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Varian MCO – Benefits in Head and Neck Planning

Dominic DiCostanzo, MS, DABR
November 3, 2017

Varian Medical Systems
Eclipse Fair Balance Safety Statement

Intended Use Summary

- The Eclipse Treatment Planning System (Eclipse TPS) is used to plan radiotherapy treatments for patients with malignant or benign diseases. Eclipse TPS is used to plan external beam irradiation with photon, electron and proton beams, as well as for brachytherapy treatments. In addition, the Eclipse Proton Eye algorithm is specifically indicated for planning proton treatment of neoplasms of the eye. Eclipse should only be used by qualified medical professionals.

Important Safety Information

- Radiation treatments may cause side effects, which, in some cases, may be serious. Severity can vary depending on the part of the body being treated. Side effects are related to the type of treatments delivered and should be discussed between the clinician and the patient.

Medical Advice Disclaimer

- Varian as a medical device manufacturer cannot and does not recommend specific treatment approaches. Individual treatment results may vary.

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Disclosures

- This presentation reflects my own opinions and not those of Varian or The Ohio State University
- Conflicts of interest:
  - Ohio State has a services agreement with Varian
  - Ohio State has an Institutional Space Use agreement with Varian
  - I have received no honorarium or compensation for this presentation
- Varian software and versions being discussed:
  - All comments are based upon experience with a pre-clinical release of v15.5 of Eclipse
  - Original plans were developed in v13.6 of Eclipse

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The New OSU James Cancer Hospital & Radiation Oncology Department

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Radiation Oncology Department

- 24 Clinical Faculty Physicians – 3 Outreach Physicians
- 17 Faculty & Staff Physicists, 13 Dosimetrists, 4 RadOnc IT staff, 2 Linac Engineers, 1 Machinist
- Residency Programs – Rad Onc & Physics
- Therapist Training Program
- 12 Laboratory Based Principle Investigators
- New James: 80,000 sq ft department (~180 patients EBRT/ day)
  - 7 TrueBeams (2 Edge, 1 STx, 4 Short Stand Standard)
  - 1 Gamma Knife Perfexion
  - 1 Brachytherapy suite with MR integration
  - 2 CT Sims, 1 PET/CT Sim, 1 MRI Sim
  - IORT – Mobetron 2nd Generation
- Stephanie Spielman Comprehensive Breast Center (40-50 EBRT per day)
  - 2 TrueBeams
  - 1 CT Sim

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Radiation Oncology Patients on Treatment

OSU Radiation Oncology treats 225-250 patients per day, making it one of the TOP 5 radiation oncology centers in the US for photon treated patient volume.

- High GI and Thoracic volumes, combined 40-60 patients on treatment at any given time. Tertiary care referral center for esophageal and pancreas cancer
- **H&N 50-70 patients on treatment at any given time**
- IORT (H&N, GI, sarcoma, Gyn)
- 483 Brachytherapy procedures (Gyn, prostate, sarcoma, H&N, GI) FY16
- 225 Gamma Knife procedures in 2015
- 1,375 Linac Based SRS/SRT, particularly for lung and liver SBRT but also brain, and spine
- 45,695 EBRT treatments for FY16
- 527 CNS patients (including primary and Mets)
- Robust pediatric program

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Agenda

Overview of Multicriteria Optimiation

Overview of Clinical MCO Workflow

Methods for Evaluation

Tradeoff Exploration

Results of MCO Navigation on Clinical HN Plans

Future Directions

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What is Multicriteria Optimization (MCO)?

- Multicriteria optimization systems rely on a database of plans which lie (or are near) the “Pareto optimal” frontier, or surface
- “Pareto optimal” means one cannot improve in one objective, with degrading at least one other.

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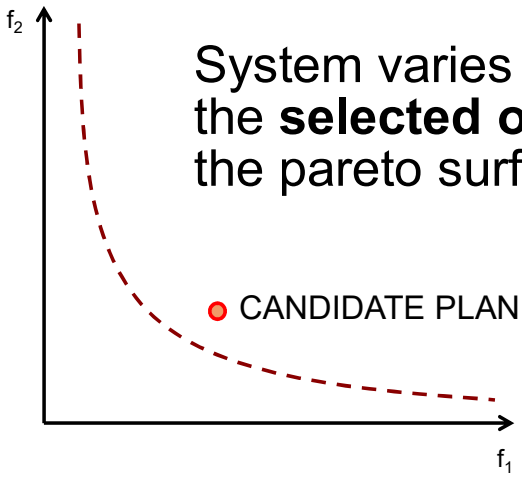
Trade Off Plan Collection Algorithm in Eclipse:
Epsilon Constraint Method



System varies the parameters of the **selected objectives** to fill out the pareto surface

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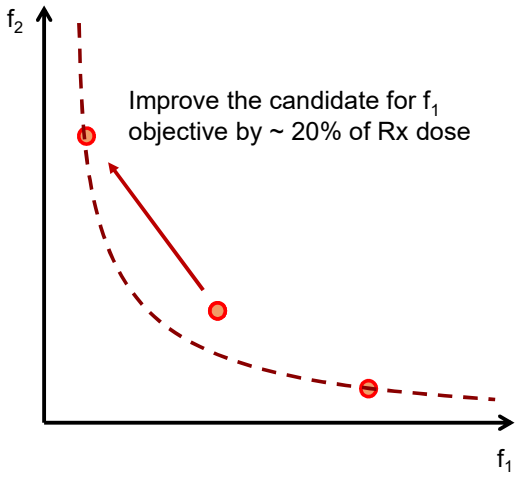

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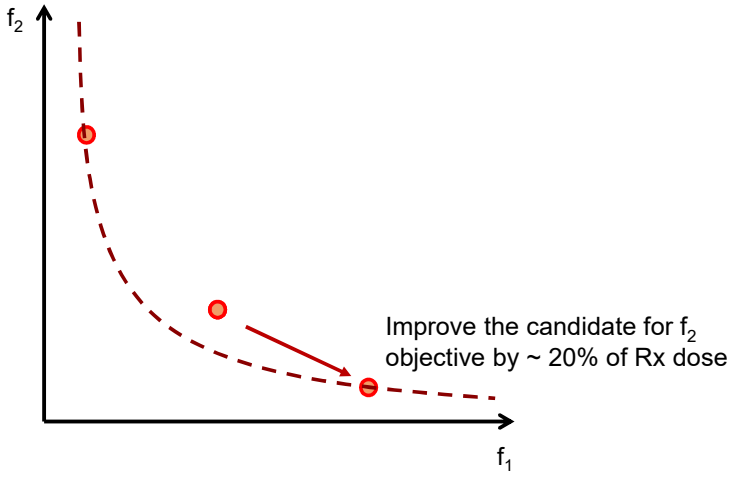

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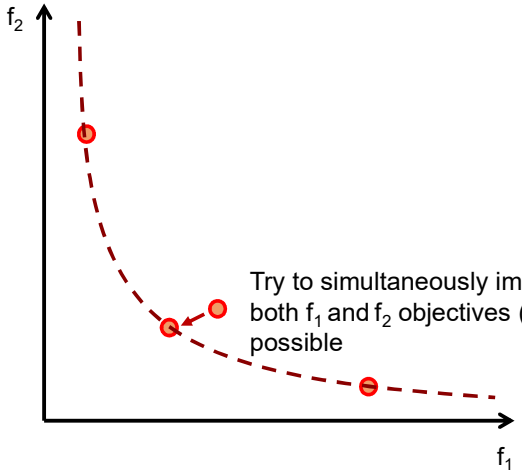

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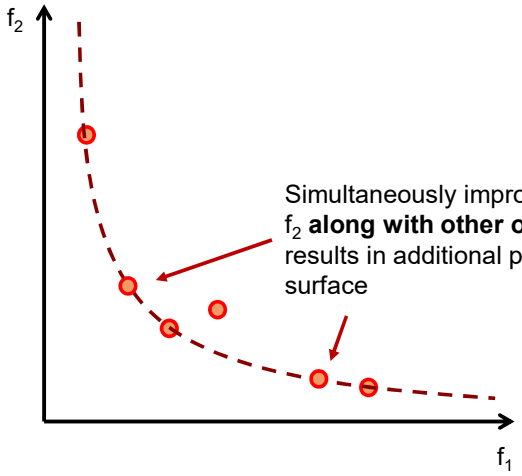

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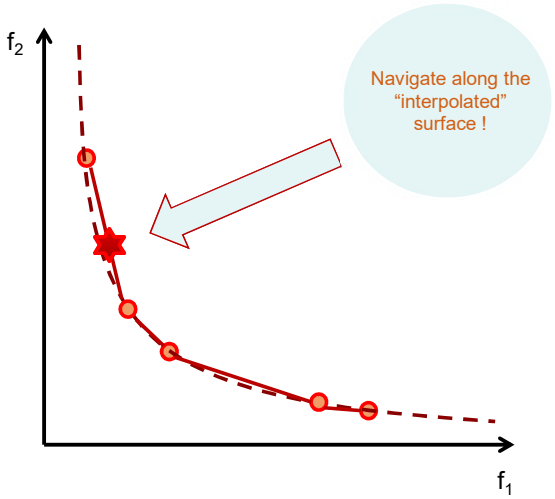

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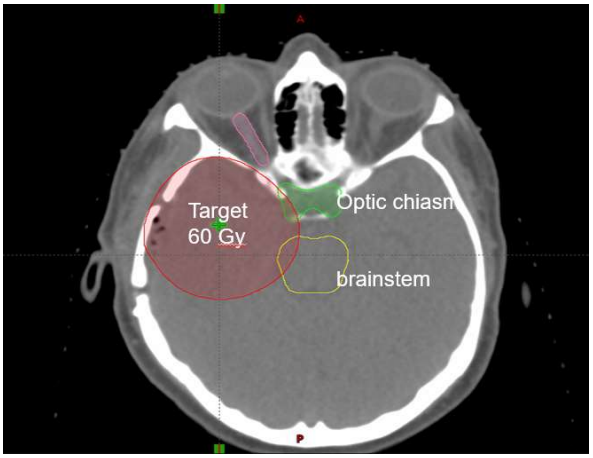
MCO Plan Database – **WHY GPU NEEDED?**

- In Eclipse v15.5, plan generation algorithm creates ~3 plans for EVERY objective selected
  - one set of plans improving ONLY the selected objective
  - one set of plans improving all objectives EXCEPT original
  - one set of plans improving a few combinations of objectives TOGETHER
- Brain with 10 objectives → ~30 plans
  - Algorithm based on Epsilon Constraint technique (well known technique for multiobjective optimization)



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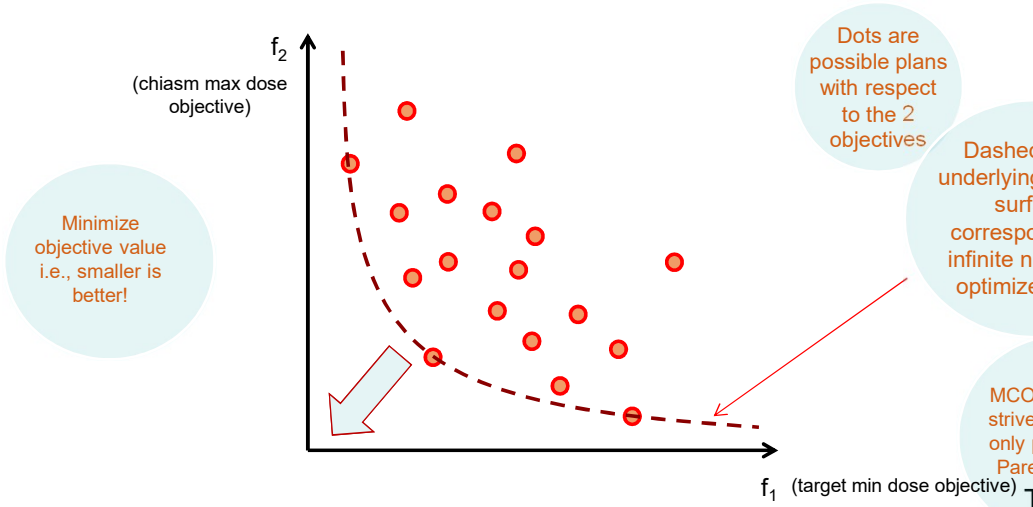
Pareto frontier: two objectives, f_1 and f_2



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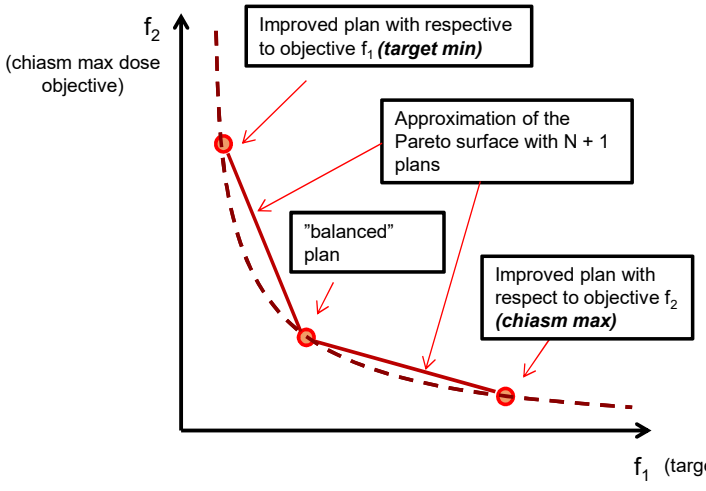
Multicriteria Optimization: How is the Pareto front used?



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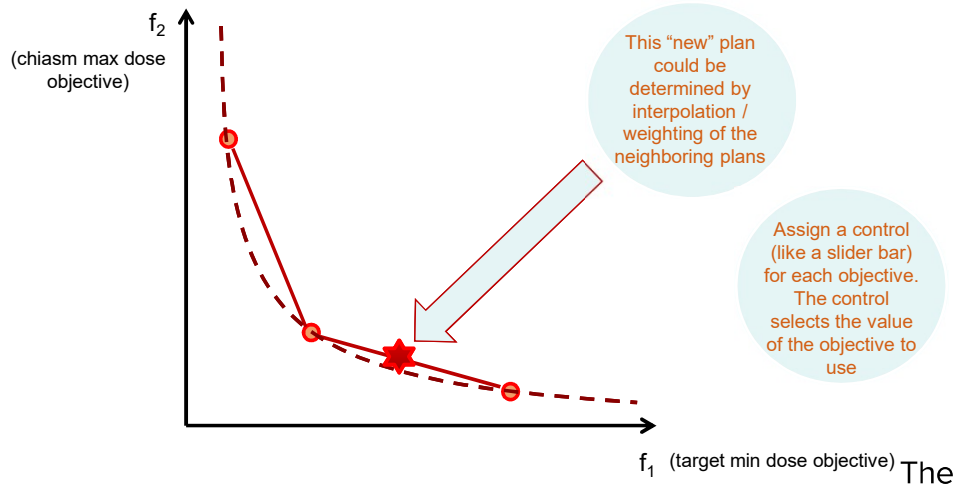

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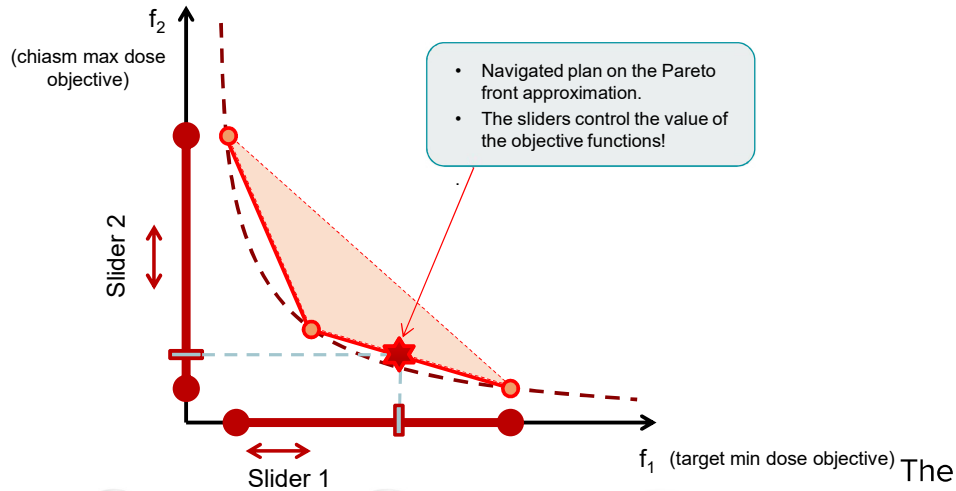

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Overview of Clinical MCO Workflow

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Overview of Clinical MCO Workflow

- Begin with standard IMRT or VMAT plan
  - Manual objectives
  - RapidPlan
- Optimization is completed but optimizer is not exited, “Explore Tradeoffs” is selected
- Explore Tradeoffs
  - Upper, Lower, gEUD, Mean, Line, or Target Homogeneity can be selected

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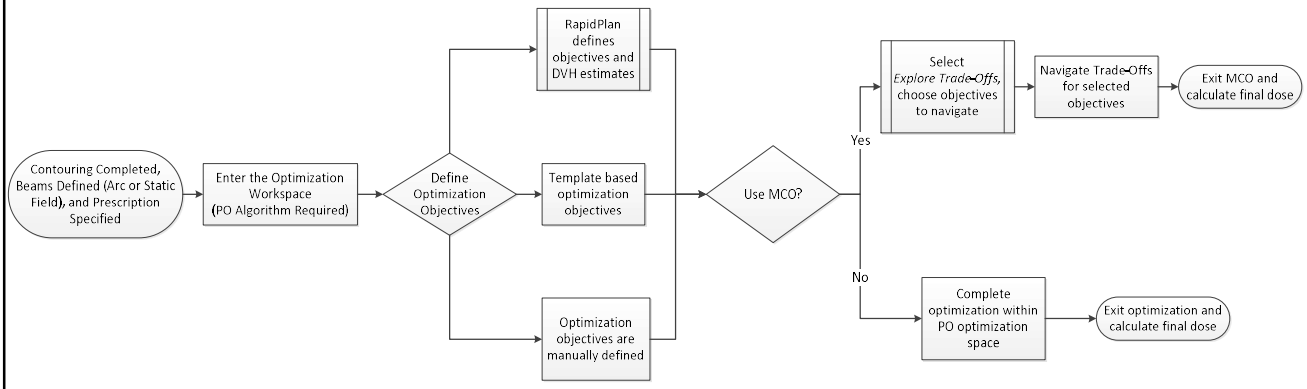
Overview of Clinical MCO Workflow



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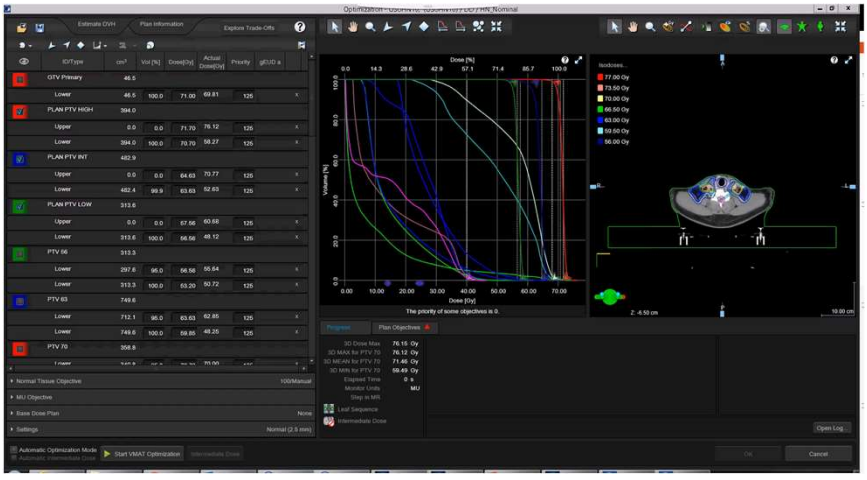
Overview of Clinical MCO Workflow



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Methods of Evaluation

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Methods of Evaluation – Initial Setup of TPS

- Treatment machines exported from clinical treatment planning system
  - Machine configurations for both HD MLC and SD MLC
  - Beam models
  - MLC dosimetric parameters: Transmission and DLG
- Clinical beam models were reconfigured in v15.5 Eclipse
- Newly configured beam data (v15.5) was validated against previously calculated plans (v13.6)

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Methods of Evaluation – Setup of Patients

- 11 HN patients were selected from 5 different physicians with identical:
  - Prescriptions
  - Coverage requirements
  - OAR tolerances
  - Delivery was RapidArc with 2-3 arcs
- Patient exported, anonymized, and imported into non-clinical Eclipse
  - Planning CT, Structure Set, Plan, Dose and Original Optimization Objectives

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Methods of Evaluation – Setup of Patients

- Copies of the clinical plans were made and recalculated with v15.5 algorithms
  - AcurosXB was used for all clinical treatment plans and in the v15.5 reconfiguration
- Normalization was set to equal original plan normalization
- DVH and dose distribution compared to ensure no significant differences

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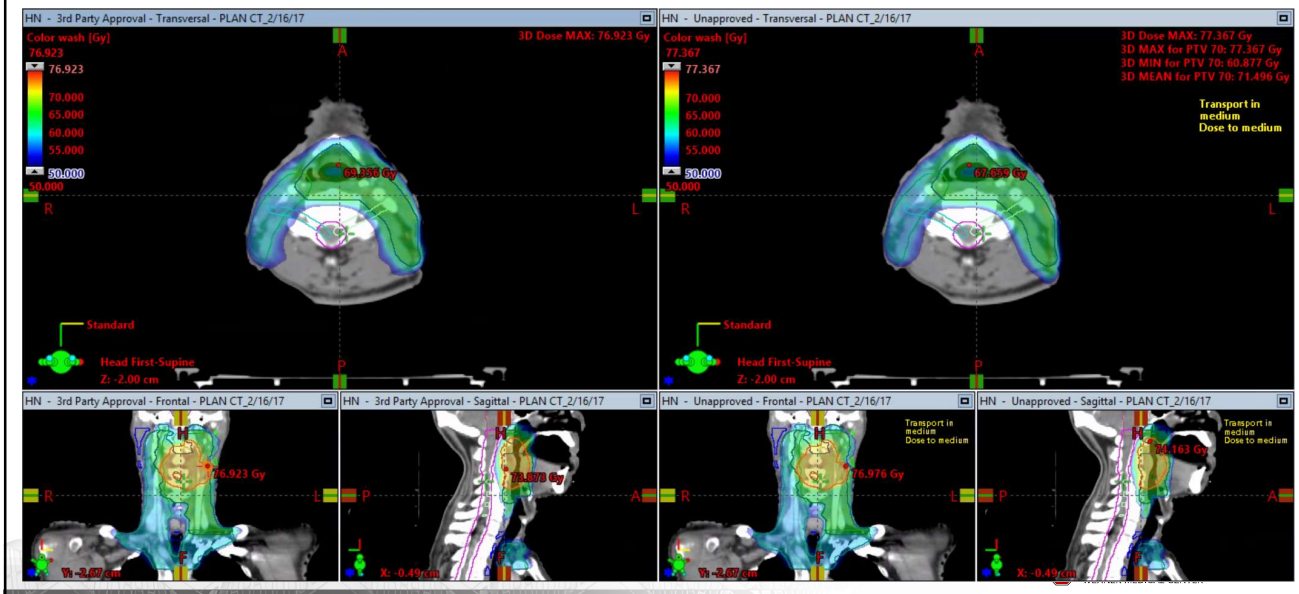
Methods of Evaluation – Setup of Patients



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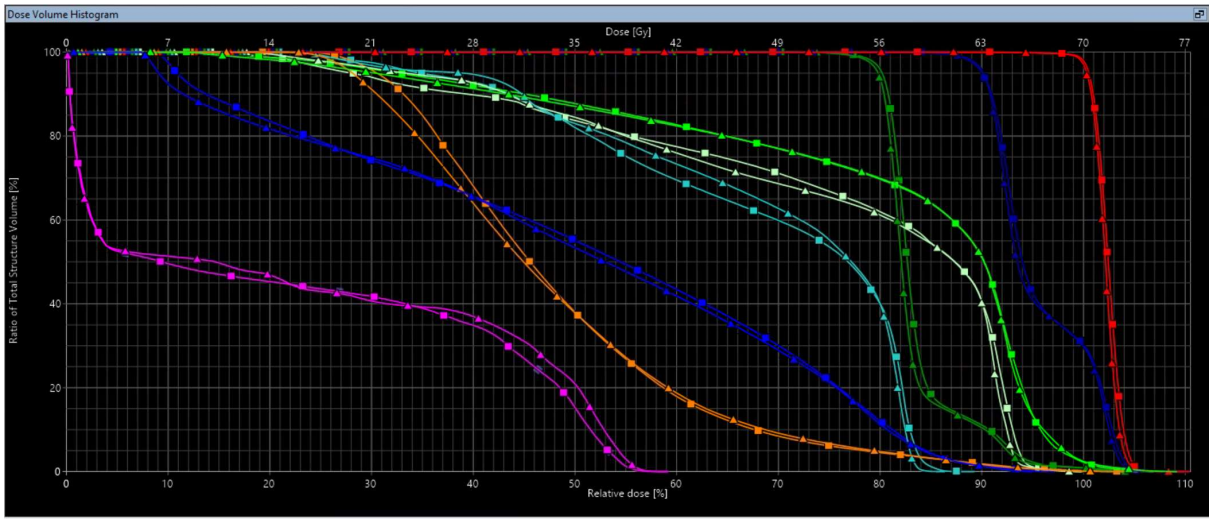
Methods of Evaluation – Setup of Patients



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Methods of Evaluation – Setup of Patients

Show DVH	Structure	Course	Min Dose [%]	Max Dose [%]	Mean Dose [%]
	Spinal Cord	C1	0.1	59.1	21.8
	Spinal Cord	DD	0.1	59.3	22.6
	Parotid R	C1	8.6	97.2	51.2
	Parotid R	DD	7.3	95.1	50.3
	Parotid L	C1	13.2	107.0	80.3
	Parotid L	DD	11.4	109.3	80.0
	PTV 70	C1	89.5	109.9	102.4
	PTV 70	DD	87.0	110.5	102.1
	PTV 63	C1	76.7	109.9	95.9
	PTV 63	DD	76.4	110.5	95.6
	PTV 56	C1	68.4	105.4	83.9
	PTV 56	DD	66.7	104.3	83.3
	Oral Cavity	C1	20.9	105.3	48.5
	Oral Cavity	DD	20.8	104.3	47.8
	Brachial Plex R	C1	20.5	89.3	68.4
	Brachial Plex R	DD	21.1	86.5	69.2
	Brachial Plex L	C1	14.8	100.1	76.0
	Brachial Plex L	DD	17.5	100.3	75.9

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Methods of Evaluation – Setup of Patients

- Plan copied again to create optimization plan
- Optimization objectives used clinically applied to plan in the PO optimization workspace
- Final dose calculated and compared to clinical plan
- Plan copied to use in Tradeoff Exploration

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Tradeoff Exploration

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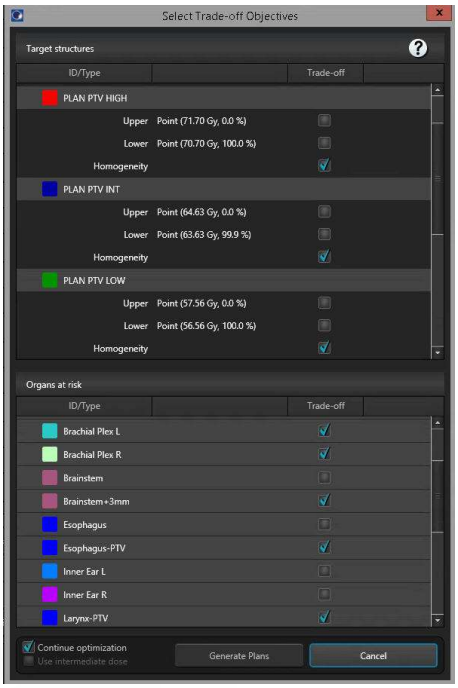
Tradeoff Exploration

- 11 total structures were selected for MCO navigation:
  - 3 target levels
    - 70Gy
    - 63Gy
    - 56Gy
  - 8 OARs
    - Brainstem
    - Left and Right Brachial Plexus
    - Left and Right Parotid Gland
    - Larynx
    - Esophagus
    - Spinal Cord



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Tradeoff Exploration – Selecting Objectives to Navigate

- Targets:
  - Target homogeneity selected for navigation
- OARs:
  - Upper objective navigated for OARs that have max dose constraint
  - Mean objective was navigated for OARs that have mean dose constraint

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Tradeoff Exploration – Navigation

- Targets:
  - Restricted the degradation of homogeneity before navigating on OAR sliders
- OARs:
  - Goal was to balance the reduction in dose across all structures
  - Sliders adjusted to meet all individual OAR objectives using real time dose estimation

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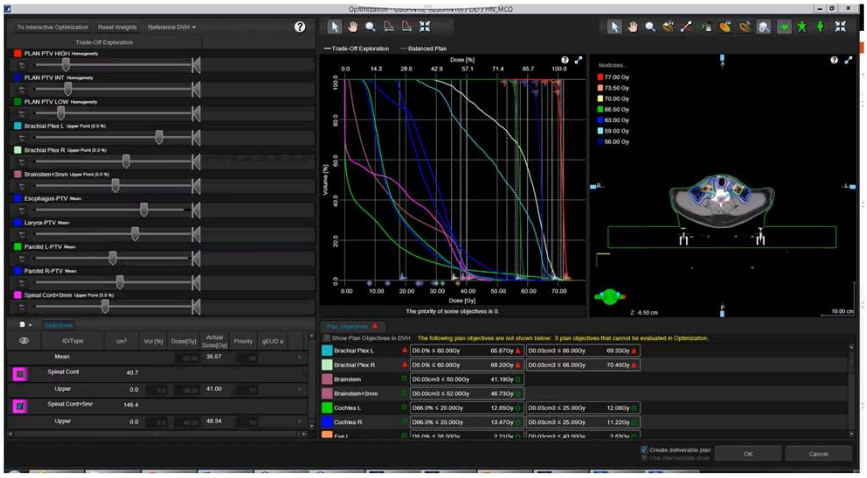
Tradeoff Exploration – Navigation



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Tradeoff Exploration – Plan Comparison

- MCO navigated plan was converted to a deliverable plan and final dose calculated
- Plan was normalized the same as the clinical plan
- DVH comparison was used to determine if navigation was successful
- If plan was deemed unacceptable, MCO navigation was repeated until target coverage and max point dose were acceptable

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Results of MCO Navigation on Clinical HN Plans

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Results of MCO Navigation – Targets

- 11 HN patients were selected from 5 different physicians with identical:
  - Prescriptions
  - Coverage requirements
  - OAR tolerances

Structure	Constraint	Clinical Plan [Gy]	MCO Navigated Plan [Gy]	Avg Difference [Gy]
PTV High	D95% of PTV	69.65±0.33	69.62±0.4	-0.04±0.19
PTV High	Max Point	76.19±0.79	75.81±0.79	-0.39±0.85
PTV Int	D95% of PTV	62.02±1.29	61.85±1.5	-0.17±0.42
PTV Int	Max Point	72.66±2.79	73.34±2.04	0.68±1.14
PTV Low	D95% of PTV	55.63±0.78	55.57±0.91	-0.05±0.46
PTV Low	Max Point	65.78±5.5	66.47±4.91	0.69±1.38

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Results of MCO Navigation – OAR

Structure	Constraint	Clinical Plan [Gy]	MCO Navigated Plan [Gy]	Avg Difference [Gy]
Larynx-PTV	Mean dose <30 Gy	32.71±4.3	29.77±6.04	-2.94±3.71
Spinal Cord	Max dose ≤ 45 Gy	41.82±4.25	39.02±4.71	-2.81±2.72
Brainstem	Max dose ≤ 50 Gy	42.61±6.18	40.2±5.11	-2.41±2.45
Larynx	Mean dose <30 Gy	43.12±8.33	41.22±8.73	-1.9±2.87
Brachial Plexus L	D5% <60 Gy	65.02±3.03	63.15±3.81	-1.87±1.44
Brachial Plexus R	D5% <60 Gy	60.93±5.62	59.35±5.42	-1.58±1.63
Esophagus-PTV	Mean dose <30 Gy	25.99±3.56	24.46±4.28	-1.53±2.05
Brainstem+3mm	Max dose ≤ 52 Gy	45.77±4.51	44.29±3.35	-1.48±2.65
Brachial Plexus R	Max dose ≤66 Gy	63.26±6.14	61.79±5.84	-1.46±1.43
Brachial Plexus L	Max dose ≤66 Gy	68.33±3.3	66.9±3.29	-1.43±1.88
Esophagus	Mean dose <30 Gy	30.29±3.19	29.26±4.48	-1.03±2.02
Spinal Cord+5mm	Max dose ≤ 50 Gy	45.8±2.8	44.81±2.64	-1.00±1.88
Cochlea L	Mean dose <20 Gy	13.49±5.18	14.54±6.97	1.05±2.46
Inner ear L	Max dose <25 Gy	21.56±5.96	22.73±8.79	1.18±3.76
Cochlea L	Max dose <25 Gy	19.56±6.52	20.8±9.48	1.25±3.87
Mandible	V60Gy <20%	17.91%±9.25	19.22%±9.6	1.31%±1.6
Pharynx-PTV	Mean dose <45 Gy	40.33±7.49	42.1±7.43	1.77±2.19
Pharynx-PTV	V50Gy <33%	22.76%±24.93	26.14%±24.36	3.39%±8.14

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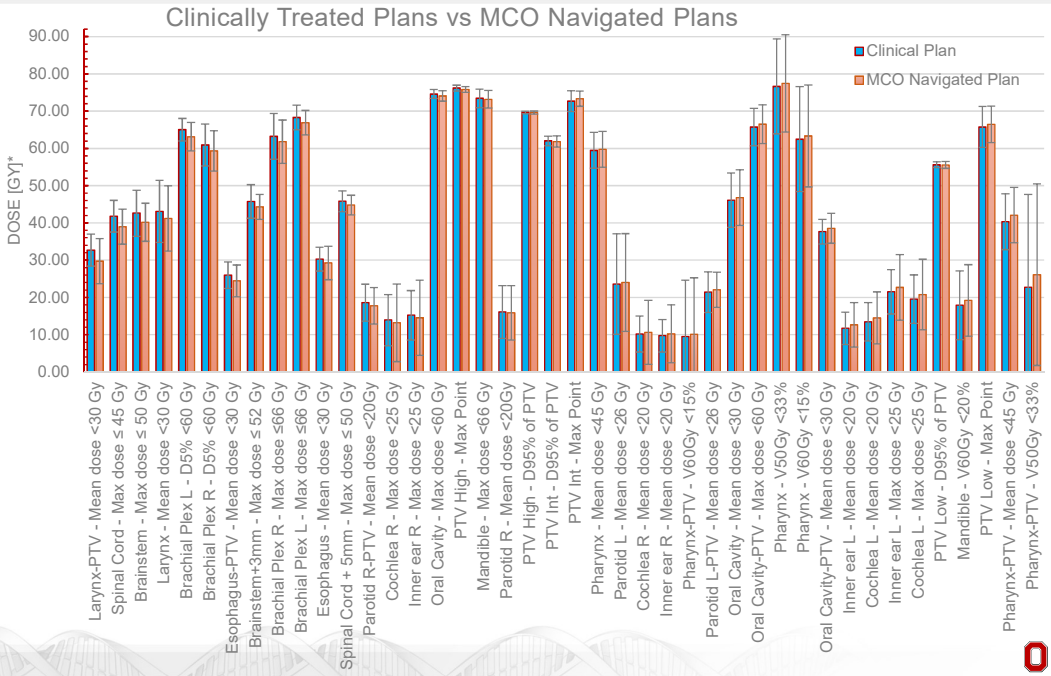

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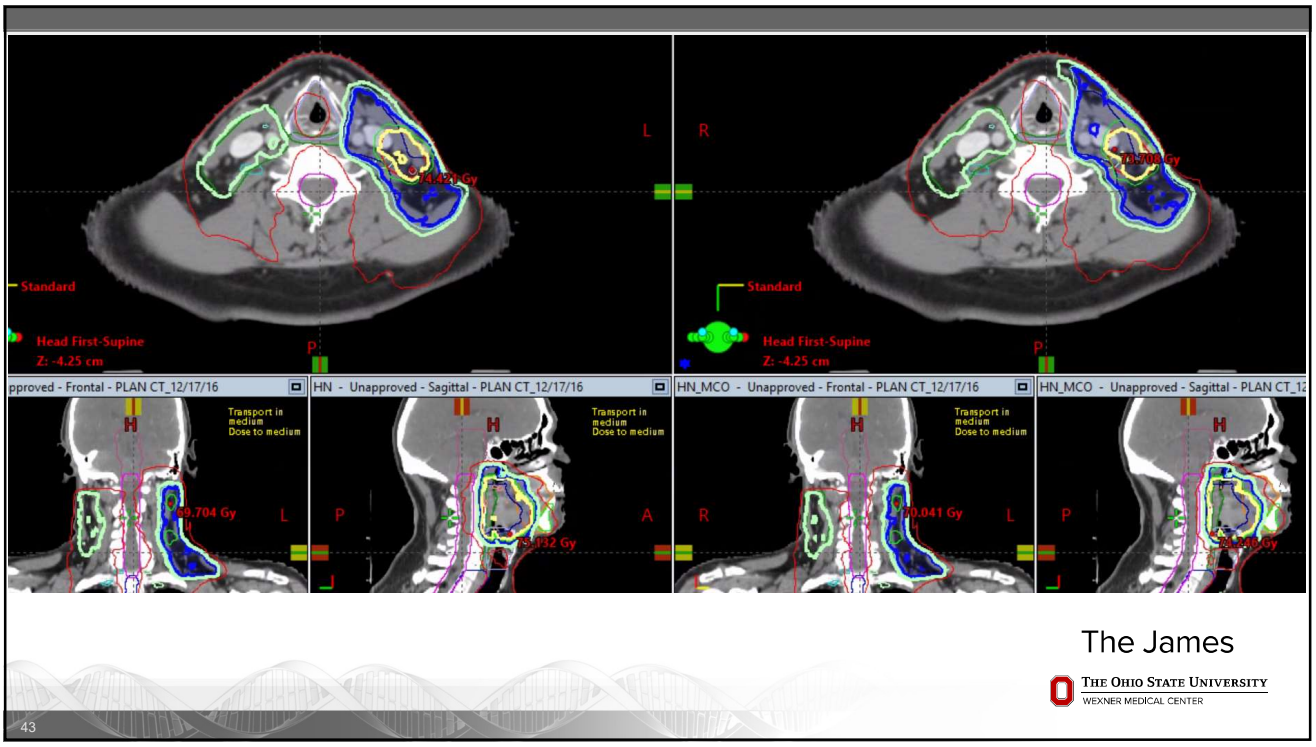
Standard
Head First-Supine
Z: -4.25 cm
Transport in medium
Dose to medium
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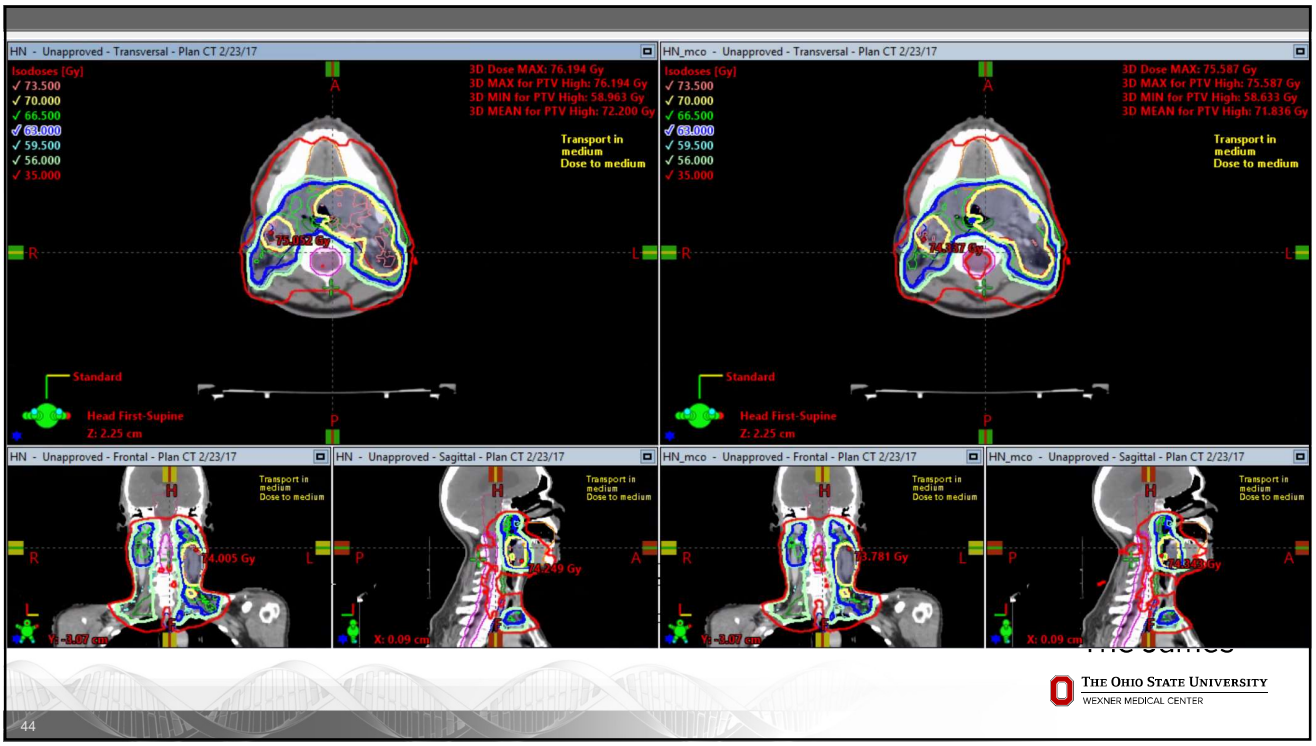
Isodoses [Gy]
✓ 73.500
✓ 70.000
✓ 66.500
✓ 63.000
✓ 59.500
✓ 56.000
✓ 35.000
Standard
Head First-Supine
Z: 2.25 cm
Transport in medium
Dose to medium
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MCO Use Cases and Future Directions

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MCO Use Cases – Known Tradeoffs

- Utilizing MCO to easily navigate to desired tradeoff between overlapping structures
  - Brain with brainstem or optics
  - Prostate with rectum and bladder

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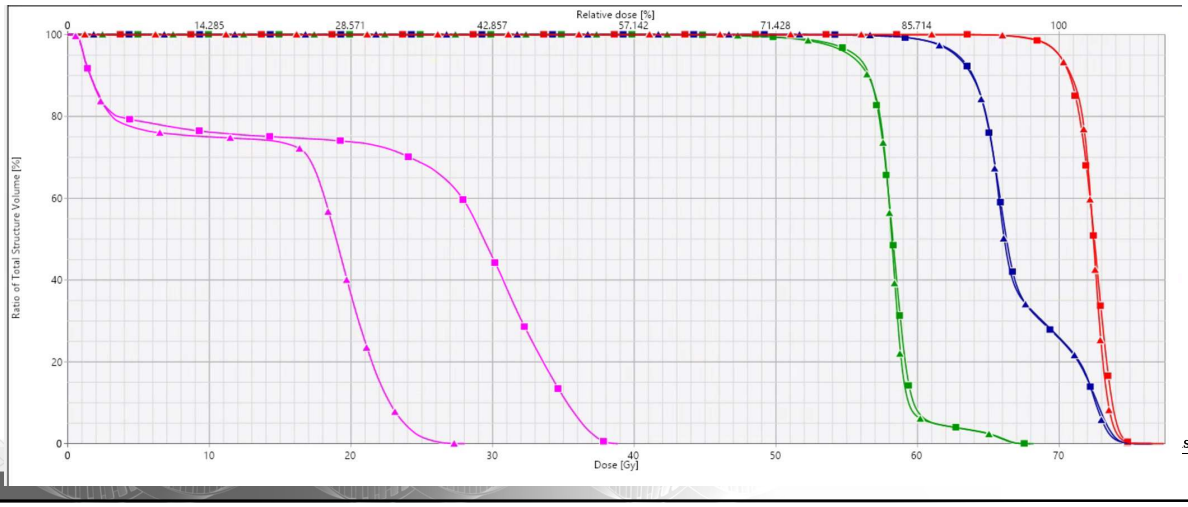
MCO Use Cases – Unknown Tradeoffs

- Improving a plan with unknown tradeoffs by optimizing balance of OARs or finding "free dose"



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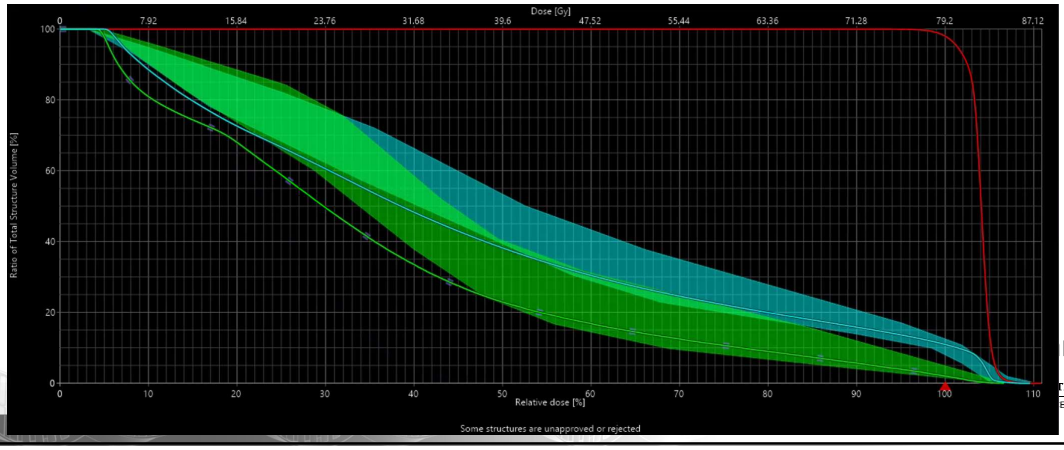
Future Directions – RapidPlan

- Optimizing RapidPlan Models
  - Using MCO to navigate plans already in model to ensure best tradeoff of plan is used in RapidPlan model



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Future Directions - Beam Geometry

- Quickly determining optimal beam geometry
  - RapidArc vs 9 Field Static IMRT

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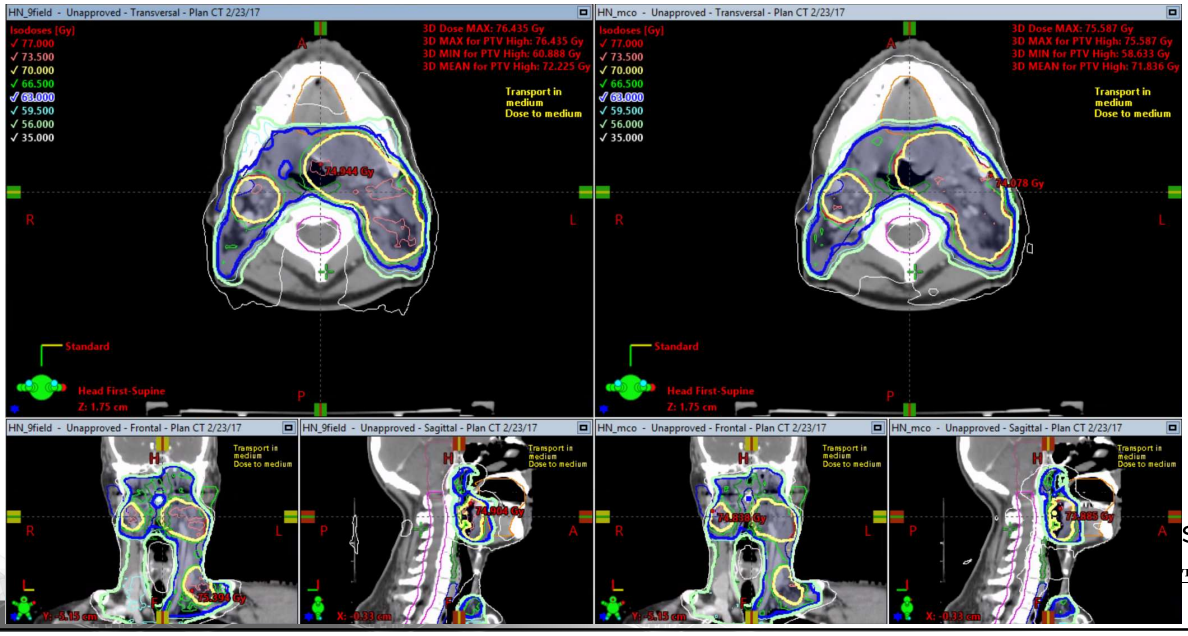
Future Directions - Beam Geometry



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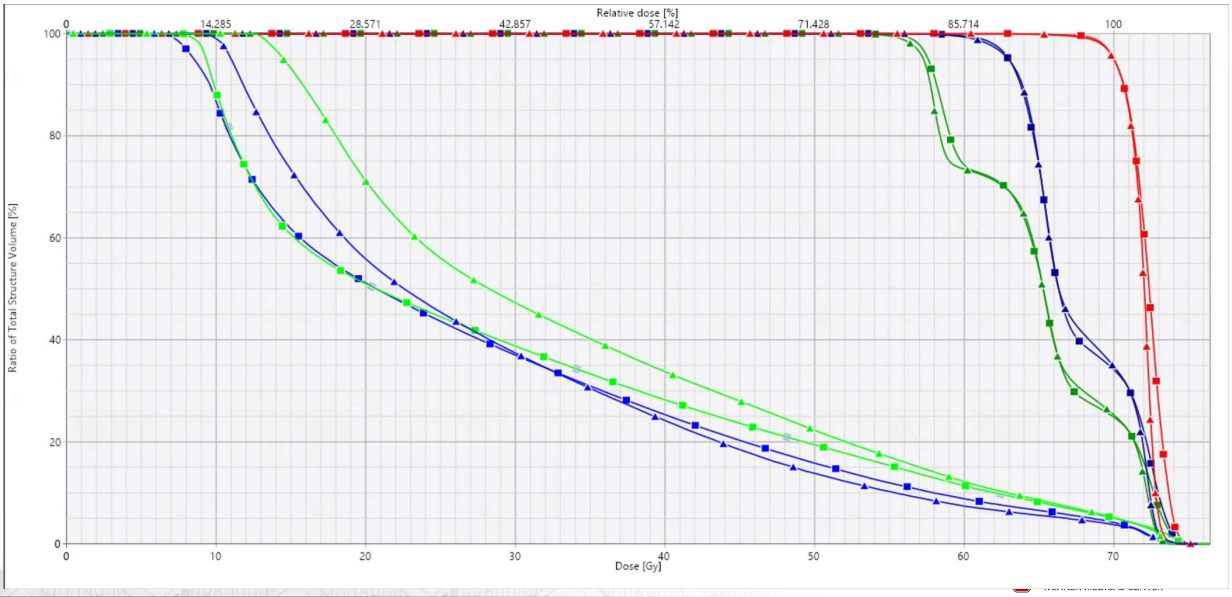
Future Directions - Beam Geometry



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Future Directions - Beam Geometry

Show DVH	Structure	Plan	Min Dose [Gy]	Max Dose [Gy]	Mean Dose [Gy]
	Brachial Plex L	HN_9field	24.226	63.860	47.226
	Brachial Plex L	HN_mco	33.454	65.612	47.376
	Brachial Plex R	HN_9field	21.035	55.097	41.636
	Brachial Plex R	HN_mco	27.980	58.167	44.309
	Esophagus	HN_9field	7.566	62.193	26.525
	Esophagus	HN_mco	5.862	60.231	31.440
	Larynx	HN_9field	13.479	69.375	28.671
	Larynx	HN_mco	18.439	69.525	33.385
	OAR Pharynx	HN_9field	13.127	74.352	50.278
	OAR Pharynx	HN_mco	20.112	74.533	54.011
	Oral Cavity	HN_9field	9.023	73.552	33.758
	Oral Cavity	HN_mco	9.568	73.255	38.895
	PTV High	HN_9field	60.888	76.435	72.225
	PTV High	HN_mco	58.633	75.587	71.836
	PTV Int	HN_9field	50.936	76.435	67.739
	PTV Int	HN_mco	49.481	75.587	67.666
	PTV Low	HN_9field	47.775	76.435	65.214
	PTV Low	HN_mco	49.191	75.587	65.023
	Parotid L	HN_9field	7.605	76.435	28.962
	Parotid L	HN_mco	12.578	74.175	34.285
	Parotid R	HN_9field	6.471	73.984	27.714
	Parotid R	HN_mco	9.109	75.587	28.701
	Spinal Cord+5mm	HN_9field	0.502	41.765	18.868
	Spinal Cord+5mm	HN_mco	0.369	44.658	21.655

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Thank You

- Danny Christ
- Ahmet Ayan
- Jeff Woollard
- Nilendu Gupta
- Stephen Thompson

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