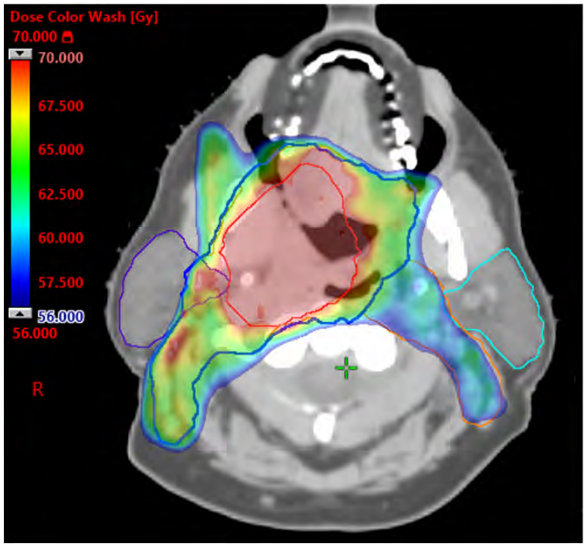
Addressing Target Conformity

Gather feedback from original plans

- **Goal:** Improve Target conformity while still sparing parotid glands.
- **Method:** Create individual ring structures for each PTV
- **Process:** Include the ring structures in the new model and scorecard



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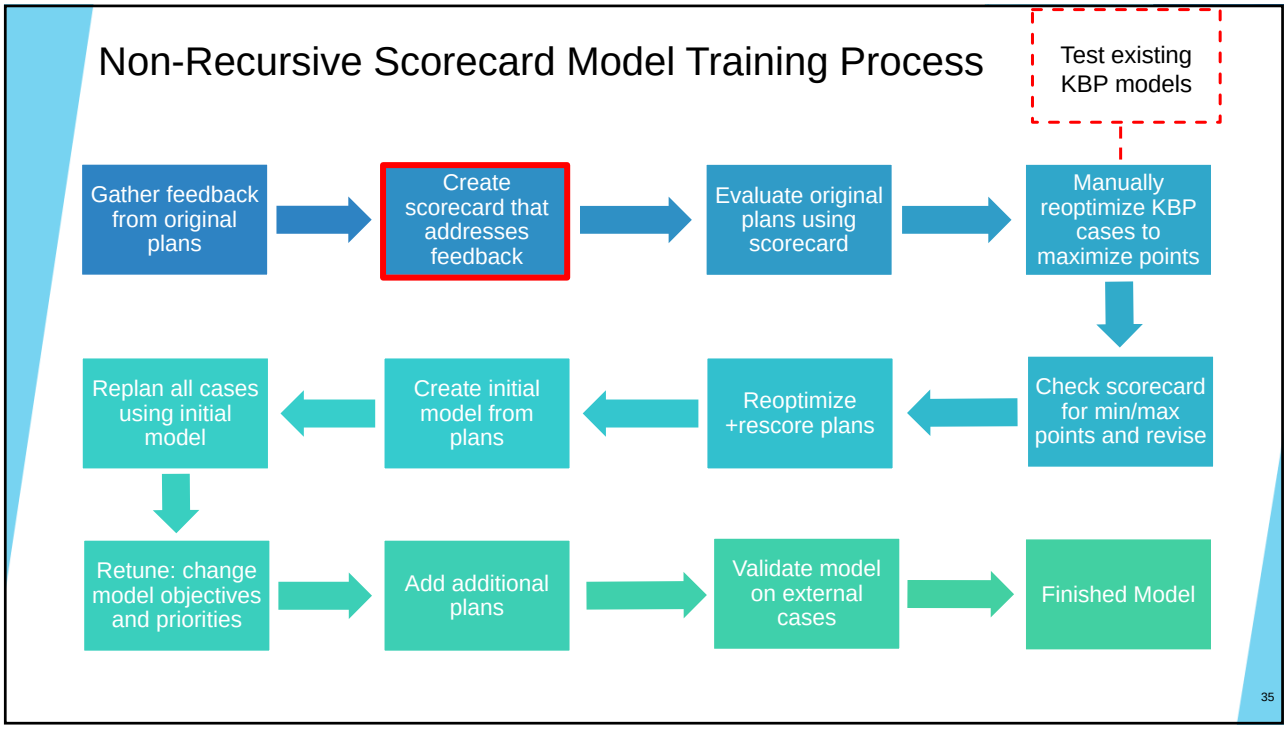
Non-Recursive Scorecard Model Training Process



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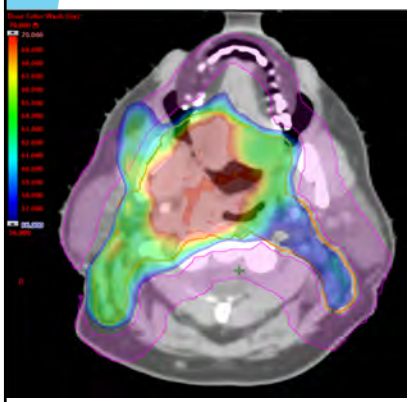
Implement Ring Structures

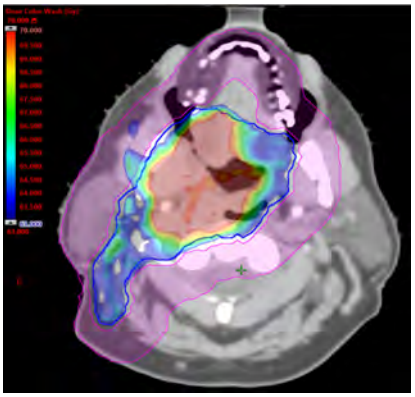
Create scorecard that addresses feedback

Ring PTV56



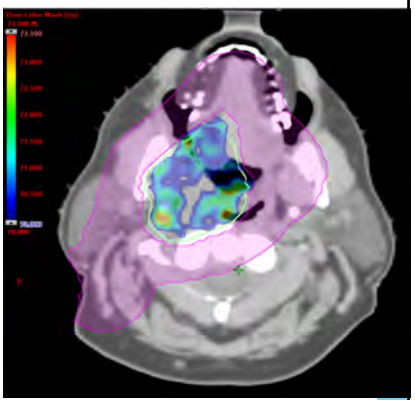
Cropped 0.2cm from PTV56, 0.6cm from PTV63, and 0.9cm from PTV70

Ring PTV63



Cropped 0.2cm from PTV63 and 0.6cm from PTV70

Ring PTV70



Cropped 0.2cm from PTV70

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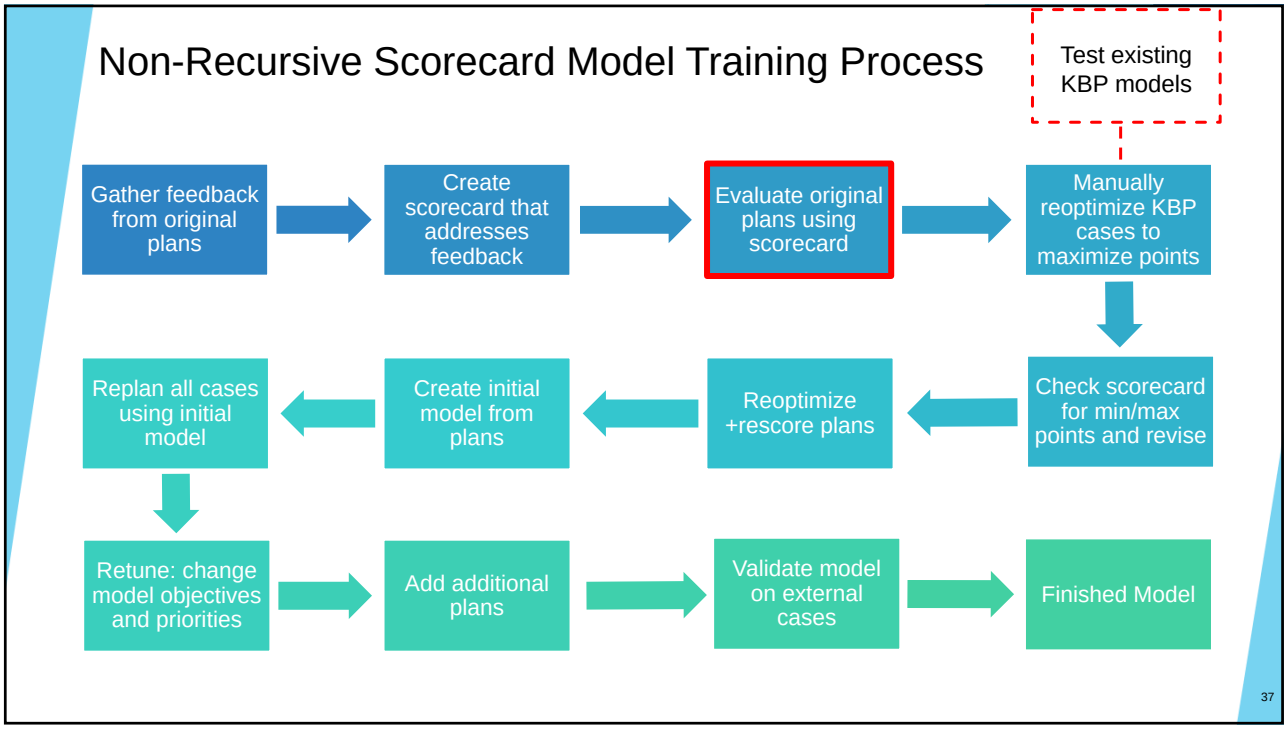
Non-Recursive Scorecard Model Training Process



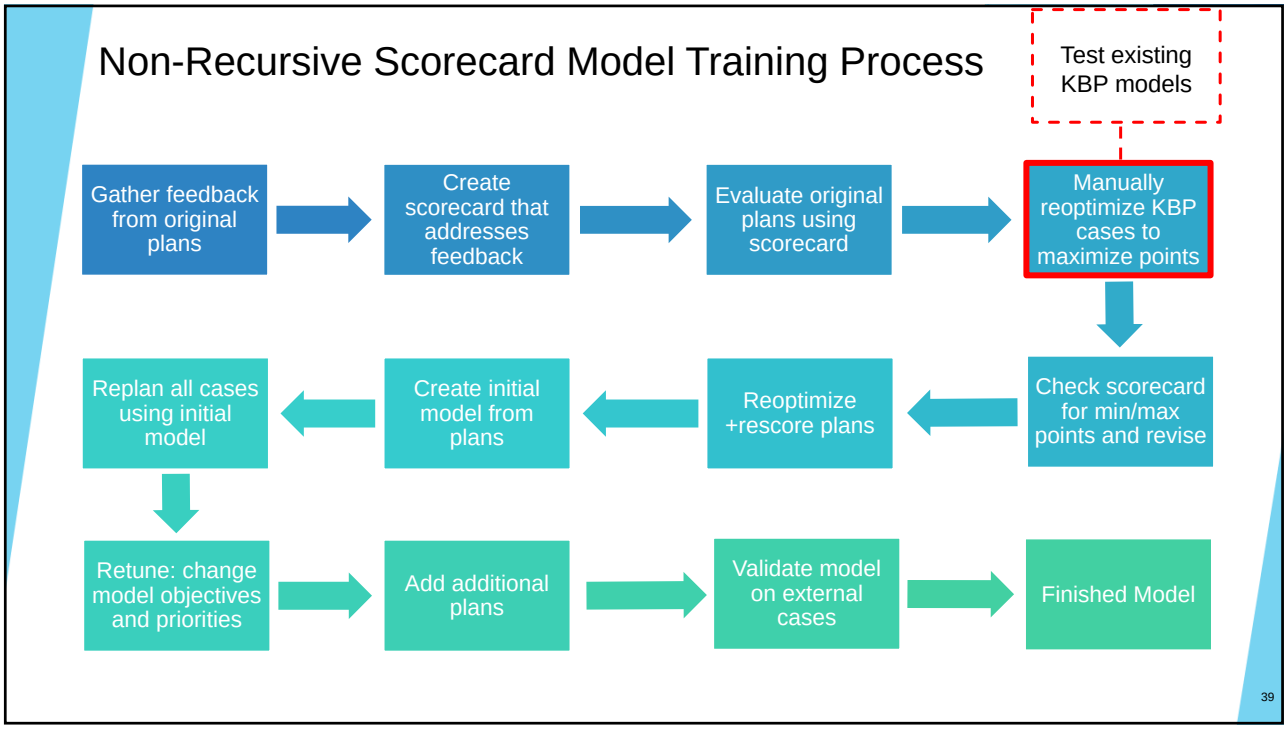
37

Ring Structure Metrics

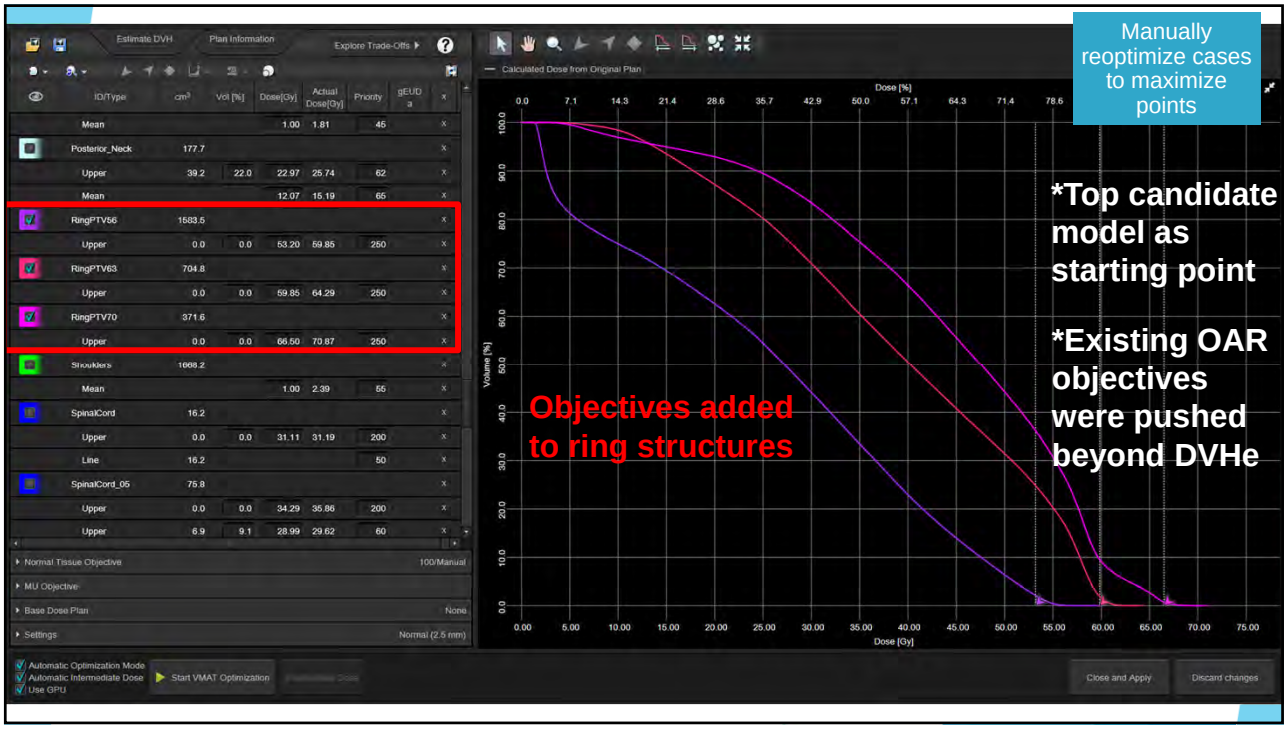
Score conformality of the candidate model

Evaluate original plans using scorecard

38

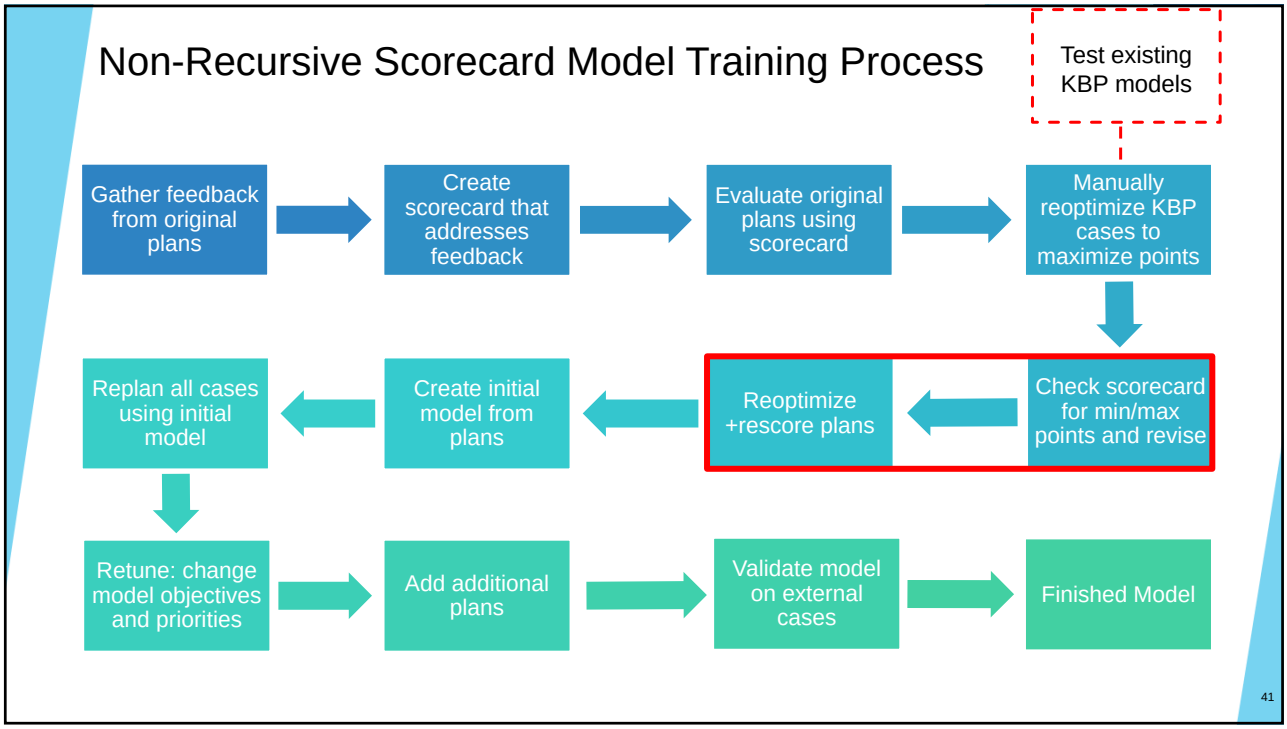

Non-Recursive Scorecard Model Training Process
Test existing KBP models
Gather feedback from original plans
Create scorecard that addresses feedback
Evaluate original plans using scorecard
Manually reoptimize KBP cases to maximize points
Check scorecard for min/max points and revise
Reoptimize +rescore plans
Create initial model from plans
Replan all cases using initial model
Retune: change model objectives and priorities
Add additional plans
Validate model on external cases
Finished Model
39

39


Manually reoptimize cases to maximize points
*Top candidate model as starting point
*Existing OAR objectives were pushed beyond DVHe
Objectives added to ring structures

40

Non-Recursive Scorecard Model Training Process



41

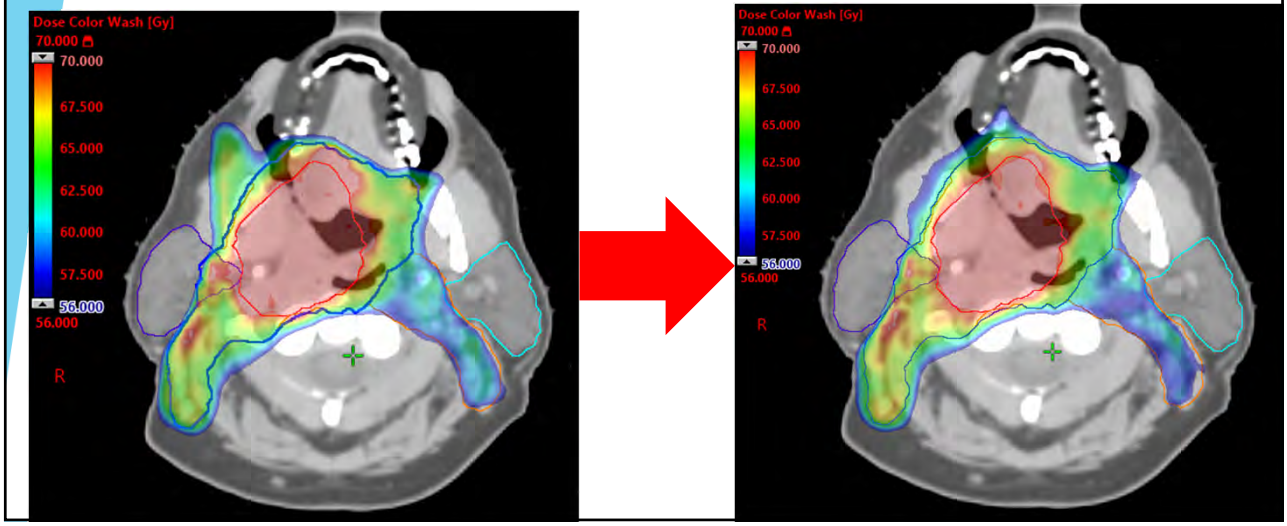
Assess and retune objectives and scorecard

Check candidate scorecard for min/max points and revise

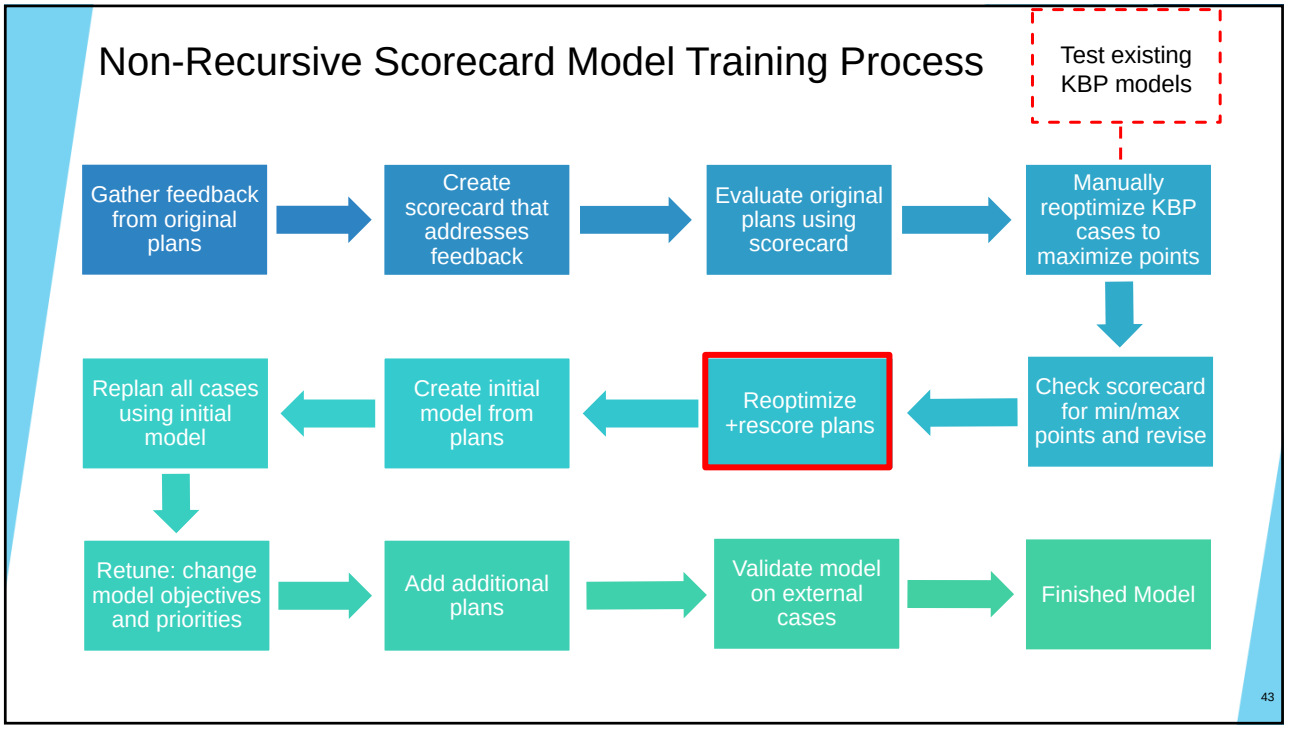
Reoptimize +rescore plans

Top Candidate Model

Edited Top Candidate



42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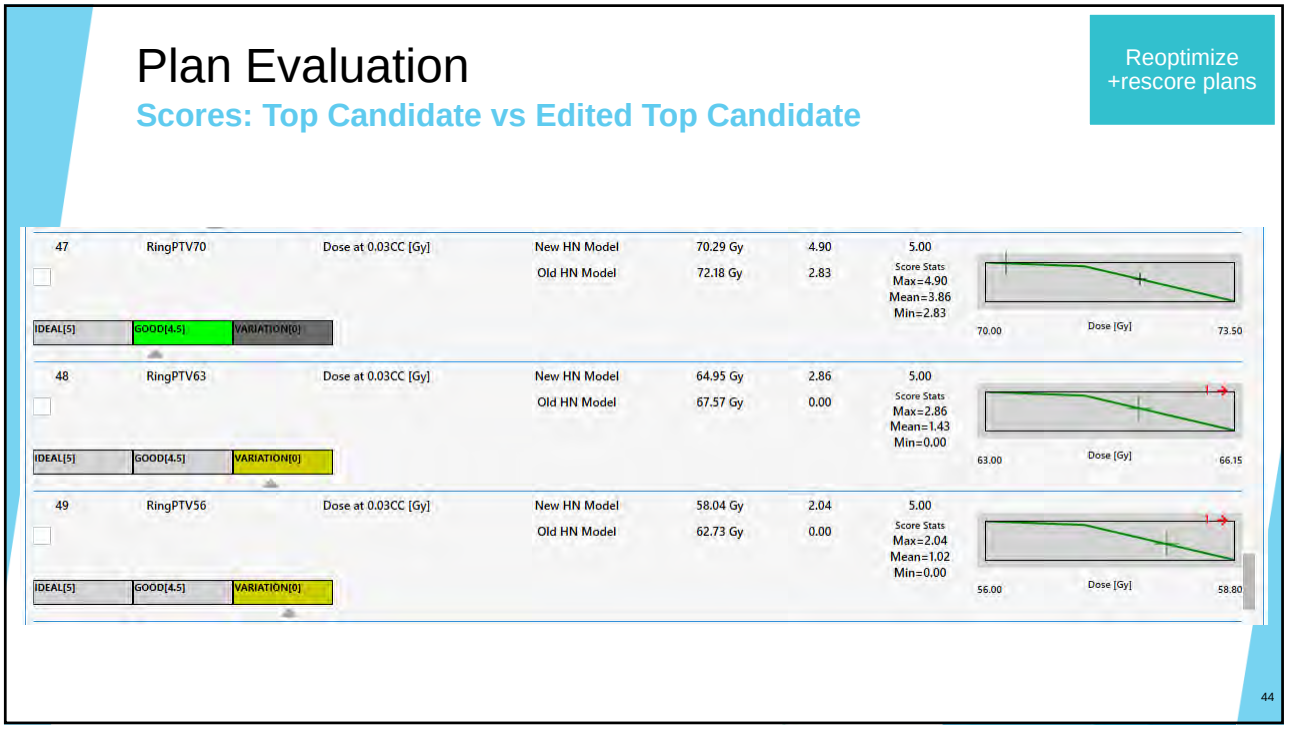
Finished Model
43

43


Plan Evaluation
Scores: Top Candidate vs Edited Top Candidate
Reoptimize +rescore plans
47 RingPTV70 Dose at 0.03CC [Gy] New HN Model 70.29 Gy 4.90 5.00
Old HN Model 72.18 Gy 2.83
Score Stats Max=4.90 Mean=3.86 Min=2.83
IDEAL[5] GOOD[4.5] VARIATION[0]
70.00 Dose [Gy] 73.50
48 RingPTV63 Dose at 0.03CC [Gy] New HN Model 64.95 Gy 2.86 5.00
Old HN Model 67.57 Gy 0.00
Score Stats Max=2.86 Mean=1.43 Min=0.00
IDEAL[5] GOOD[4.5] VARIATION[0]
63.00 Dose [Gy] 66.15
49 RingPTV56 Dose at 0.03CC [Gy] New HN Model 58.04 Gy 2.04 5.00
Old HN Model 62.73 Gy 0.00
Score Stats Max=2.04 Mean=1.02 Min=0.00
IDEAL[5] GOOD[4.5] VARIATION[0]
56.00 Dose [Gy] 58.80
44

44

Training Set Cases

(Edited Top Candidate Cases)

- Record the total score of all optimized plans
- Calculate the average score (used as a benchmark to track the overall performance of future versions of the model)
- Take note of any unique patient anatomy that could affect the overall score for future reference
- Utilize these cases to train the first iteration of the new model

Patient	Notes	Plan Score
RP_HN_C05_006	Thymus	230.66
RP_HN_C05_016	Thymus	208.04
RP_HN_C05_021	Thymus	233.95
RP_HN_C05_131	Oropharynx	215.58
RP_HN_C05_196	Posterior LNs	209.78
RP_HN_C05_271	Oropharynx	232.01
RP_HN_C05_293	Oropharynx	231.87
RP_HN_C05_314	Oropharynx	231.87
RP_HN_C05_318	Oropharynx	221.25
RP_HN_C05_325	Oropharynx	226.71
RP_HN_C05_342	Oropharynx	236.25
RP_HN_C05_345	Oropharynx	226.1
RP_HN_C05_347	Oropharynx	233.55
RP_HN_C05_356	Oropharynx	237.51
RP_HN_C05_402	Oropharynx	217.5
RP_HN_C05_413	Oropharynx	228.93
RP_HN_C05_434	Posterior LNs	232.1
RP_HN_C05_452	Inferior PTV70	231.82
RP_HN_C05_529	Anterior LNs	223.59
RP_HN_C05_604	OVL with mandible	215.48
RP_HN_C05_623	Oropharynx	220.29
RP_HN_C05_681	Oropharynx	229.21
RP_HN_C05_682	Oropharynx	230.86
RP_HN_C05_768	Small PTV63	234.14
RP_HN_C05_775	High OVL with BP	224
RP_HN_C05_785	Oropharynx	232.33
RP_HN_C05_771	Posterior LNs	232.59
Average Score		**226.96**

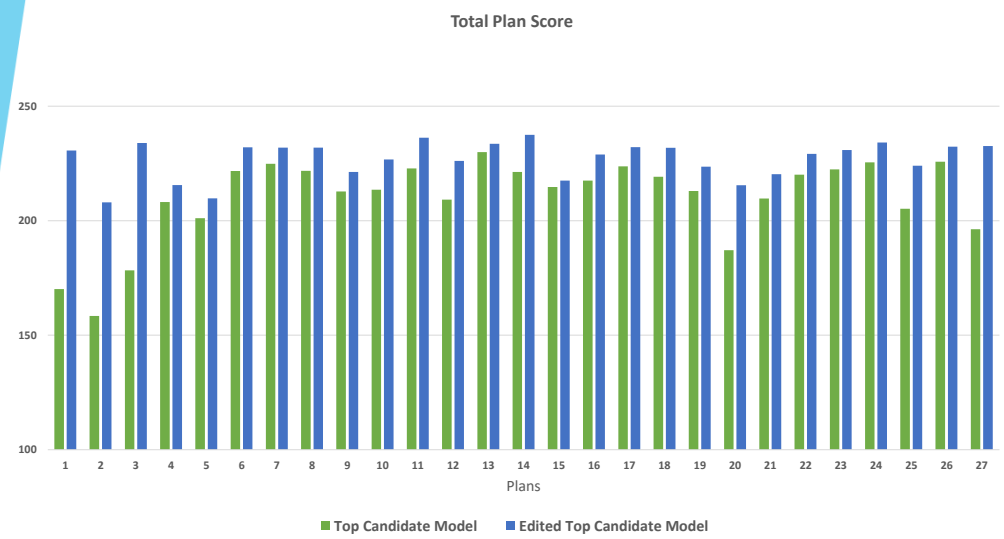
Score plans

45

45

Plan Score Comparison

Top candidate model vs edited top candidate model



Average Scores

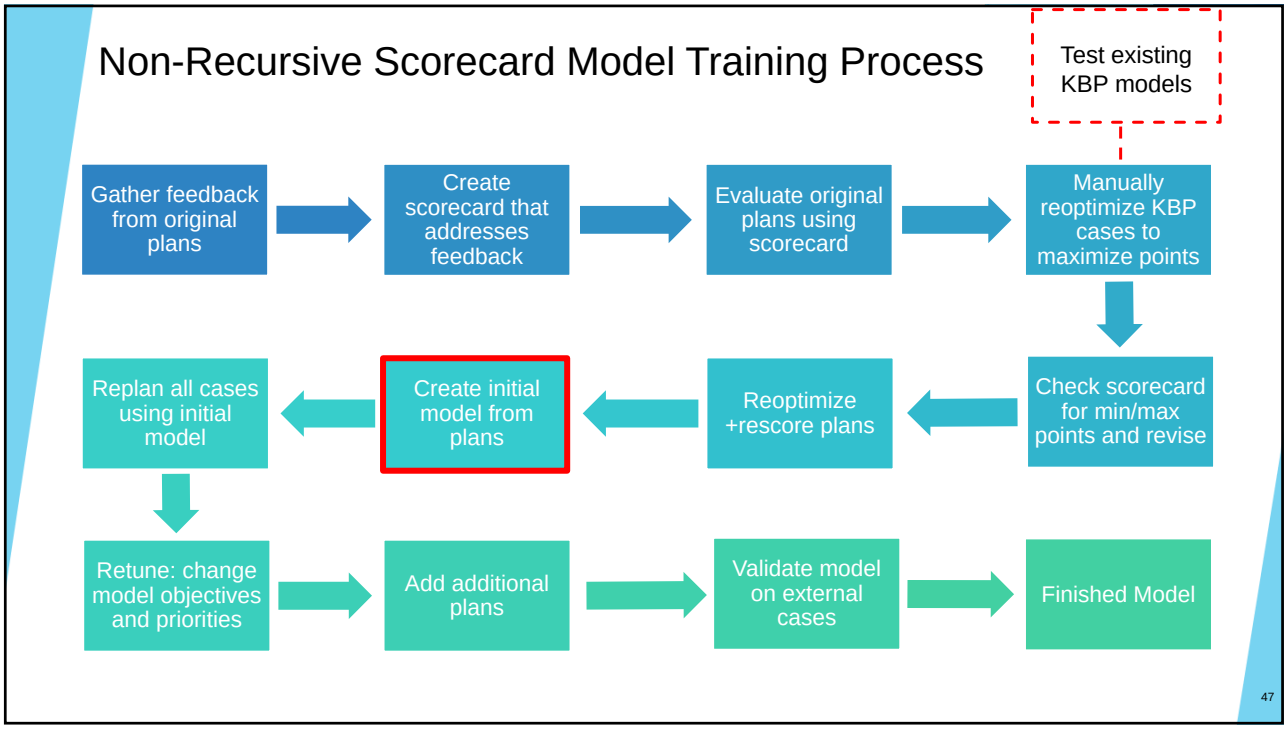
Top Candidate Model – 210.15

Edited Top Candidate Model – 226.96

Score plans

46

46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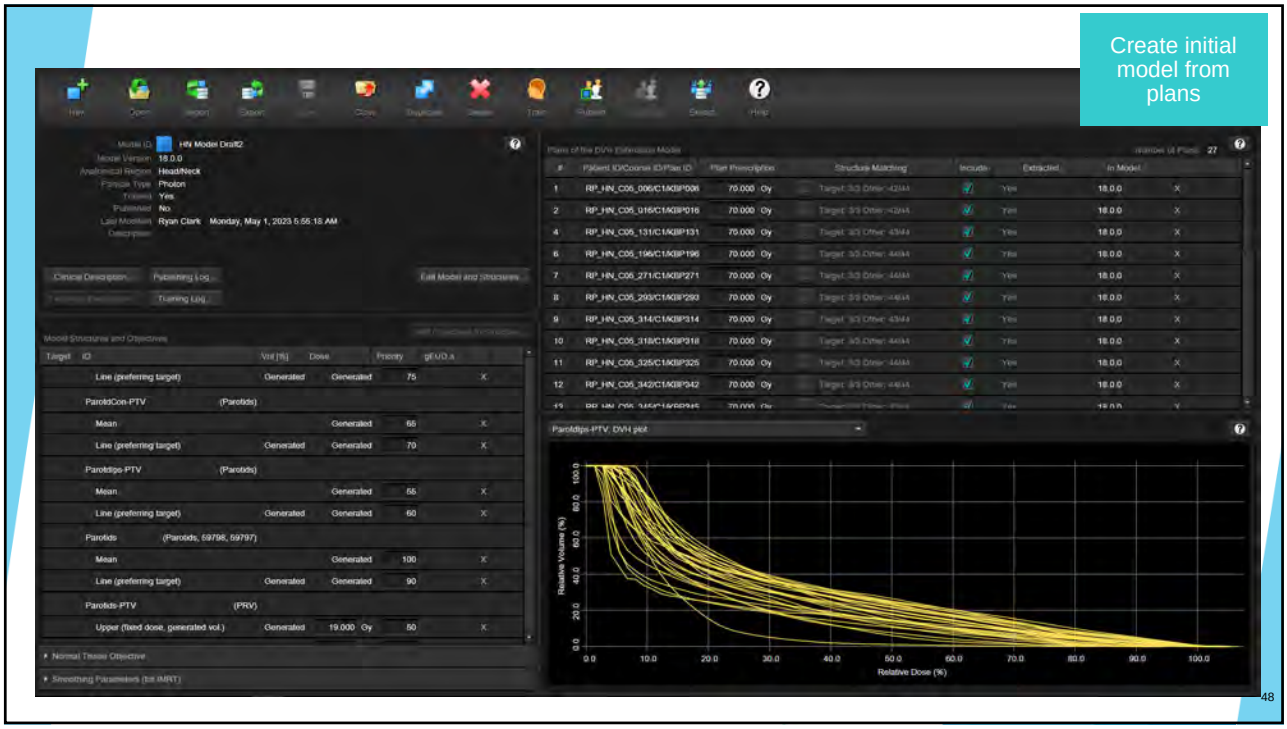
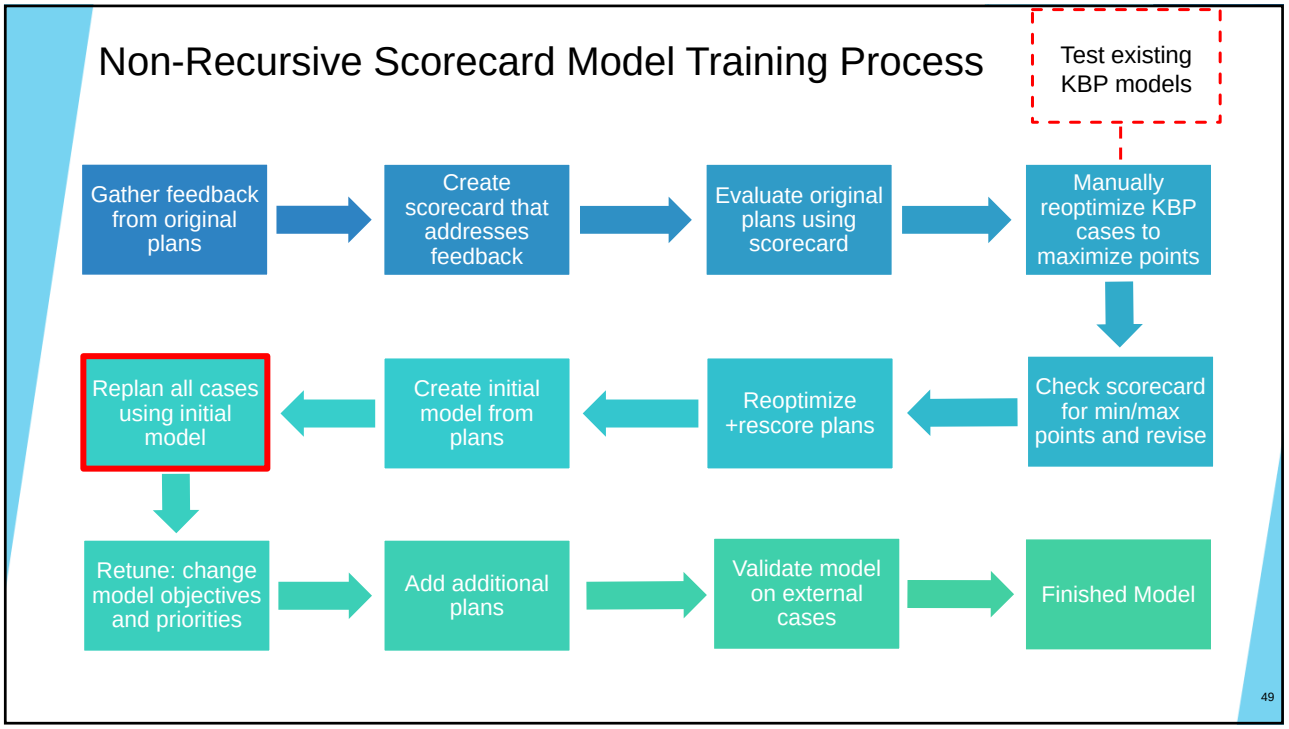
Finished Model
47

47


Create initial model from plans
48

48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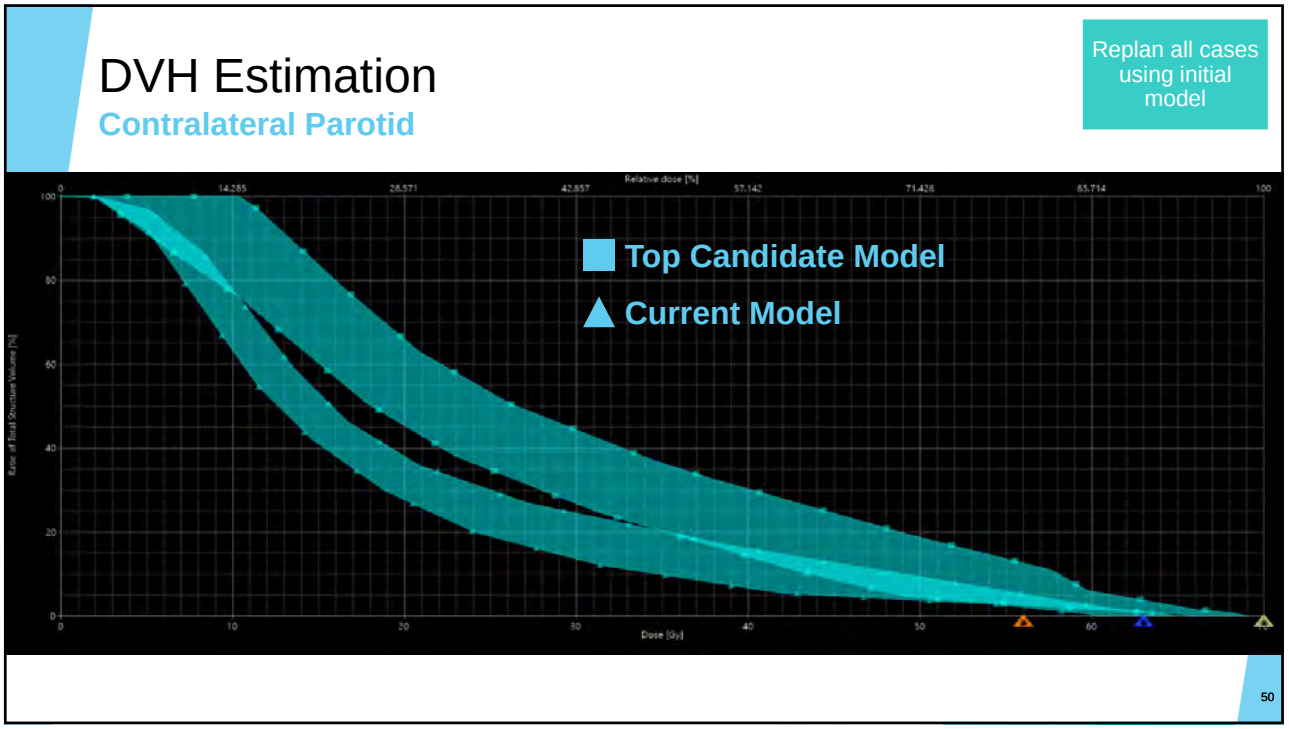
Finished Model
49

49

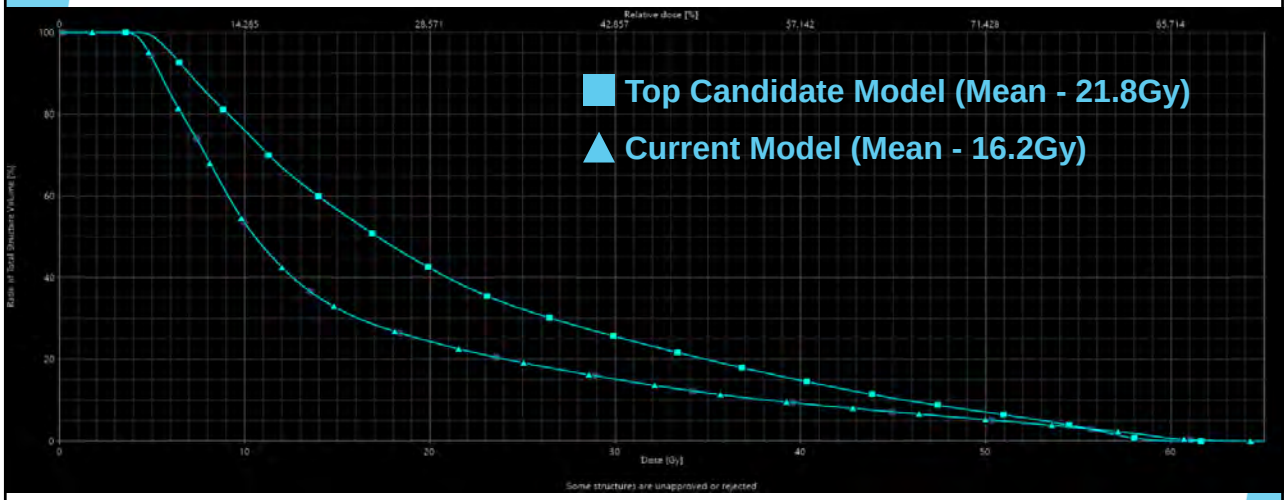

DVH Estimation
Contralateral Parotid
Replan all cases using initial model
Top Candidate Model
Current Model
Relative dose [%]
Dose [Gy]
50

50

DVH

Contralateral Parotid

Replan all cases using initial model



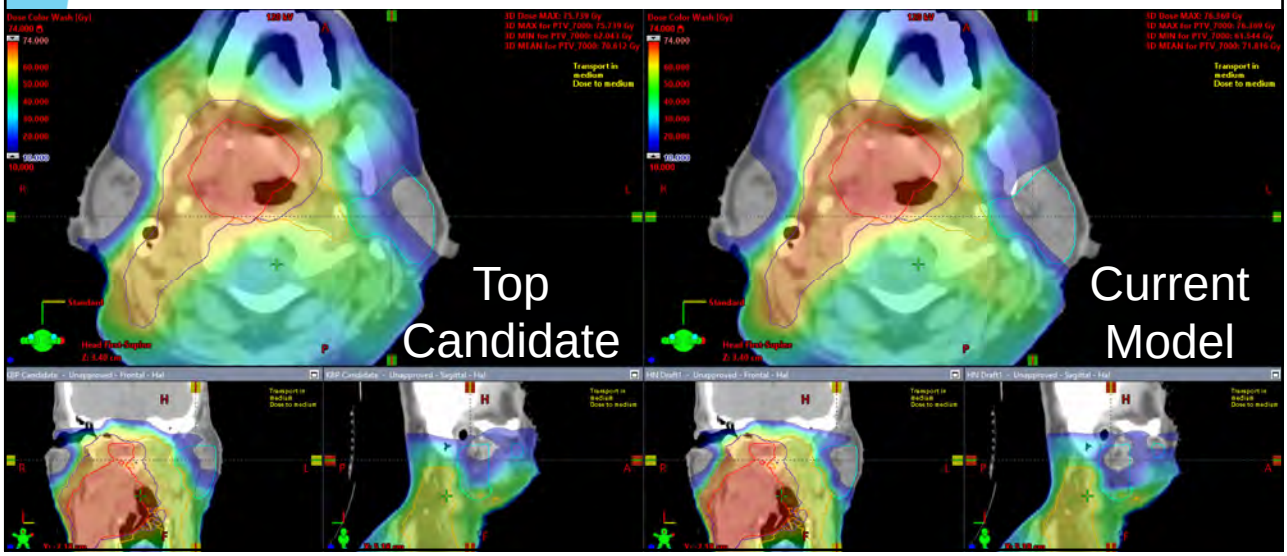
51

51

Isodose

Contralateral (Left) Parotid

Replan all cases using initial model



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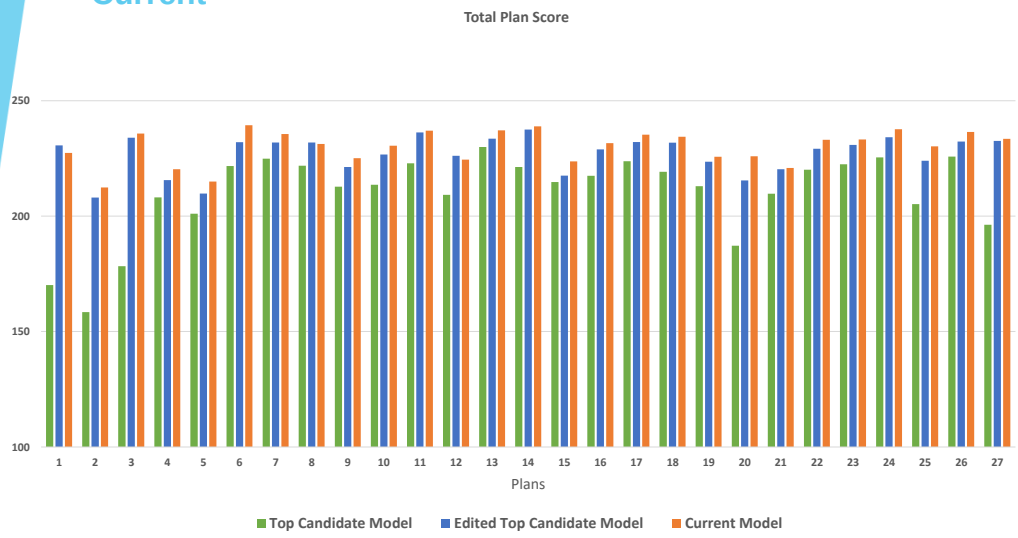
Plan Score Comparison

Top candidate model vs edited top candidate model vs Current



Replan all cases using model

Average Scores

Top Candidate Model – 210.15

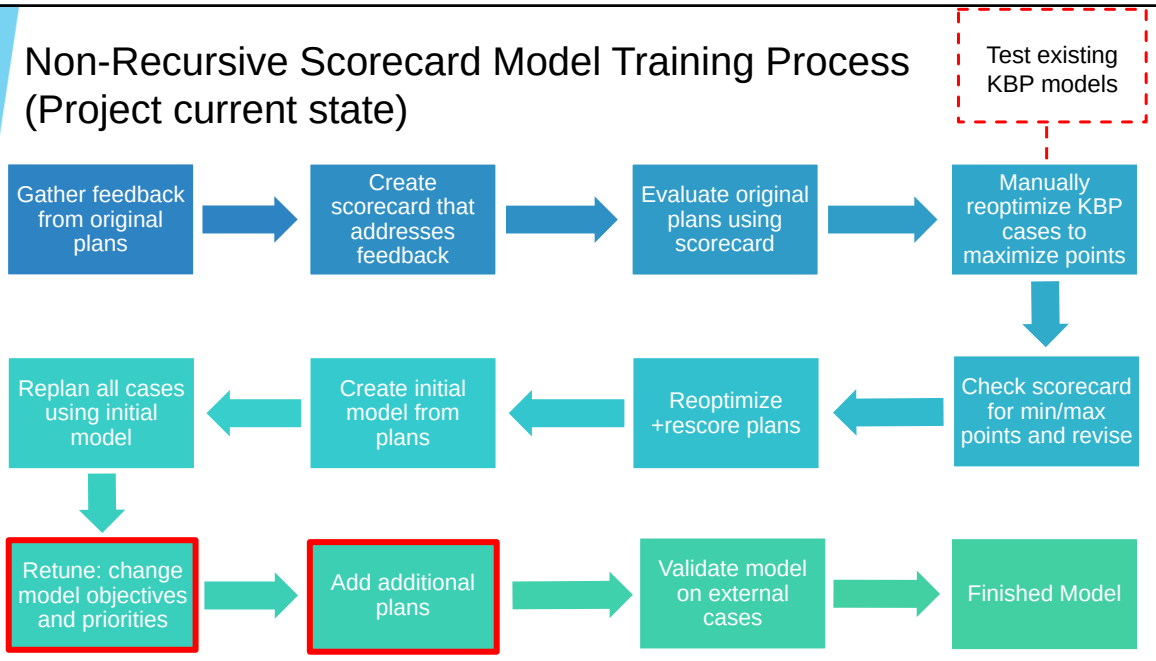
Edited Top Candidate Model – 226.96

Current Model – 230.1

53

53

Non-Recursive Scorecard Model Training Process (Project current state)



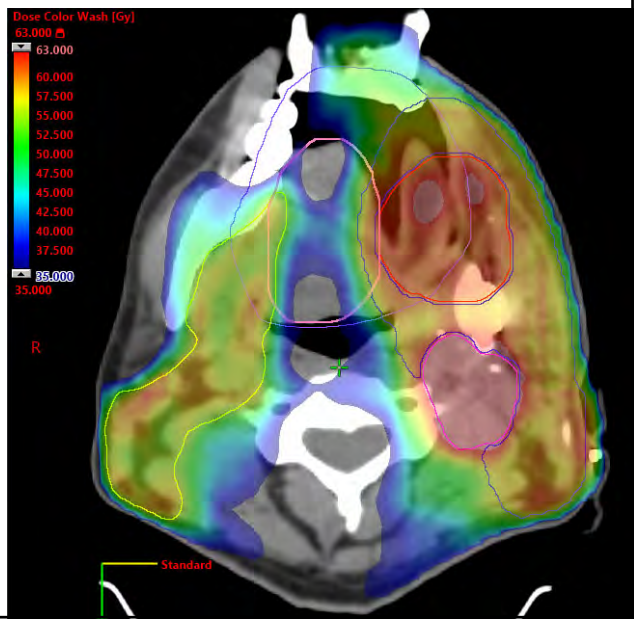
54

54

Initial Results

AAMD 2023 Plan Study- Isodose

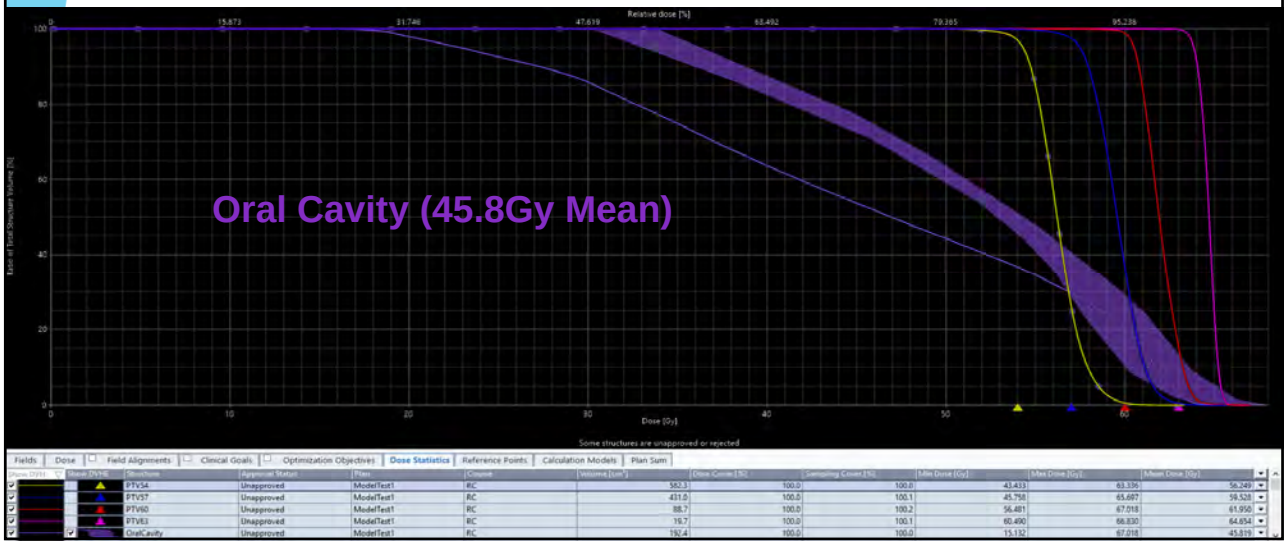
- "Oral avoid" structure was used for plan challenge case (shown in pink)
- Added "oral cavity" structure (purple) that matched the model training set cases.
- Unwanted dose bridging still occurred within the "oral avoid"
- Manual adjustments were needed during optimization to pass



55

Initial Results

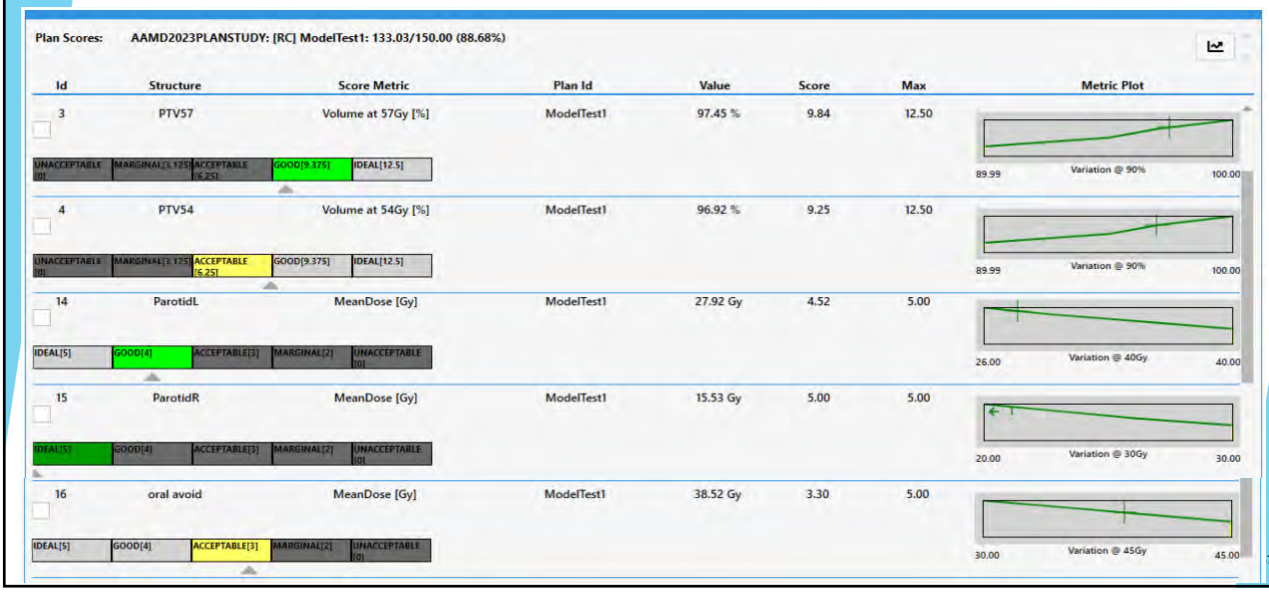
AAMD 2023 Plan Study- DVH



56

Initial Results

AAMD 2023 Plan Study- Scorecard (133.03 / 150 points)



57

Plan Score Comparison

Total Scores: Top candidate vs current model (Four external validation cases)

Average Scores

Top Candidate model – 205.4

Current Model – 222.06

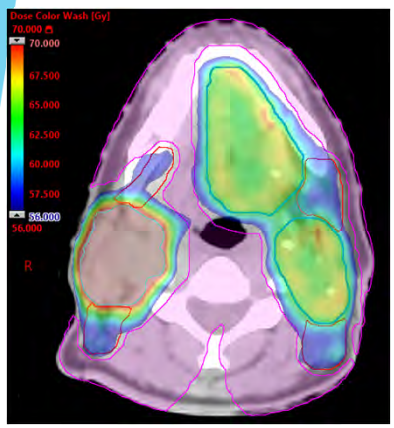
58

58

Initial Results

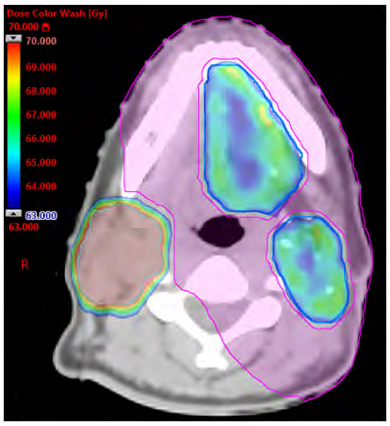
Improved Conformality

Ring PTV56



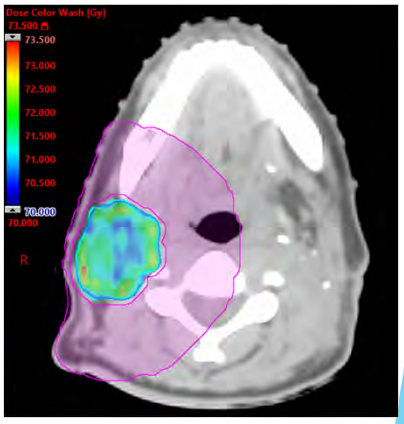
Cropped 0.2cm from PTV56, 0.6cm from PTV63, and 0.9cm from PTV70

Ring PTV63



Cropped 0.2cm from PTV63 and 0.6cm from PTV70

Ring PTV70



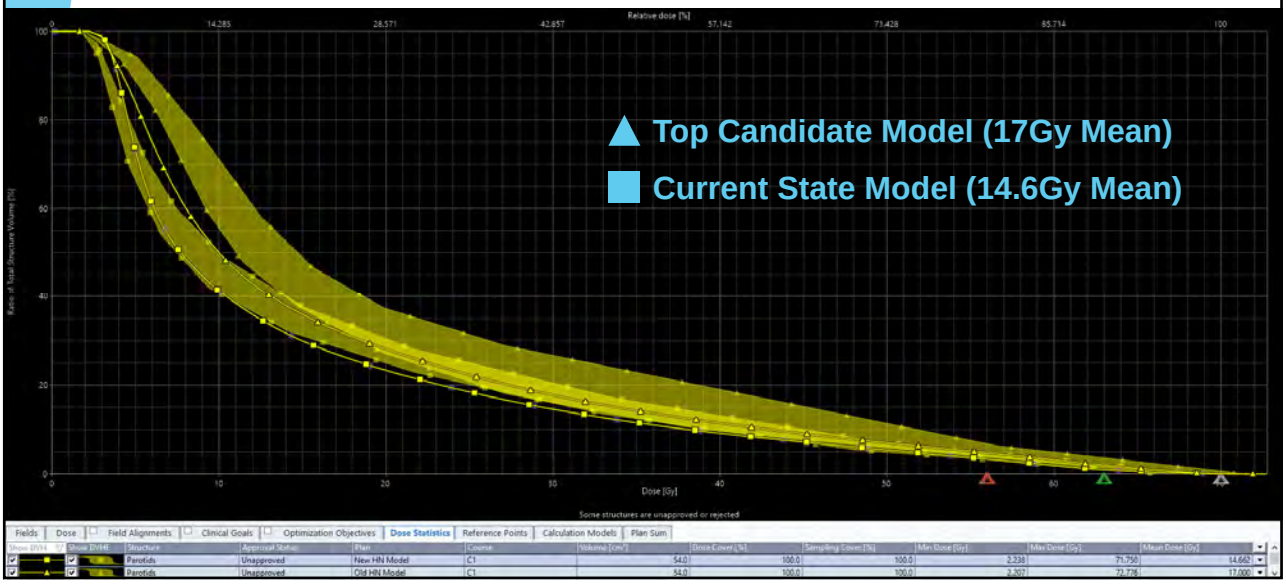
Cropped 0.2cm from PTV70

59

59

Initial Results

Improved parotid sparing and DVHe



60

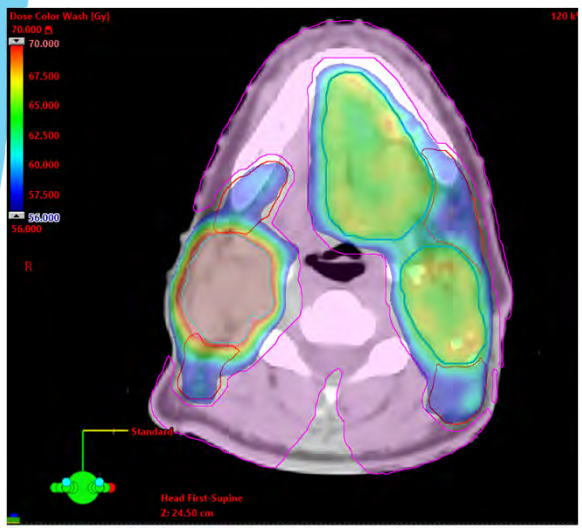
Automation Tools

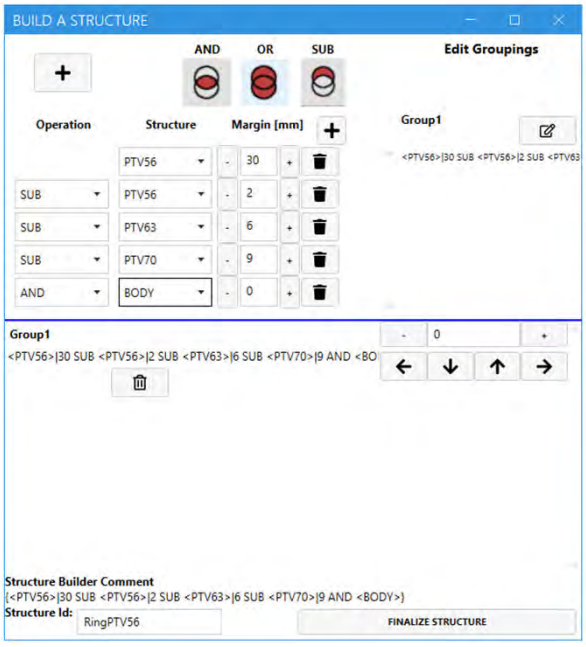
61

61

Structure Generation

Automatically create rings





62

62

Structure Generation

Boolean operations to generate rings are nested in the scorecard metrics


```
"Structure": {
    "StructureId": "RingPTV56",
    "StructureComment": "(<PTV56>|30 SUB <PTV56>|2 SUB <PTV63>|6 SUB <PTV70>|9 AND <BODY>)",
    "TemplateStructureId": "RingPTV56",
    "StructureCode": "9999",
    "AutoGenerated": true,
    "bMakeVisibleInPatientSearch": false
},
"Rank": 0,
"MetricType": "DoseAtVolume",
"InputValue": 0.03,
"InputUnit": "CC",
"OutputUnit": "Gy",
"AcceptableLevel": null,
"VariationLevel": null,
"FailLevel": null,
"HI_HiValue": 0.0,
"HI_LowValue": 0.0,
"HI_Target": 0.0,
"HI_TargetUnit": null,
"MetricComment": null,
"TemplateNumber": 48,
"ScorePoints": [
    {
        "PointX": 56.0,
        "Score": 5.0,
        "Variation": false,
        "Colors": [
            0.0,
            153.0,
            0.0
        ],
        "Label": "IDEAL[5]",
        "ColorValue": 5.0
```


63

63

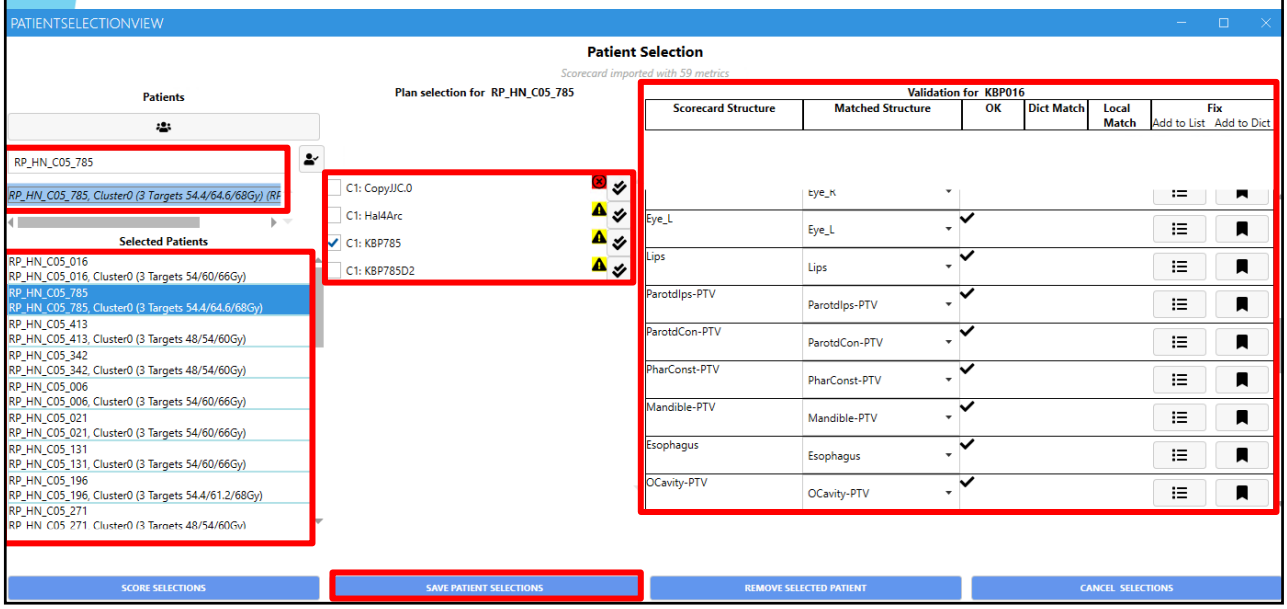
Batch Scoring

Score multiple plans at once

64

Batch Scoring

Query TPS, select patients + course/plan, and match structures to scorecard



65

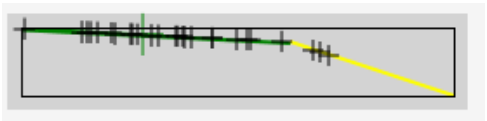
Batch Scoring

Contralateral parotid scores for 27 plans

Contralateral Parotid (Mean Dose)

- 27 plans scored
- Value = Mean dose
- Score out of 15 possible points

Metric Plot



- Max points: 5Gy
- Variation: 18Gy
- Zero points 26Gy

Plan Id	Value	Score	Max	Metric Plot
KBP016D2	10.90 Gy	13.64	15.00	
KBP785D2	11.63 Gy	13.47	Score Stats	
KBP413D2	12.89 Gy	13.18	Max=14.97	
KBP342D2	7.95 Gy	14.32	Mean=13.05	
KBP006D2	5.13 Gy	14.97	Min=9.10	
KBP021D2	8.37 Gy	14.22		
KBP131D2	19.15 Gy	10.27		
KBP196D2	15.45 Gy	12.59		
KBP271D2	8.18 Gy	14.27		
KBP293D2	14.21 Gy	12.87		
KBP314D2	10.32 Gy	13.77		
KBP318D2	12.52 Gy	13.27		
KBP325D2	13.28 Gy	13.09		
KBP345D2	17.63 Gy	12.09		
KBP347D2	8.69 Gy	14.15		
KBP356D2	9.37 Gy	13.99		
KBP402D2	10.62 Gy	13.70		
KBP434D2	9.53 Gy	13.96		
KBP452D2	11.28 Gy	13.55		
KBP529D2	16.09 Gy	12.44		
KBP604D2	19.50 Gy	9.75		
KBP623D2	12.52 Gy	13.26	5.00	Variation @ 18Gy 26.00
KBP681D2	14.28 Gy	12.86		
KBP682D2	12.82 Gy	13.20		
KBP768D2	15.92 Gy	12.48		

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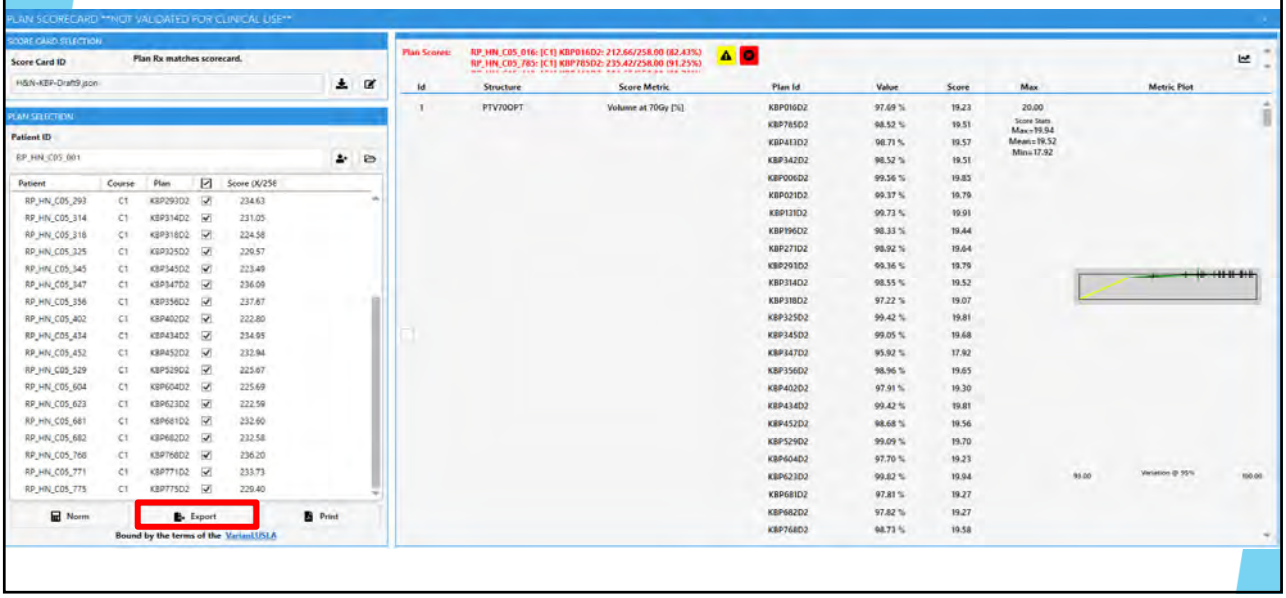
Batch Scoring

Score results can be exported as a CSV for data analysis



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Batch Scoring

Contralateral parotid scores for 27 plans in CSV

Metric Id	Patient Id	Course Id	Plan Id	StructureId	Metric Text	Metric Value	Score	Max Score
30	RP_HN_C05_016	C1	KBP016D2	ParotdCon-PTV	MeanDose [Gy]	10.89995406	13.63847214	15
30	RP_HN_C05_785	C1	KBP785D2	ParotdCon-PTV	MeanDose [Gy]	11.63374166	13.46913654	15
30	RP_HN_C05_413	C1	KBP413D2	ParotdCon-PTV	MeanDose [Gy]	12.88846921	13.17958403	15
30	RP_HN_C05_342	C1	KBP342D2	ParotdCon-PTV	MeanDose [Gy]	7.948892451	14.31948636	15
30	RP_HN_C05_006	C1	KBP006D2	ParotdCon-PTV	MeanDose [Gy]	5.12981632	14.97004239	15
30	RP_HN_C05_021	C1	KBP021D2	ParotdCon-PTV	MeanDose [Gy]	8.373056649	14.22160231	15
30	RP_HN_C05_131	C1	KBP131D2	ParotdCon-PTV	MeanDose [Gy]	19.15231413	10.2715288	15
30	RP_HN_C05_196	C1	KBP196D2	ParotdCon-PTV	MeanDose [Gy]	15.44828304	12.58885776	15
30	RP_HN_C05_271	C1	KBP271D2	ParotdCon-PTV	MeanDose [Gy]	8.182532946	14.26556932	15
30	RP_HN_C05_293	C1	KBP293D2	ParotdCon-PTV	MeanDose [Gy]	14.21413461	12.87366124	15
30	RP_HN_C05_314	C1	KBP314D2	ParotdCon-PTV	MeanDose [Gy]	10.31891416	13.77255827	15
30	RP_HN_C05_318	C1	KBP318D2	ParotdCon-PTV	MeanDose [Gy]	12.51621788	13.26548818	15
30	RP_HN_C05_325	C1	KBP325D2	ParotdCon-PTV	MeanDose [Gy]	13.27648483	13.09004196	15
30	RP_HN_C05_345	C1	KBP345D2	ParotdCon-PTV	MeanDose [Gy]	17.6276355	12.08593027	15
30	RP_HN_C05_347	C1	KBP347D2	ParotdCon-PTV	MeanDose [Gy]	8.690954828	14.14824119	15
30	RP_HN_C05_356	C1	KBP356D2	ParotdCon-PTV	MeanDose [Gy]	9.367021136	13.99222589	15
30	RP_HN_C05_402	C1	KBP402D2	ParotdCon-PTV	MeanDose [Gy]	10.62072982	13.7029085	15
30	RP_HN_C05_434	C1	KBP434D2	ParotdCon-PTV	MeanDose [Gy]	9.527350758	13.95522675	15
30	RP_HN_C05_452	C1	KBP452D2	ParotdCon-PTV	MeanDose [Gy]	11.2752259	13.55187095	15
30	RP_HN_C05_529	C1	KBP529D2	ParotdCon-PTV	MeanDose [Gy]	16.08590426	12.4417144	15
30	RP_HN_C05_604	C1	KBP604D2	ParotdCon-PTV	MeanDose [Gy]	19.49747593	9.753786099	15
30	RP_HN_C05_623	C1	KBP623D2	ParotdCon-PTV	MeanDose [Gy]	12.52315812	13.26388659	15
30	RP_HN_C05_681	C1	KBP681D2	ParotdCon-PTV	MeanDose [Gy]	14.28048378	12.8583499	15
30	RP_HN_C05_682	C1	KBP682D2	ParotdCon-PTV	MeanDose [Gy]	12.81607352	13.19629073	15
30	RP_HN_C05_768	C1	KBP768D2	ParotdCon-PTV	MeanDose [Gy]	15.91807267	12.48044477	15
30	RP_HN_C05_771	C1	KBP771D2	ParotdCon-PTV	MeanDose [Gy]	10.3761298	13.75935466	15
30	RP_HN_C05_775	C1	KBP775D2	ParotdCon-PTV	MeanDose [Gy]	19.93124133	9.103138009	15
Average						12.53779	13.0452	15

Head and neck batch scoring:

- 53 metrics per patient
- 27 patients
- 3 iterations of plan scoring

4293 rows of data

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Normalize Plans to Max Score

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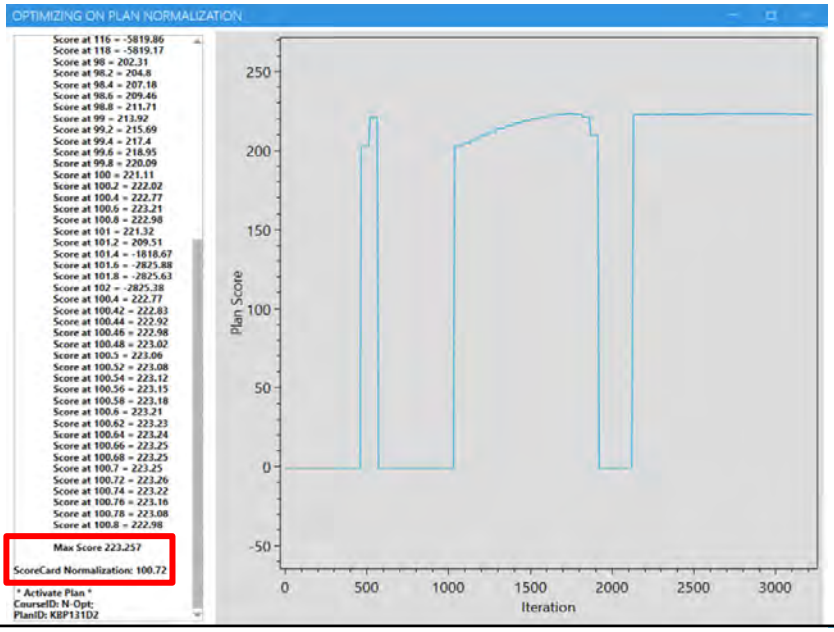
Normalize Plans to Max Score



Thousands of normalization iterations are used to find the max score.

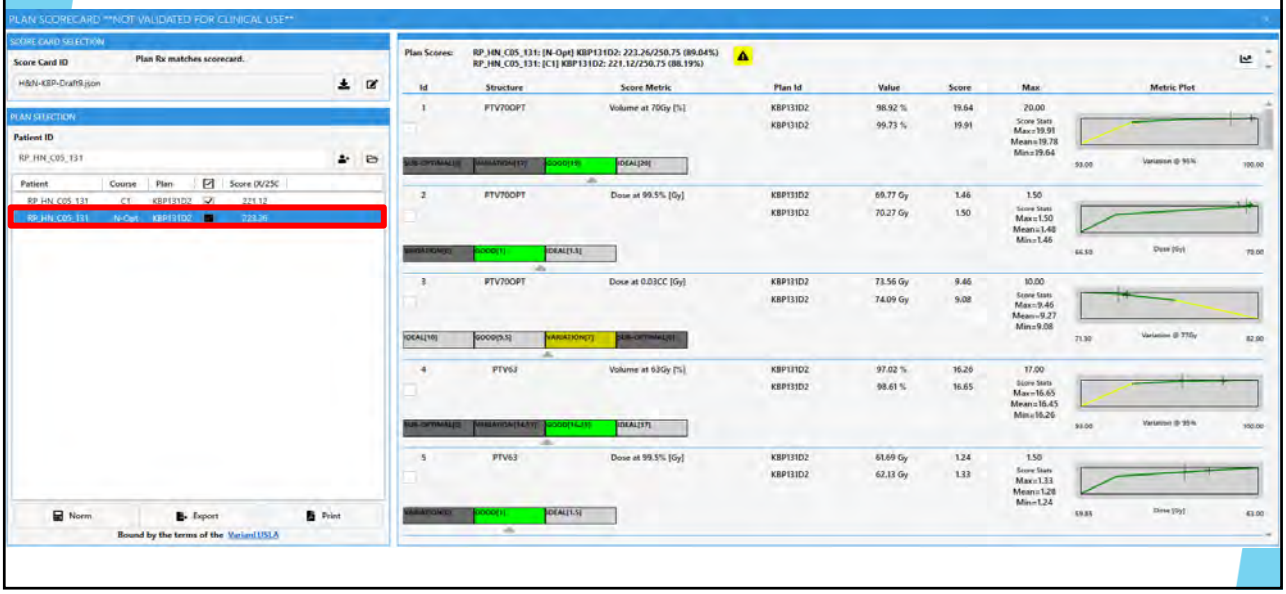
Optimized Normalization: 100.72%

New Score: 223.26 points

70

Normalize Plans to Max Score

Plan copied under new course with Max



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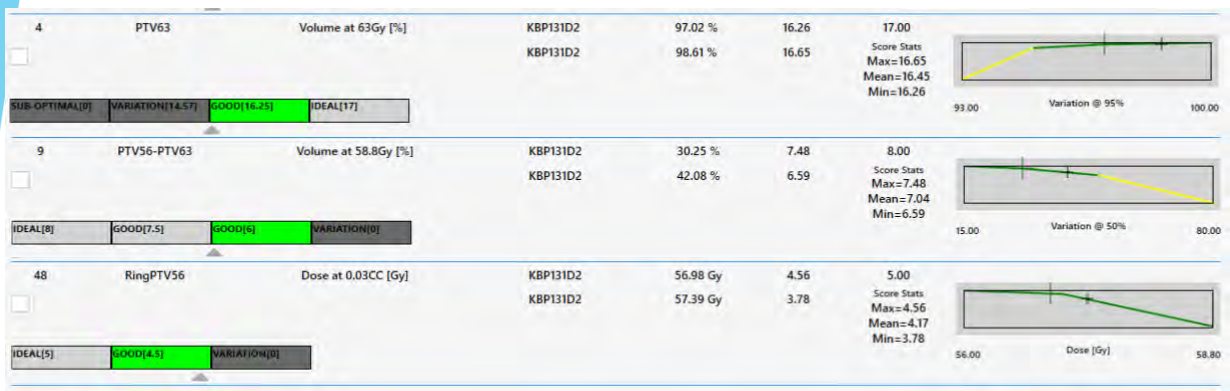
Normalize Plans to Max Score

Over 2 points gained (221.12 vs 223.6)

Bold Crosshair (Normalized Plan)

- Lower PTV63 Coverage
- Improved PTV 56 heterogeneity
- Improved PTV 56 conformality



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Future Developments: Works in Progress

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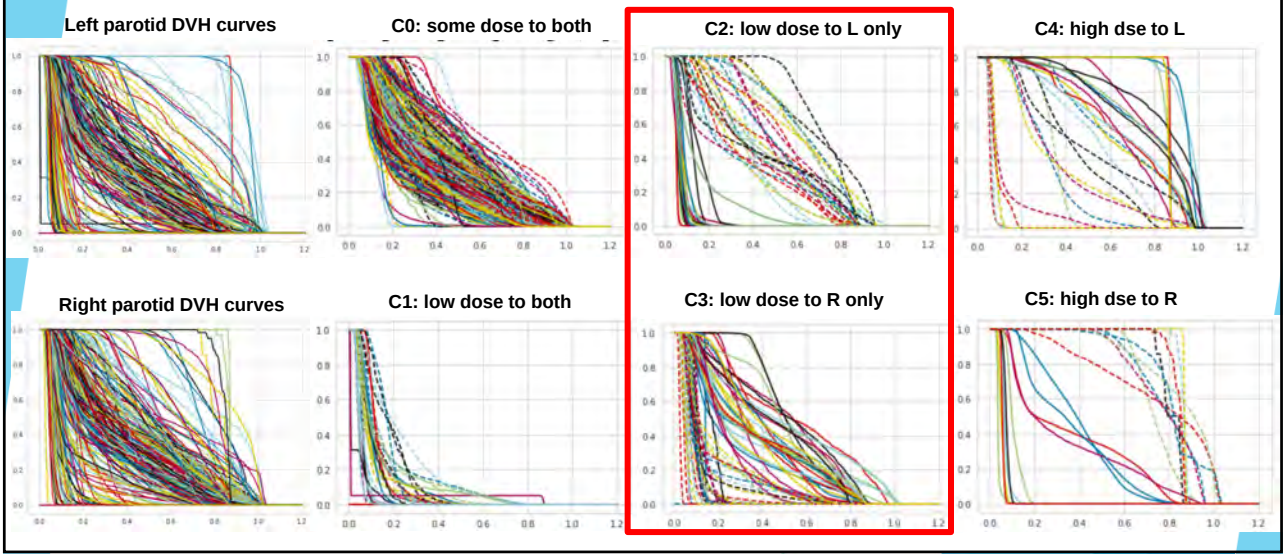
Additional Models

Unilateral only model with two PTV targets

Works in Progress



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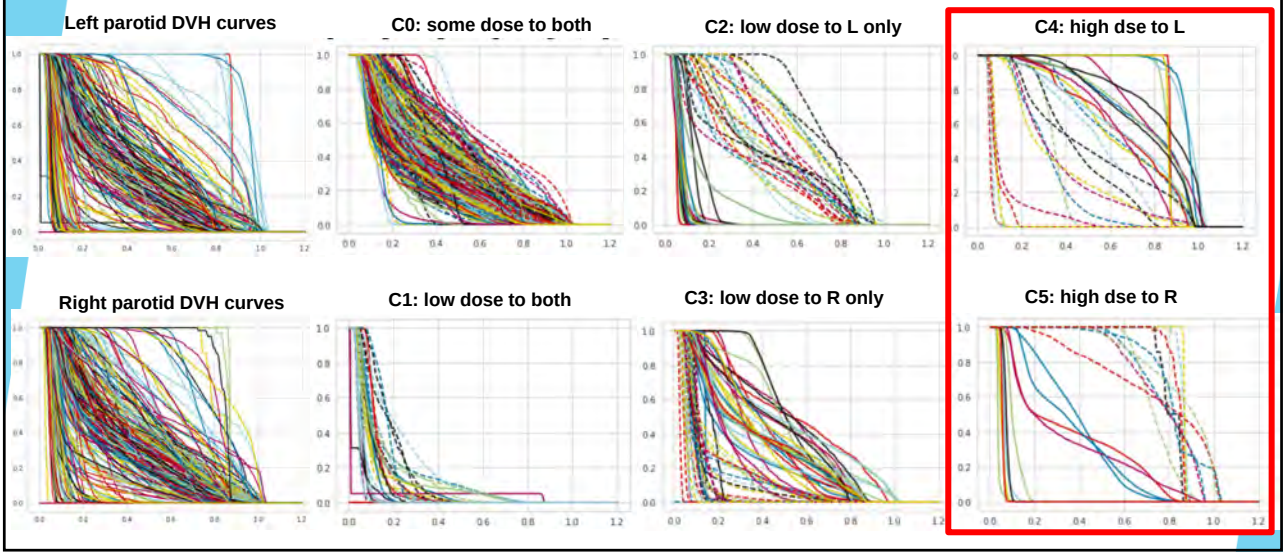
Additional Models

One parotid completely involved

Works in Progress



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3D Dose Prediction Research

Works in Progress

- Predict 3D dose maps from individual patient data
- Use a CNN model that combines the 3D patient images with the used field geometry
- Input data: CT, PTVs, OARs, field geometry, and prescription dose levels

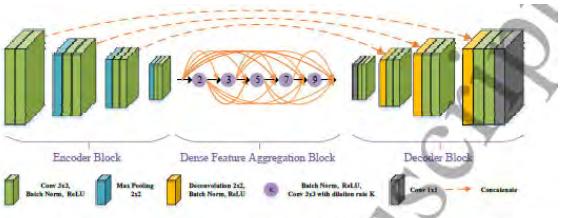

Figure 2. The schematic architecture of the DCNN, which consists of an encoder block, a dense feature aggregation block, and a decoder block. The numbers in the middle block represent the dilation rate of each convolution operation. The input is a four-channel feature image, and the output is the predicted dose image.

"Predicting Voxel-level Dose Distributions for Esophageal Radiotherapy Using Densely Connected Network with Dilated Convolutions", Zhang et al.,Phys. Med. Biol. July 2020 (Anhui Univ.)

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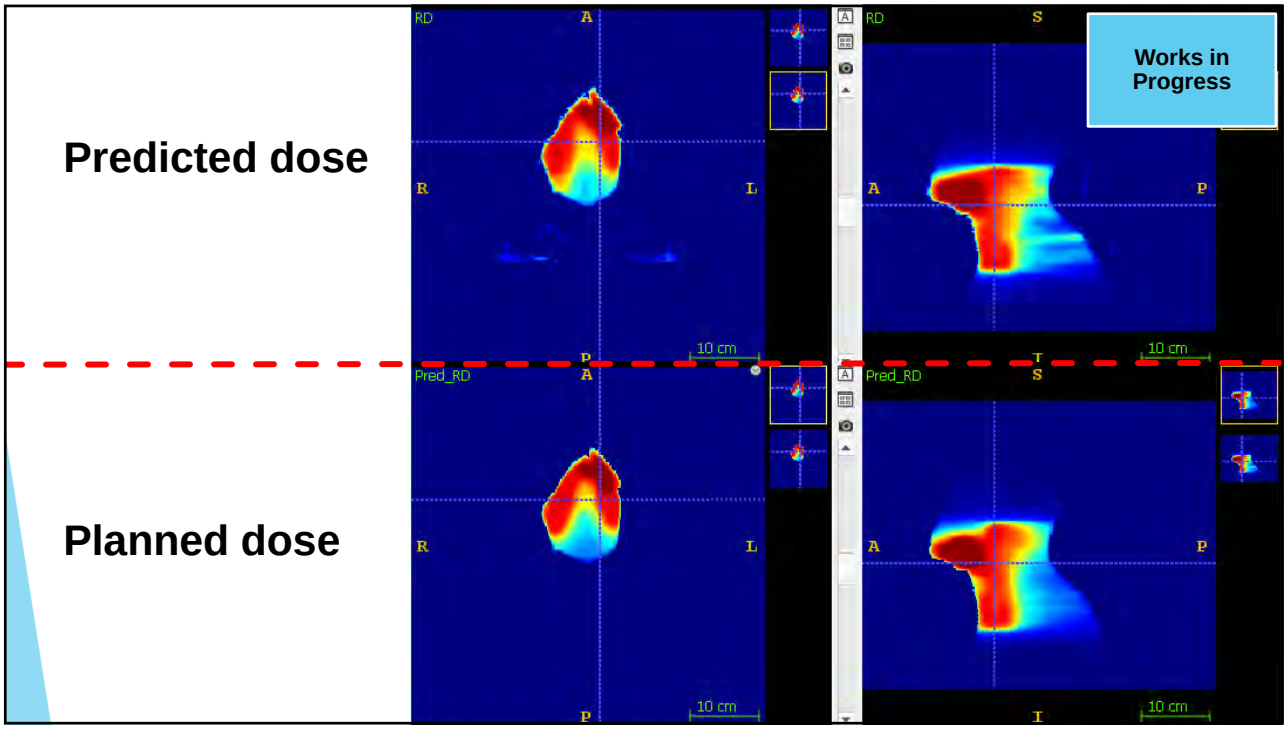
Predicted dose
Planned dose
Works in Progress
RD
Pred_RD
10 cm

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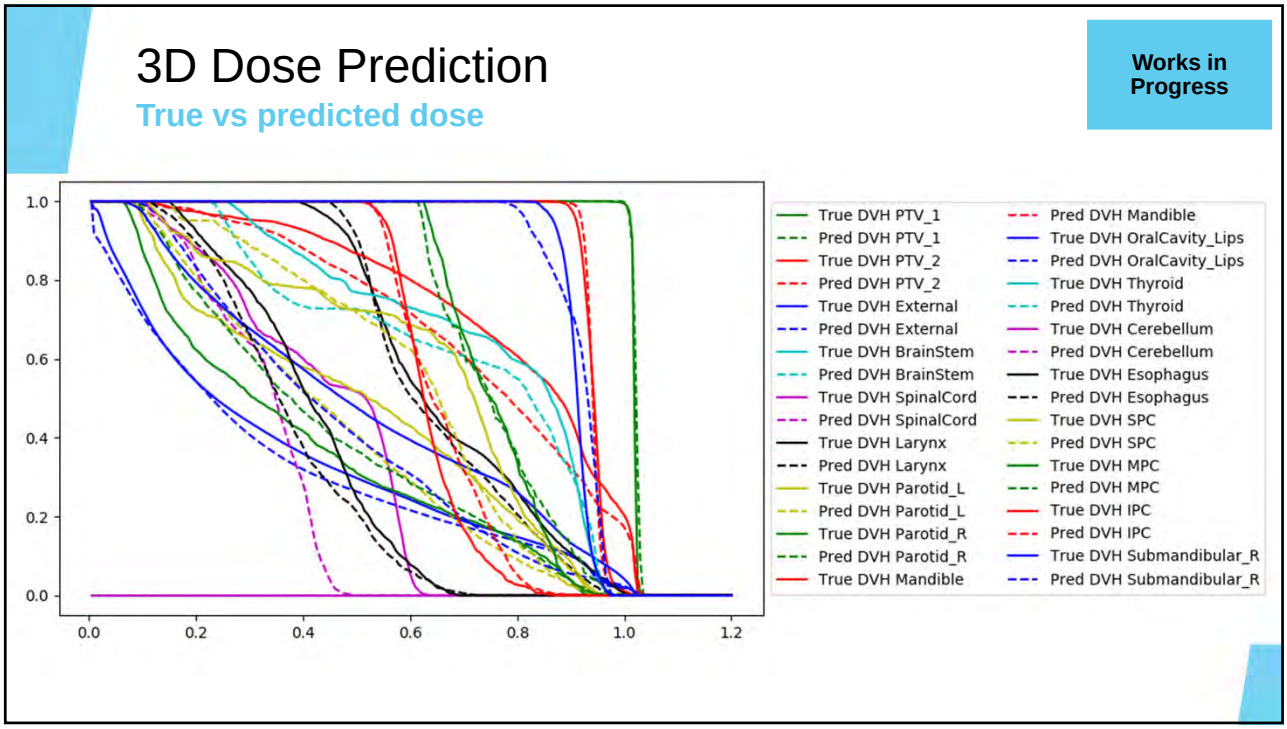
3D Dose Prediction
True vs predicted dose
Works in Progress
True DVH PTV_1
Pred DVH PTV_1
True DVH PTV_2
Pred DVH PTV_2
True DVH External
Pred DVH External
True DVH BrainStem
Pred DVH BrainStem
True DVH SpinalCord
Pred DVH SpinalCord
True DVH Larynx
Pred DVH Larynx
True DVH Parotid_L
Pred DVH Parotid_L
True DVH Parotid_R
Pred DVH Parotid_R
True DVH Mandible
Pred DVH Mandible
True DVH OralCavity_Lips
Pred DVH OralCavity_Lips
True DVH Thyroid
Pred DVH Thyroid
True DVH Cerebellum
Pred DVH Cerebellum
True DVH Esophagus
Pred DVH Esophagus
True DVH SPC
Pred DVH SPC
True DVH MPC
Pred DVH MPC
True DVH IPC
Pred DVH IPC
True DVH Submandibular_R
Pred DVH Submandibular_R

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3D Dose Prediction

Comparator for scorecard evaluation

Works in Progress

Scoring 3D generated doses quickly helps compare the performance of KBP models

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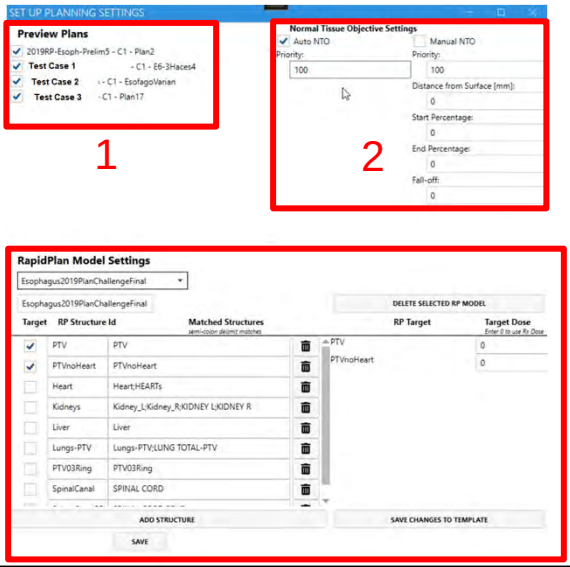
Score based plan reoptimization

Assign RapidPlan model to multiple cases

Works in Progress



1. List of plans automatically selected from batch scoring template.
2. Specific NTO settings can be set. Additional optimization settings such as convergence mode, aperture shape control, and intermediate dose calculations will also be added.
3. Select the RapidPlan model and match the structures to the model.

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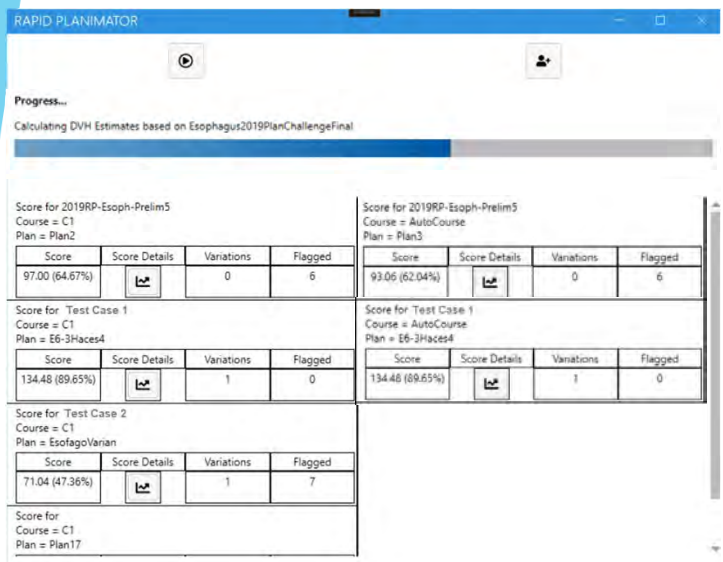
Score based plan reoptimization

Run RapidPlan optimization on multiple cases

Works in Progress



1. Calculates the DVHe from the selected model
2. Automatically proceeds with optimization, calculation, and plan scoring before starting the next case in the list
3. The newly optimized plans are then created under a new course
4. Plans can then be scored to evaluate any new changes that were made to a RapidPlan model
5. This process saves time when iteratively tuning models

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Resources

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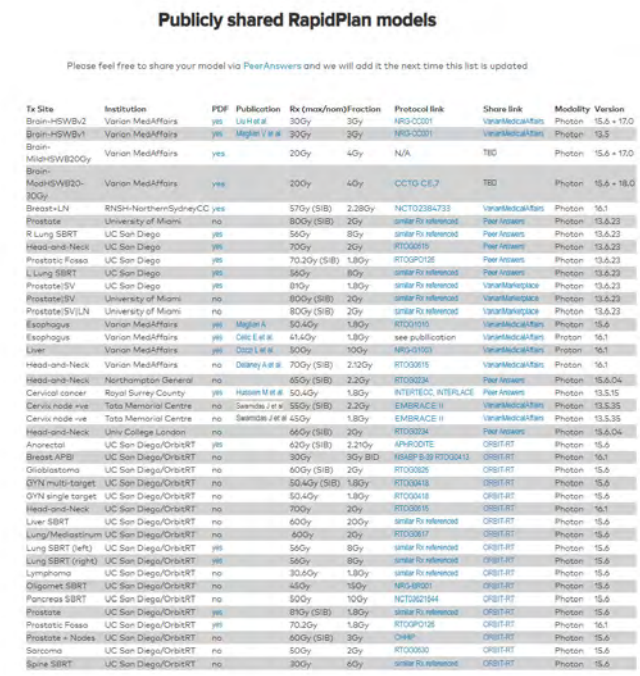
Resources

RapidPlan Model

List of publicly shared RapidPlan Models, eventually including the final head and neck model discussed in this presentation

https://medicalaffairs.varian.com/rapidplan-dir



Publicly shared RapidPlan models

Please feel free to share your model via PeerAnswers and we will add it the next time this list is updated

Tx Site	Institution	PDF	Publication	Rx (max/nom)	Fraction	Protocol link	Share link	Modality	Version
Brain-HSWBv2	Varian MedAffairs	yes	Liu H et al	30Gy	3Gy	NRG-CC001	VarianMedicalAffairs	Photon	15.6 + 17.0
Brain-HSWBv1	Varian MedAffairs	yes	Meglian V et al	30Gy	2Gy	NRG-CC001	VarianMedicalAffairs	Photon	13.5
Brain-MidHSWB20Gy	Varian MedAffairs	yes		20Gy	4Gy	N/A	TBD	Photon	15.6 + 17.0
Brain-ModHSWB20-30Gy	Varian MedAffairs	yes		20Gy	4Gy	CCTG CE.7	TBD	Photon	15.6 + 18.0
Breast+LN	RNSH-NorthernSydneyCC	yes		57Gy (SIB)	2.28Gy	NCT02384733	VarianMedicalAffairs	Photon	16.1
Prostate	University of Miami	no		80Gy (SIB)	2Gy	similar Rx referenced	Peer Answers	Photon	13.6.23
R Lung SBRT	UC San Diego	yes		56Gy	8Gy	similar Rx referenced	Peer Answers	Photon	13.6.23
Head-and-Neck	UC San Diego	yes		70Gy	2Gy	RTOG0615	Peer Answers	Photon	13.6.23
Prostatic Fossa	UC San Diego	yes		70.2Gy (SIB)	1.8Gy	RTOGP0126	Peer Answers	Photon	13.6.23
L Lung SBRT	UC San Diego	yes		56Gy	8Gy	similar Rx referenced	Peer Answers	Photon	13.6.23
Prostate/SV	UC San Diego	yes		81Gy	1.8Gy	similar Rx referenced	VarianMarketplace	Photon	13.6.23
Prostate/SV	University of Miami	no		80Gy (SIB)	2Gy	similar Rx referenced	VarianMarketplace	Photon	13.6.23
Prostate/SV/LN	University of Miami	no		80Gy (SIB)	2Gy	similar Rx referenced	VarianMarketplace	Photon	13.6.23
Esophagus	Varian MedAffairs	yes	Meglian A	50.4Gy	1.8Gy	RTOG1010	VarianMedicalAffairs	Photon	15.6
Esophagus	Varian MedAffairs	yes	Celic E et al.	41.4Gy	1.8Gy	see publication	VarianMedicalAffairs	Photon	16.1
Liver	Varian MedAffairs	yes	Dzizi L et al.	50Gy	10Gy	NRG-01003	VarianMedicalAffairs	Photon	16.1
Head-and-Neck	Varian MedAffairs	no	Delaney A et al.	70Gy (SIB)	2.12Gy	RTOG0615	VarianMedicalAffairs	Photon	16.1
Head-and-Neck	Northampton General	no		65Gy (SIB)	2.2Gy	RTOG0234	Peer Answers	Photon	15.6.04
Cervical cancer	Royal Surrey County	yes	Hussein M et al.	50.4Gy	1.8Gy	INTERTECC, INTERLACE	Peer Answers	Photon	13.5.15
Cervix node +ve	Tata Memorial Centre	no	Swamidas J et al.	55Gy (SIB)	2.2Gy	EMBRACE II	VarianMedicalAffairs	Photon	13.5.35
Cervix node -ve	Tata Memorial Centre	no	Swamidas J et al.	45Gy	1.8Gy	EMBRACE II	VarianMedicalAffairs	Photon	13.5.35
Head-and-Neck	Univ College London	no		66Gy (SIB)	2Gy	RTOG0234	Peer Answers	Photon	15.6.04
Anorectal	UC San Diego/OrbitRT	yes		62Gy (SIB)	2.21Gy	APHRODITE	ORBIT-RT	Photon	15.6
Breast APBI	UC San Diego/OrbitRT	no		30Gy	3Gy BID	NSABP B-39 RTOG0413	ORBIT-RT	Photon	16.1
Glioblastoma	UC San Diego/OrbitRT	no		60Gy (SIB)	2Gy	RTOG0825	ORBIT-RT	Photon	15.6
GYN multi-target	UC San Diego/OrbitRT	no		50.4Gy (SIB)	1.8Gy	RTOG0418	ORBIT-RT	Photon	15.6
GYN single target	UC San Diego/OrbitRT	no		50.4Gy	1.8Gy	RTOG0418	ORBIT-RT	Photon	15.6
Head-and-Neck	UC San Diego/OrbitRT	no		70Gy	2Gy	RTOG0615	ORBIT-RT	Photon	16.1
Liver SBRT	UC San Diego/OrbitRT	no		60Gy	20Gy	similar Rx referenced	ORBIT-RT	Photon	15.6
Lung/Mediastinum	UC San Diego/OrbitRT	no		60Gy	20Gy	RTOG0617	ORBIT-RT	Photon	15.6
Lung SBRT (left)	UC San Diego/OrbitRT	no		56Gy	8Gy	similar Rx referenced	ORBIT-RT	Photon	15.6
Lung SBRT (right)	UC San Diego/OrbitRT	yes		56Gy	8Gy	similar Rx referenced	ORBIT-RT	Photon	15.6
Lymphoma	UC San Diego/OrbitRT	no		30.6Gy	1.8Gy	similar Rx referenced	ORBIT-RT	Photon	15.6
Oligomet SBRT	UC San Diego/OrbitRT	no		45Gy	15Gy	NRG-BR001	ORBIT-RT	Photon	15.6
Pancreas SBRT	UC San Diego/OrbitRT	no		50Gy	10Gy	NCT03021044	ORBIT-RT	Photon	15.6
Prostate	UC San Diego/OrbitRT	yes		81Gy (SIB)	1.8Gy	similar Rx referenced	ORBIT-RT	Photon	15.6
Prostatic Fossa	UC San Diego/OrbitRT	yes		70.2Gy	1.8Gy	RTOGP0126	ORBIT-RT	Photon	16.1
Prostate + Nodes	UC San Diego/OrbitRT	no		60Gy (SIB)	3Gy	CHHP	ORBIT-RT	Photon	15.6
Sarcoma	UC San Diego/OrbitRT	no		50Gy	2Gy	RTOG0630	ORBIT-RT	Photon	15.6
Spine SBRT	UC San Diego/OrbitRT	no		30Gy	6Gy	similar Rx referenced	ORBIT-RT	Photon	15.6

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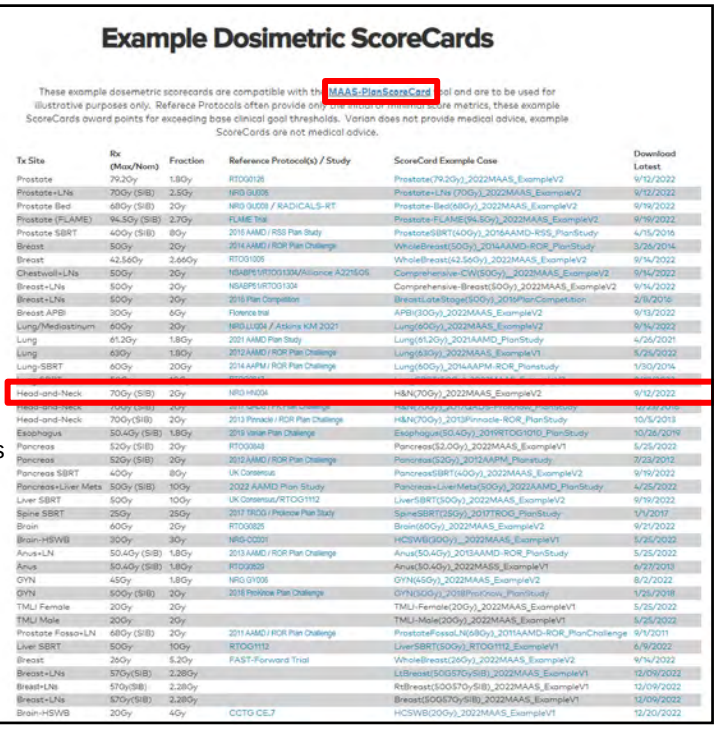
Resources

Scorecards

List of publicly shared scorecards, eventually including the final head and neck scorecard shown in this presentation

https://medicalaffairs.varian.com/dose-scorecards



Example Dosimetric ScoreCards

These example dosemetric scorecards are compatible with the MAAS-PlanScoreCard tool and are to be used for illustrative purposes only. Reference Protocols often provide only one critical or minimal score metrics, these example ScoreCards award points for exceeding base clinical goal thresholds. Varian does not provide medical advice, example ScoreCards are not medical advice.

Tx Site	Rx (Max/Nom)	Fraction	Reference Protocol(s) / Study	ScoreCard Example Case	Download Latest
Prostate	79.2Gy	1.8Gy	RTOG0126	Prostate(79.2Gy)_2022MAAS_ExampleV2	9/12/2022
Prostate+LNs	70Gy (SIB)	2.5Gy	NRG GU009	Prostate+LNs (70Gy)_2022MAAS_ExampleV2	9/12/2022
Prostate Bed	68Gy (SIB)	2Gy	NRG GU009 / RADICALS-RT	Prostate-Bed(68Gy)_2022MAAS_ExampleV2	9/19/2022
Prostate (FLAME)	94.5Gy (SIB)	2.7Gy	FLAME Trial	Prostate-FLAME(94.5Gy)_2022MAAS_ExampleV2	9/19/2022
Prostate SBRT	40Gy (SIB)	8Gy	2016 AAMD / RSS Plan Study	ProstateSBRT(40Gy)_2016AAMD-RSS_PlanStudy	4/15/2016
Breast	50Gy	2Gy	2014 AAMD / ROR Plan Challenge	WholeBreast(50Gy)_2014AAMD-ROR_PlanStudy	3/26/2014
Breast	42.56Gy	2.66Gy	RTOG1005	WholeBreast(42.56Gy)_2022MAAS_ExampleV2	9/14/2022
Chestwall+LNs	50Gy	2Gy	NSABP51/RTOG1304/Alliance A221505	Comprehensive-CW(50Gy)_2022MAAS_ExampleV2	9/14/2022
Breast+LNs	50Gy	2Gy	NSABP51/RTOG1304	Comprehensive-Breast(50Gy)_2022MAAS_ExampleV2	9/14/2022
Breast+LNs	50Gy	2Gy	2016 Plan Competition	BreastLateStage(50Gy)_2016PlanCompetition	2/11/2016
Breast APBI	30Gy	6Gy	Florence trial	APBI(30Gy)_2022MAAS_ExampleV2	9/13/2022
Lung/Mediastinum	60Gy	2Gy	NRG LU04 / Atkins KM 2021	Lung(60Gy)_2022MAAS_ExampleV2	9/14/2022
Lung	61.2Gy	1.8Gy	2021 AAMD Plan Study	Lung(61.2Gy)_2021AAMD_PlanStudy	4/26/2021
Lung	63Gy	1.8Gy	2012 AAMD / ROR Plan Challenge	Lung(63Gy)_2022MAAS_ExampleV1	5/25/2022
Lung-SBRT	60Gy	20Gy	2014 AAPM / ROR Plan Challenge	Lung(60Gy)_2014AAPM-ROR_PlanStudy	1/30/2014
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Head-and-Neck	70Gy (SIB)	2Gy	NRG HN004	H&N(70Gy)_2022MAAS_ExampleV2	9/12/2022
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Head-and-Neck	70Gy(SIB)	2Gy	2013 Pinnacle / ROR Plan Challenge	H&N(70Gy)_2013Pinnacle-ROR_PlanStudy	10/5/2013
Esophagus	50.4Gy (SIB)	1.8Gy	2019 Varian Plan Challenge	Esophagus(50.4Gy)_2019RTOG1010_PlanStudy	10/26/2019
Pancreas	52Gy (SIB)	2Gy	RTOG0848	Pancreas(52.0Gy)_2022MAAS_ExampleV1	5/25/2022
Pancreas	52Gy (SIB)	2Gy	2012 AAMD / ROR Plan Challenge	Pancreas(52Gy)_2012AAPM_PlanStudy	7/23/2012
Pancreas SBRT	40Gy	8Gy	UK Consensus	PancreasSBRT(40Gy)_2022MAAS_ExampleV2	9/19/2022
Pancreas+Liver Mets	50Gy (SIB)	10Gy	2022 AAMD Plan Study	Pancreas+LiverMets(50Gy)_2022AAMD_PlanStudy	4/25/2022
Liver SBRT	50Gy	10Gy	UK Consensus/RTOG1112	LiverSBRT(50Gy)_2022MAAS_ExampleV2	9/19/2022
Spine SBRT	25Gy	25Gy	2017 TROG / Polence Plan Study	SpineSBRT(25Gy)_2017TROG_PlanStudy	1/1/2017
Brain	60Gy	2Gy	RTOG0825	Brain(60Gy)_2022MAAS_ExampleV2	9/21/2022
Brain-HSWB	30Gy	3Gy	NRG-CC001	HCSWB(30Gy)_2022MAAS_ExampleV1	5/25/2022
Anus+LN	50.4Gy (SIB)	1.8Gy	2013 AAMD / ROR Plan Challenge	Anus(50.4Gy)_2013AAMD-ROR_PlanStudy	5/25/2022
Anus	50.4Gy (SIB)	1.8Gy	RTOG0529	Anus(50.4Gy)_2022MASS_ExampleV1	6/27/2013
GYN	45Gy	1.8Gy	NRG GY006	GYN(45Gy)_2022MAAS_ExampleV2	8/2/2022
GYN	50Gy (SIB)	2Gy	2018 ProKnow Plan Challenge	GYN(50Gy)_2018ProKnow_PlanStudy	1/25/2018
TMLI Female	20Gy	2Gy		TMLI-Female(20Gy)_2022MAAS_ExampleV1	5/25/2022
TMLI Male	20Gy	2Gy		TMLI-Male(20Gy)_2022MAAS_ExampleV1	5/25/2022
Prostate Fossa+LN	68Gy (SIB)	2Gy	2011 AAMD / ROR Plan Challenge	ProstateFossaLN(68Gy)_2011AAMD-ROR_PlanChallenge	9/1/2011
Liver SBRT	50Gy	10Gy	RTOG1112	LiverSBRT(50Gy)_RTOG1112_ExampleV1	6/9/2022
Breast	26Gy	5.2Gy	FAST-Forward Trial	WholeBreast(26Gy)_2022MAAS_ExampleV2	9/14/2022
Breast+LNs	57Gy(SIB)	2.28Gy		LtBreast(50G57GySIB)_2022MAAS_ExampleV1	12/09/2022
Breast+LNs	57Gy(SIB)	2.28Gy		RtBreast(50G57GySIB)_2022MAAS_ExampleV1	12/09/2022
Breast+LNs	57Gy(SIB)	2.28Gy		Breast(50G57GySIB)_2022MAAS_ExampleV1	12/09/2022
Brain-HSWB	20Gy	4Gy	CCTG CE.7	HCSWB(20Gy)_2022MAAS_ExampleV1	12/20/2022

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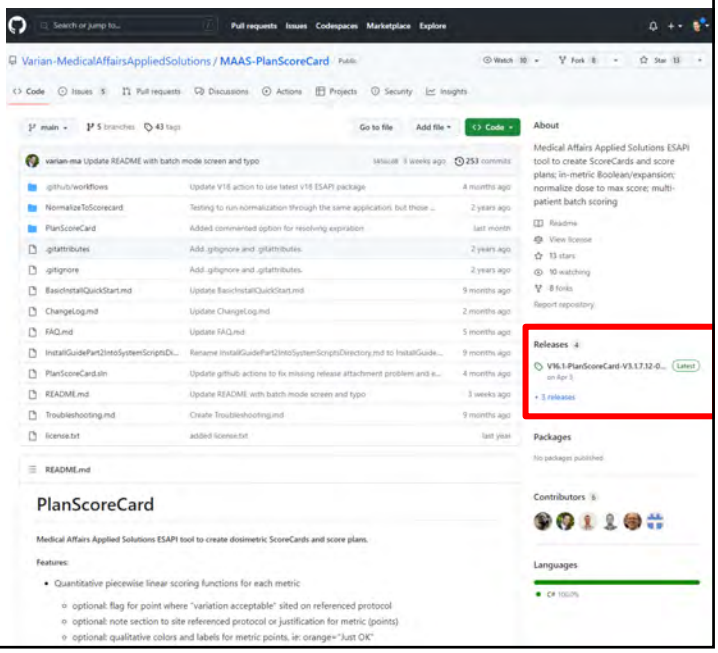
Resources

Scorecard Tool

Open-source, ESAPI plan scorecard tool that was used in this project. Create your own dosimetric scorecards and score plans. Instructions for download and usage are available.

https://github.com/Varian-MedicalAffairsAppliedSolutions/MAAS-PlanScoreCard



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Acknowledgments

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Questions?

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