Review and guidelines for treating head and neck tumors using IMRT and VMAT

Debbie Schofield,

Laurence Court,

Chuck Mayo

Educational Objectives:

- Discuss the issues surrounding plan evaluation: Variability in target definition, prescriptions, margins, etc.
- Discuss different approaches for the use of IMRT for treating head and neck tumors
- Describe the use of VMAT to treat head and neck tumors
- Comparison of VMAT and IMRT for head and neck tumors

Variability in planning criteria and plan evaluation

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Houston, TX

- Target / prescription variability
- Contouring variability
- Margins
- Coverage / hotspots

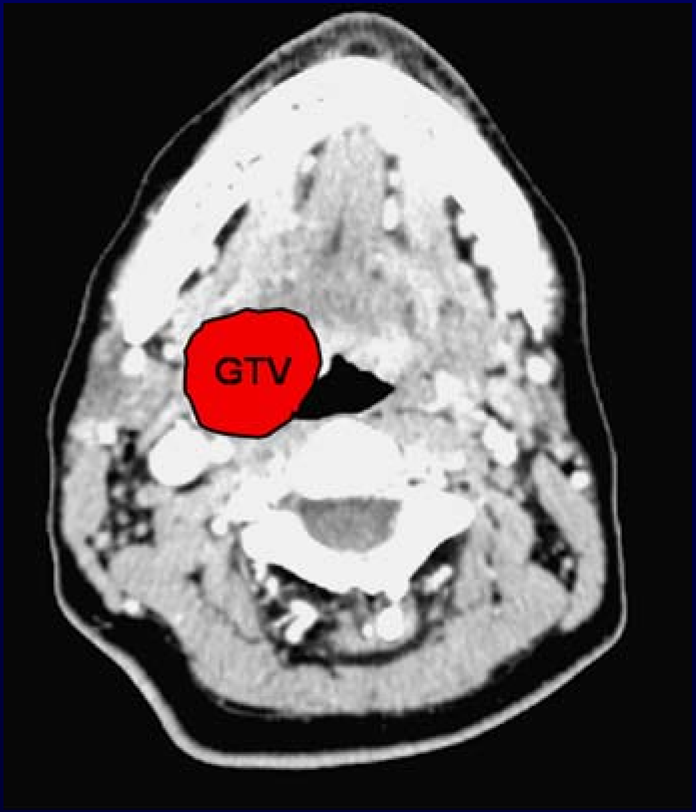
Acknowledgements

- Roy Tishler, DFCI
- Indra Das, Indiana University
- Martin Murphy, Virginia Commonwealth University
- Wolfgang Tomé, University of Wisconsin
- Debbie Schofield, Baptist Cancer Institute
- Chuck Mayo, Mayo Clinic

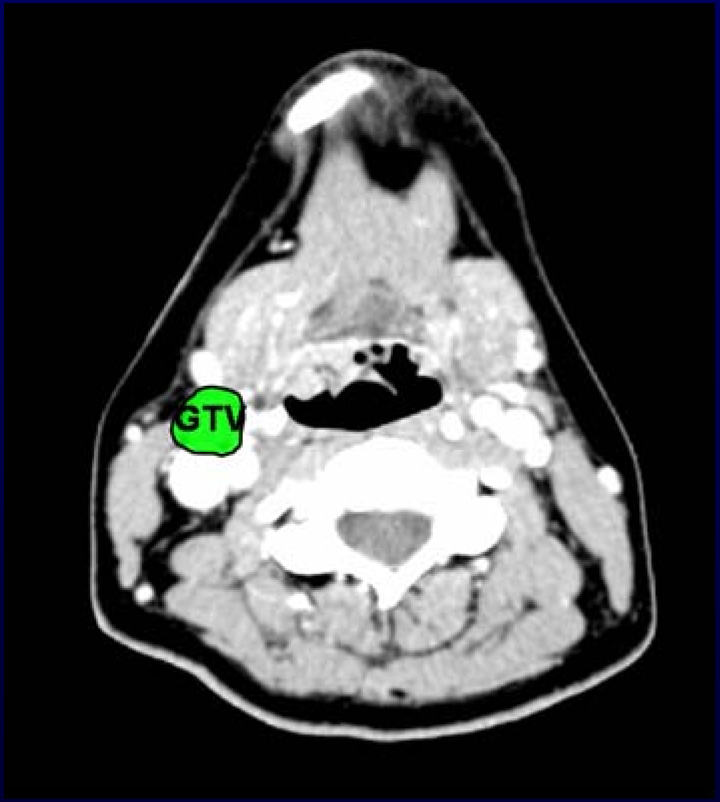
Variations in CTV Design

T2 N1 M0 Tonsil Cancer

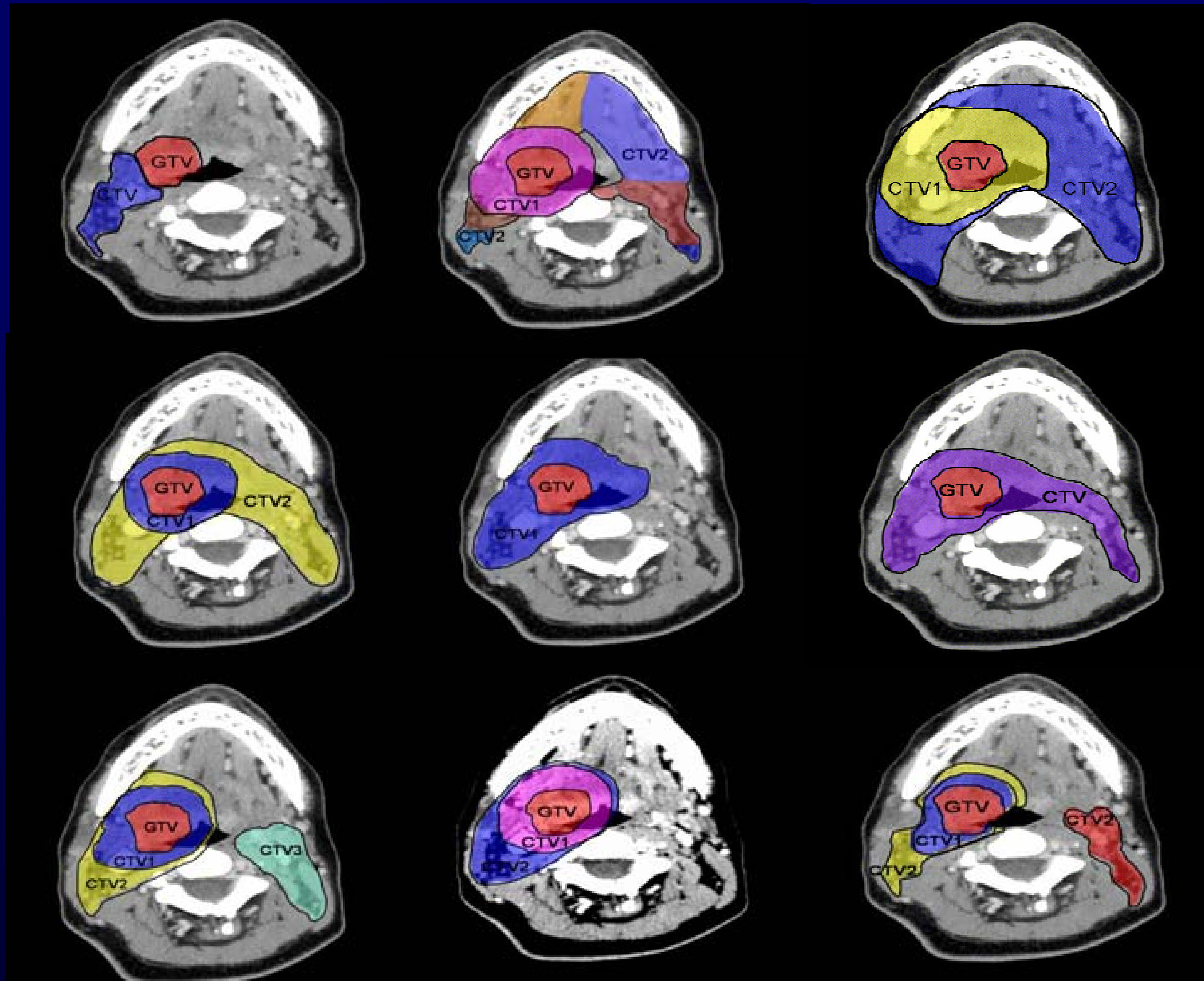
Primary Tumor



Neck Node



Theodore S. Hong, Wolfgang A. Tomé, Richard J. Chappell, and Paul M. Harari
University of Wisconsin



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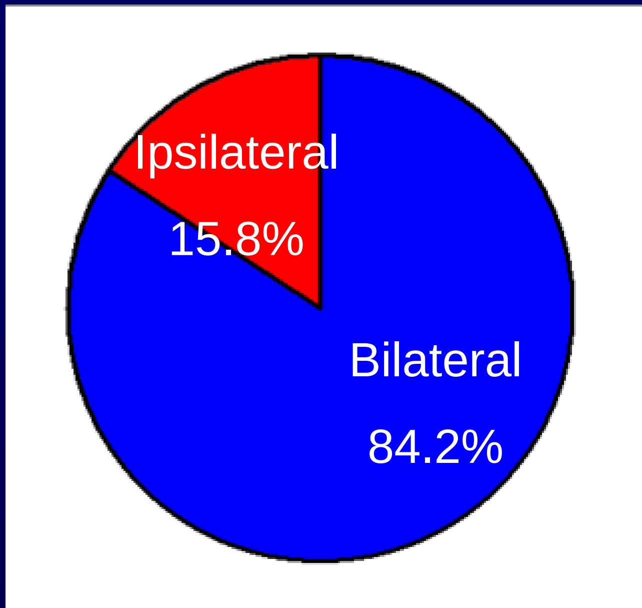
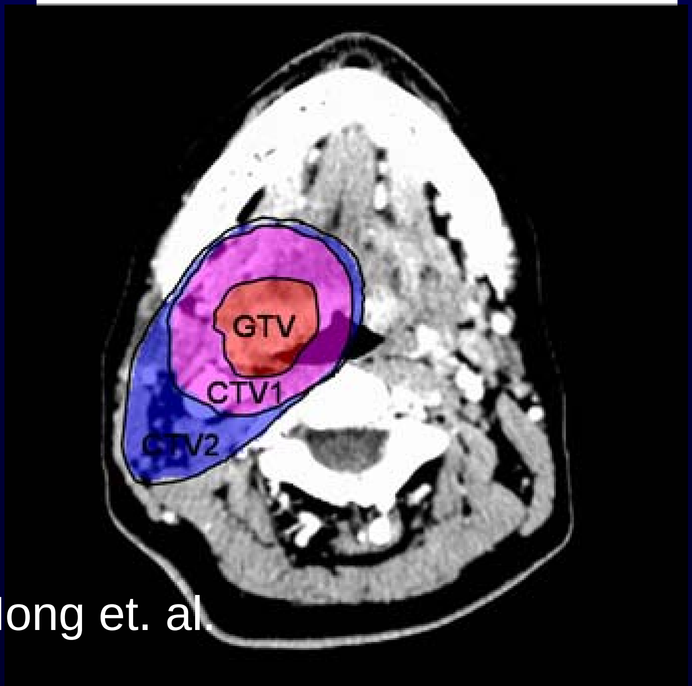
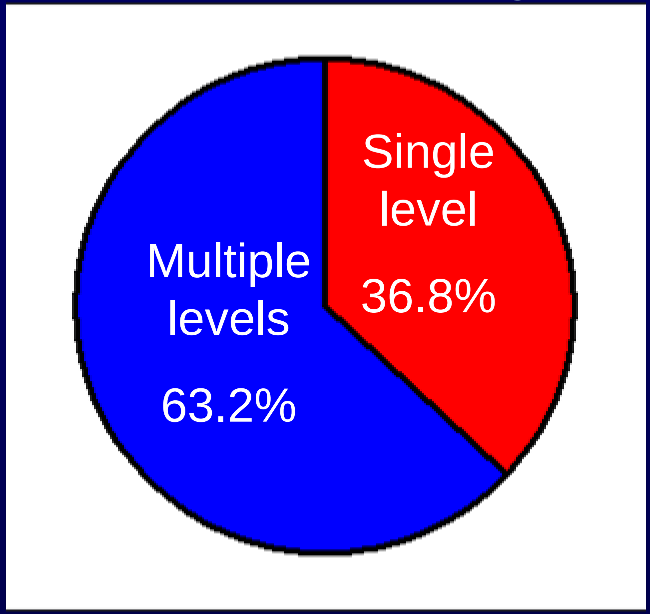
University of Wisconsin

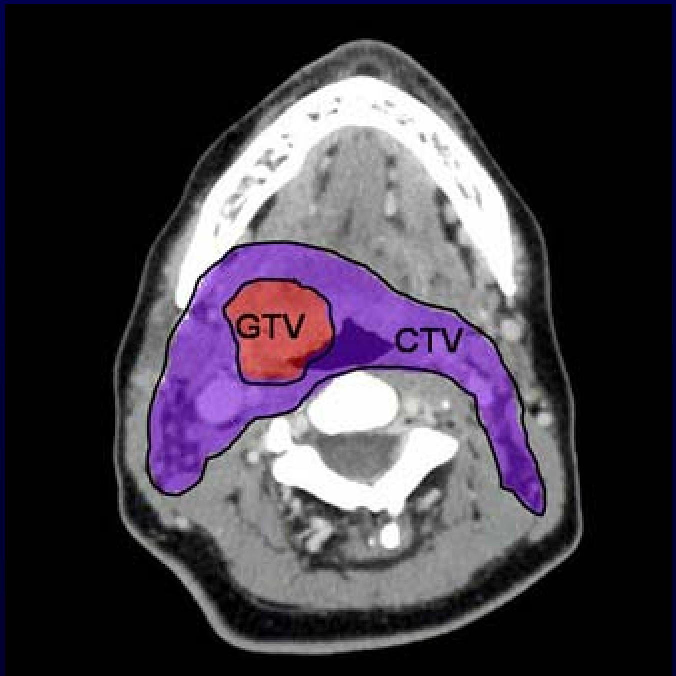
Bilateral vs. Ipsilateral





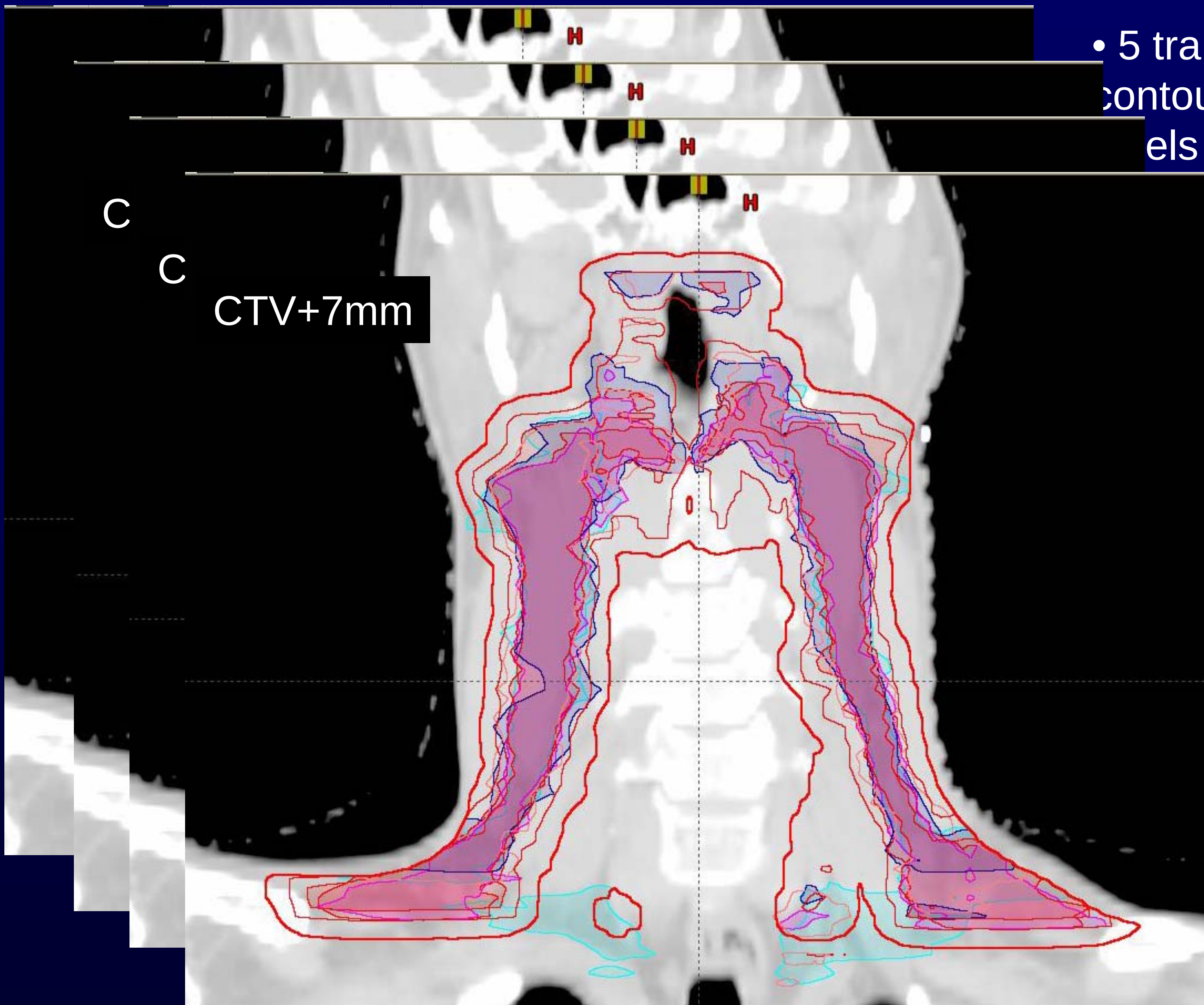
Elective CTV Design





TS Hong et. al.

Contouring variability



- 5 trained residents
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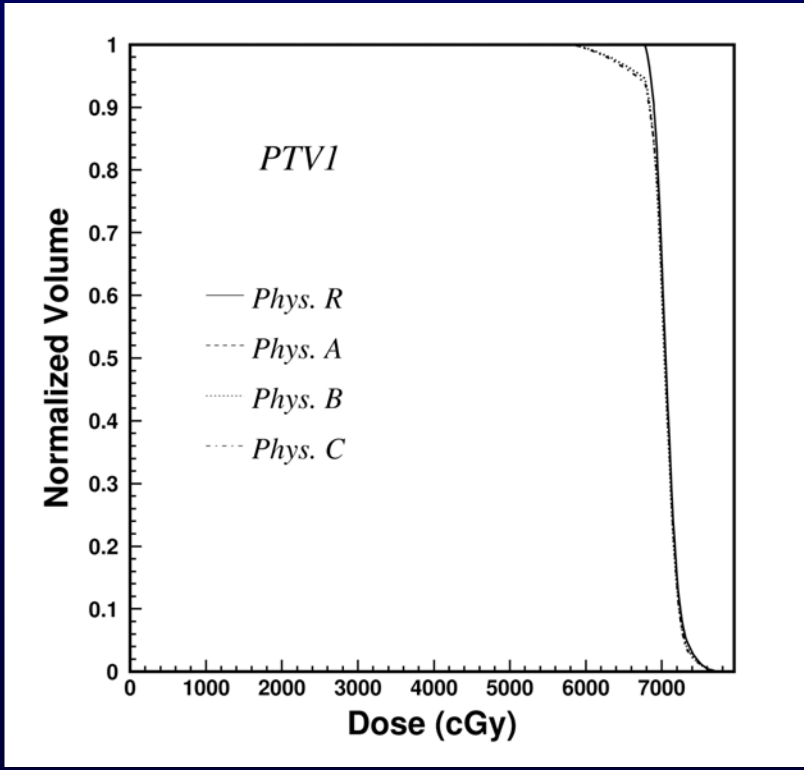
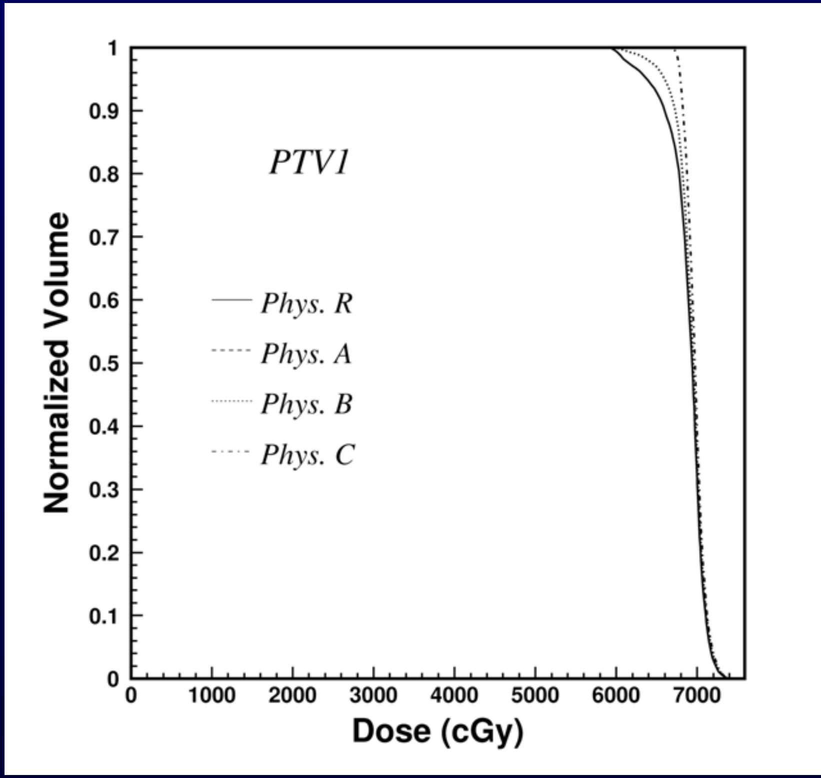
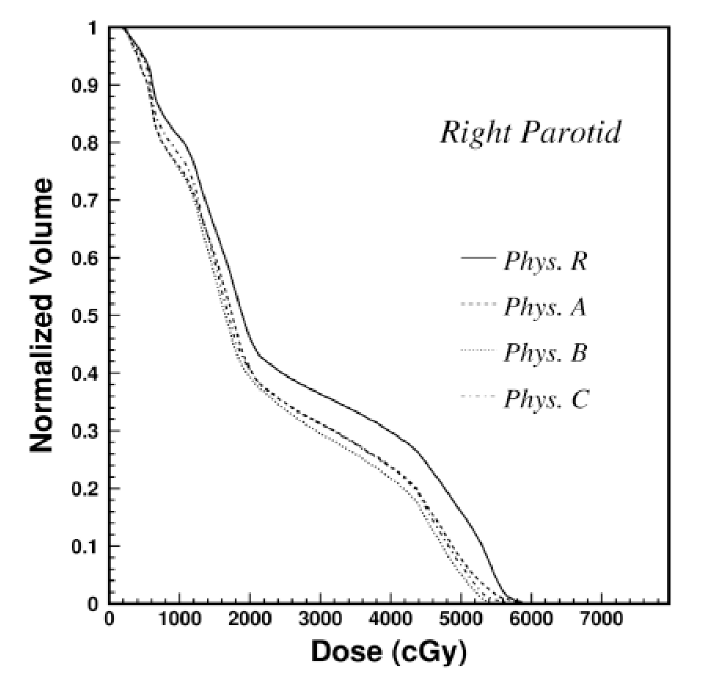
Effect of contouring on target dose

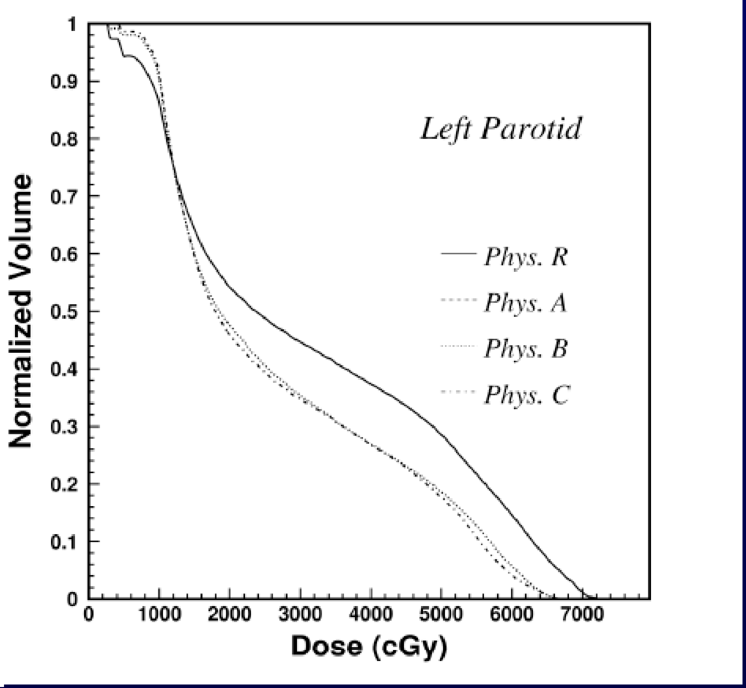




Data from Lu et al, VCU (Martin Murphy)
PTV=CTV+ (3 - 5mm)

Effect of contouring on parotid dose





Patient	D_{50} range (Gy) left parotid	D_{50} range (Gy) right parotid
1	18.7 – 28.2	16.1 – 32.8
2	14.4 – 16.6	53.4 – 55.7
3	17.8 – 34.0	16.4 – 20.3
4	16.2 – 28.4	17.3 – 21.6
5	16.6 – 20.5	64.2 – 65.3
6	12.9 – 16.6	41.5 – 41.6
7	14.4 – 19.4	53.6 – 60.5

Data from Lu et al, VCU (Martin Murphy)

Margins

- PTV expansions to account for setup
  - Mean: 4.1 mm (Hong et al)
  - Range: 0-15 mm
  - UMass: 3-5mm, MDACC: 3-4, DFCI: 3-5mm, Mayo: 3mm
  - MD draws PTV
- Use of optimization structures
- Pull back from skin (3-5mm)
  - DFCI: 3mm (PTV),
  - UMass: 4mm (IMRT PTV)
- Planning Risk Volume: 0 – 10mm
  - Cord: 5mm (MDACC, MNCJAX), 7mm (DFCI), 1cm (UMass) [3cm posterior]
  - Optic nerves: 3mm (DFCI and UMass)
  - Parotid: 0mm

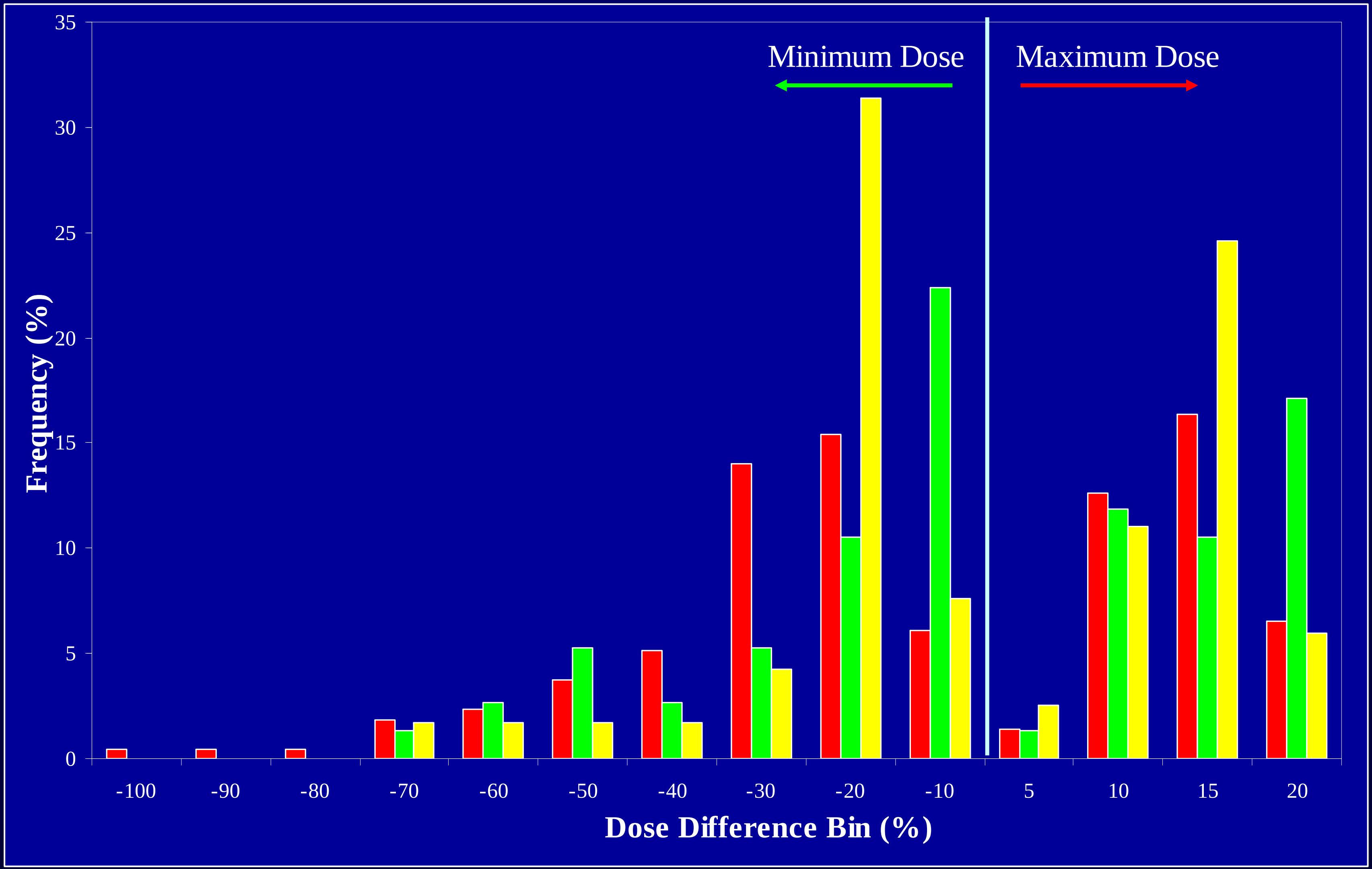
Target coverage

- 100% PTV covered by 100% (Mayo)
- 95% of PTV getting 100% prescription, ‘most’ covered by 98% isodose (DFCI)
- 99%+ CTV covered by 100% (MDACC)

Hotspots

- 105%+
- DFCI: Aim for 5%, <110%
- UMass: aim for <110%. Typically 8% vol < 10% (will accept ~10% of PTV > 110% if necessary)
- 105-110% (MDACC)
- MGH:110-115%, 120%+ if necessary
- Impact of chemotherapy

Variations in minimum and maximum dose

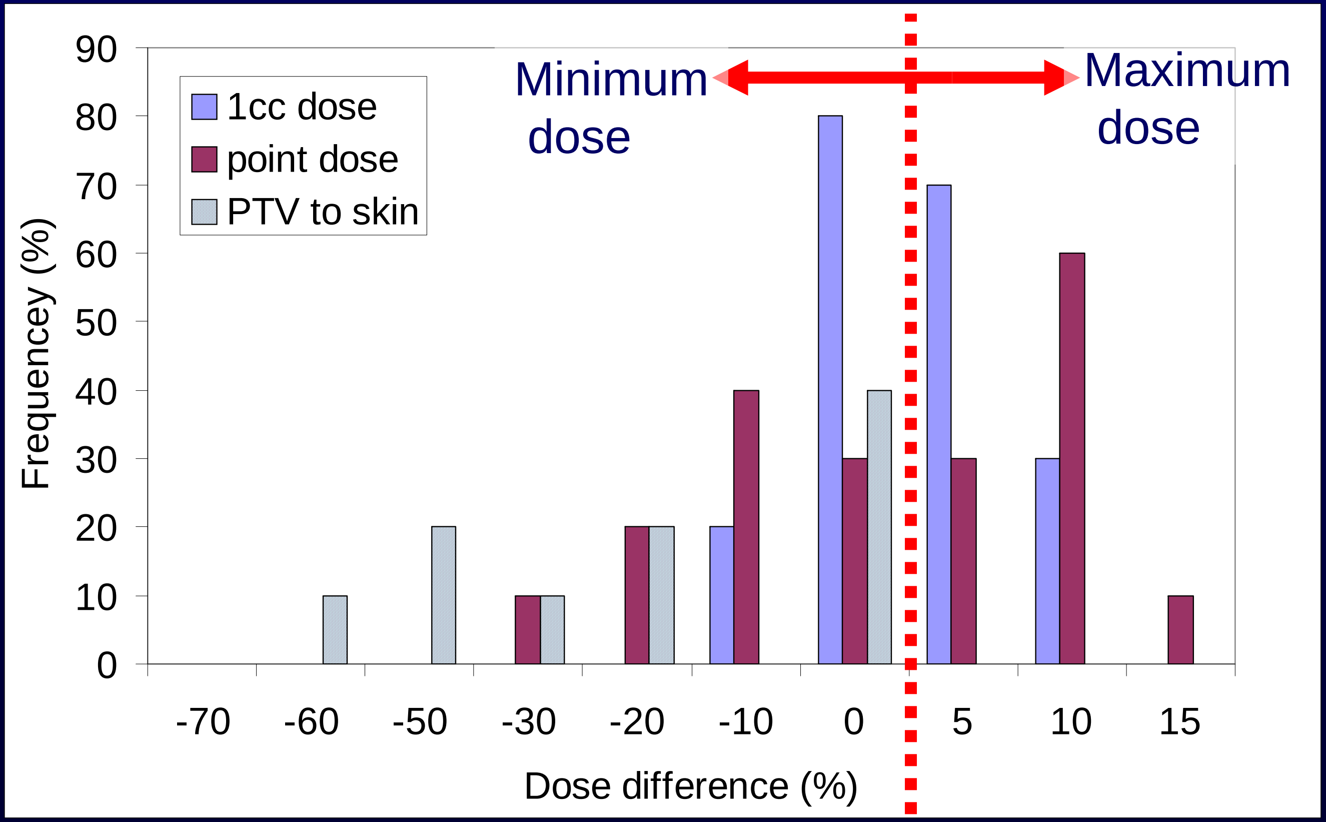


Indra Das et al. J Natl Cancer Inst 100 (5), 300-3007, 2008

(209 H&N patients)

Impact of how dose is reported

- 1cc or point dose
- Definition of PTV



DFCI data

Summary

- H&N IMRT (or VMAT) planning is remarkably heterogeneous
  - Contouring
  - Margins
  - Prescription, including coverage and hotspots
- Care needed when comparing data from different clinics

The Use of IMRT in the Treatment of Head and Neck Cancer

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Immobilization and Localization

Treatment Planning Tips

Acknowledgements

Roy Tishler, MD, PhD – Dana Farber

Tracy Balboni, MD – Dana Farber

David Sher, MD – Dana Farber

Laurence Court, PhD – MD Anderson

Chuck Mayo, PhD – Mayo Clinic

Immobilization

The H&N region allows for excellent immobilization and localization

Thermoplastic Mask: “standard”

Head Rests: Standard cups or custom forms

Bite Blocks: Consider for certain cases (oral tongue, floor of mouth, hard palate)

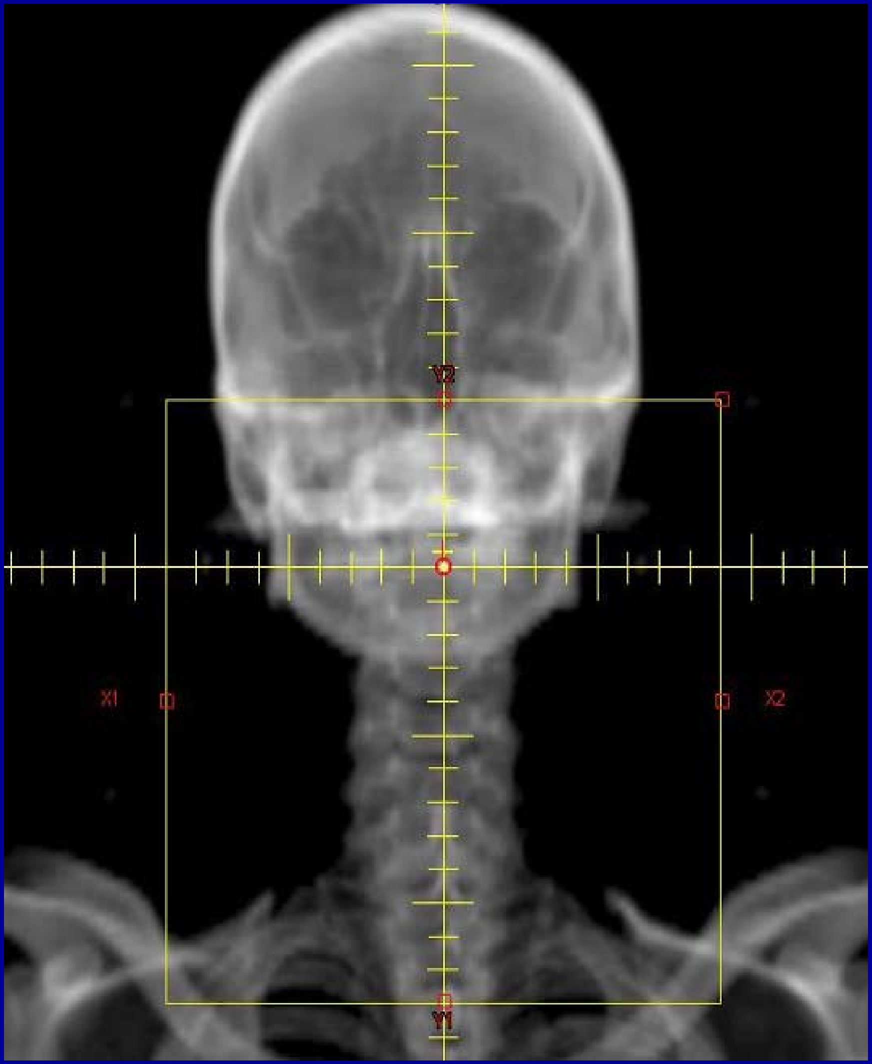
Immobilization

Notes of Caution:

(1) Good Immobilization does NOT always equal good localization

(2) Continuous evaluation of immobilization performance throughout the treatment

Localization



Verification of localization can be accomplished with orthogs

For MV Imaging, the dose delivered during daily imaging can be accounted for and included in a final plan sum and DVH’s.

Daily Imaging

Study at DF/BWH Cancer Center retrospectively evaluated patient setup based on daily ports (Court, et al, JACMP, 9(3), 2008)

Isocenter: within 3mm for a median of 92.5% patients.

Shoulders: 30% of repositioning involved shoulder shifts ≥ 1cm!

20% patients required ≥ 1 cm shoulder shifts for 7/35 fraction

same direction/patient

Example of Shoulder Shift

Overview

- Immobilization and Localization

- Treatment Planning Tips
    - Routine Cases
    - Extended Disease
    - Sinus
    - Retreatments

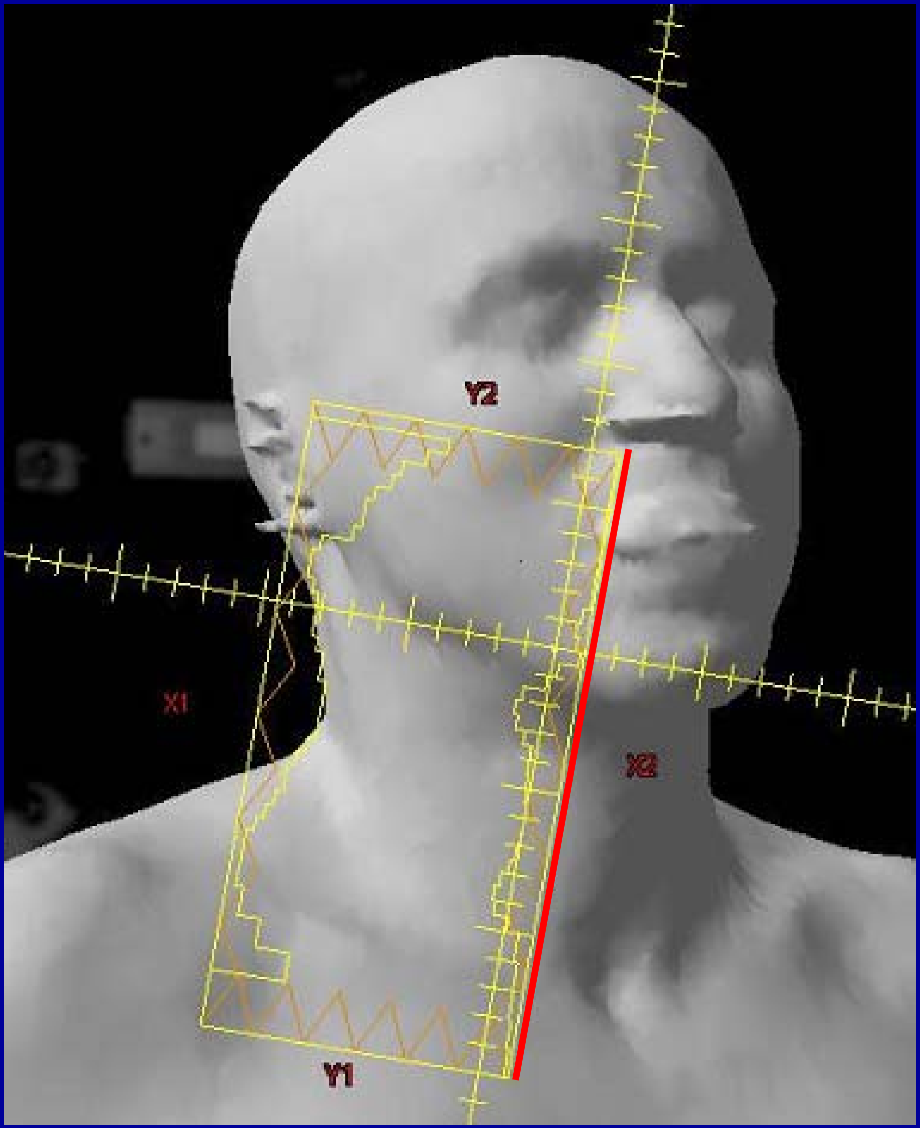
Routine Cases

- Typical plan consists of 7 – 9 beam angles

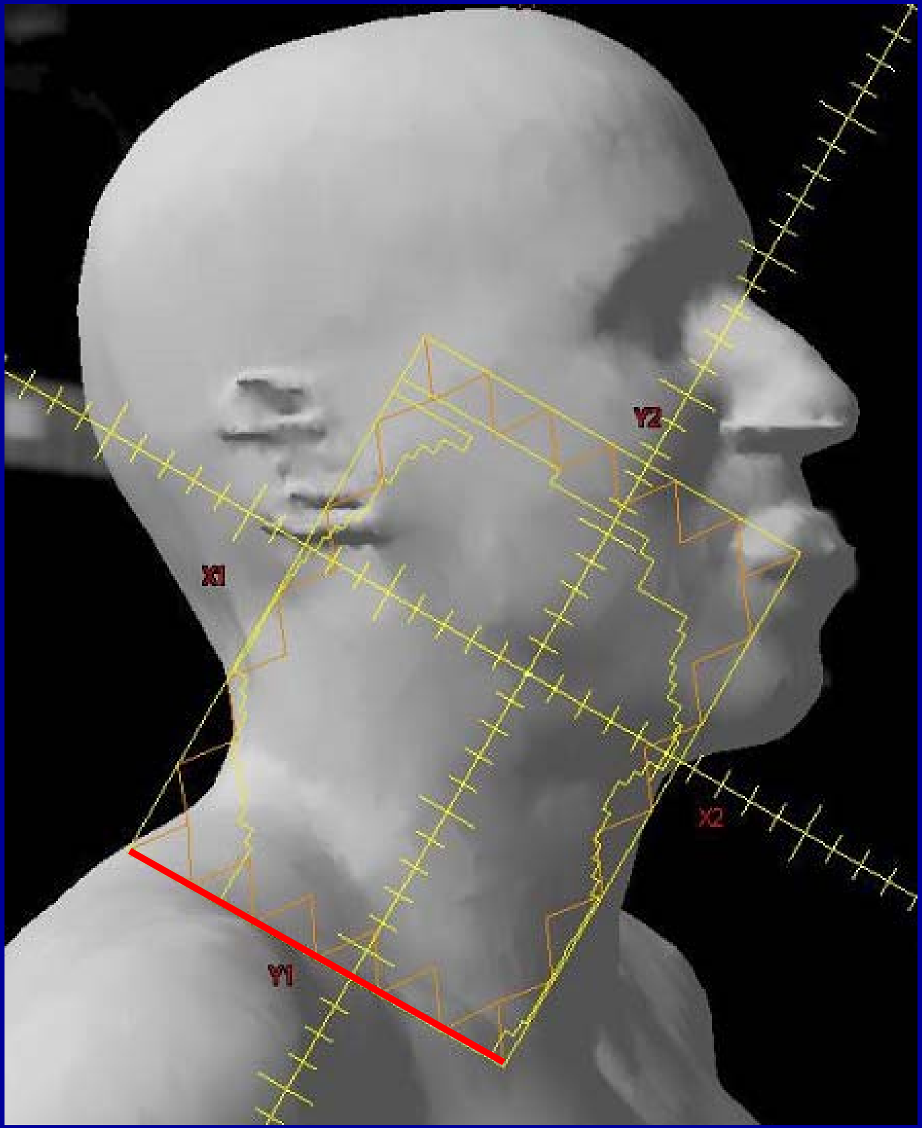
- The beams do not need to be evenly spaced. Instead they should be based on a critical evaluation of patient anatomy and target geometry

- Beams should avoid (fixed jaws):
  - Entering through bite blocks
  - Shoulders
  - Compressed shoulder area on larger patients

Bite Block



Shoulders



Objectives (DFCI/BWH)

Coverage	"Good" coverage of PTV Look at 100% and 98% coverage
Hot Spots	$\leq$ 5%
Cord	< 46 Gy
Exp Cord (7mm)	50Gy isodose line shouldn't cross
Parotid	Mean dose ~ 26 (contralateral)
Uninvolved Larynx / post cricoid	As low as possible Mean < 30 Gy
Oral cavity	No hot spots outside volumes and no hot spots in the mandible

How to Treat the S/C

Four possible approaches:

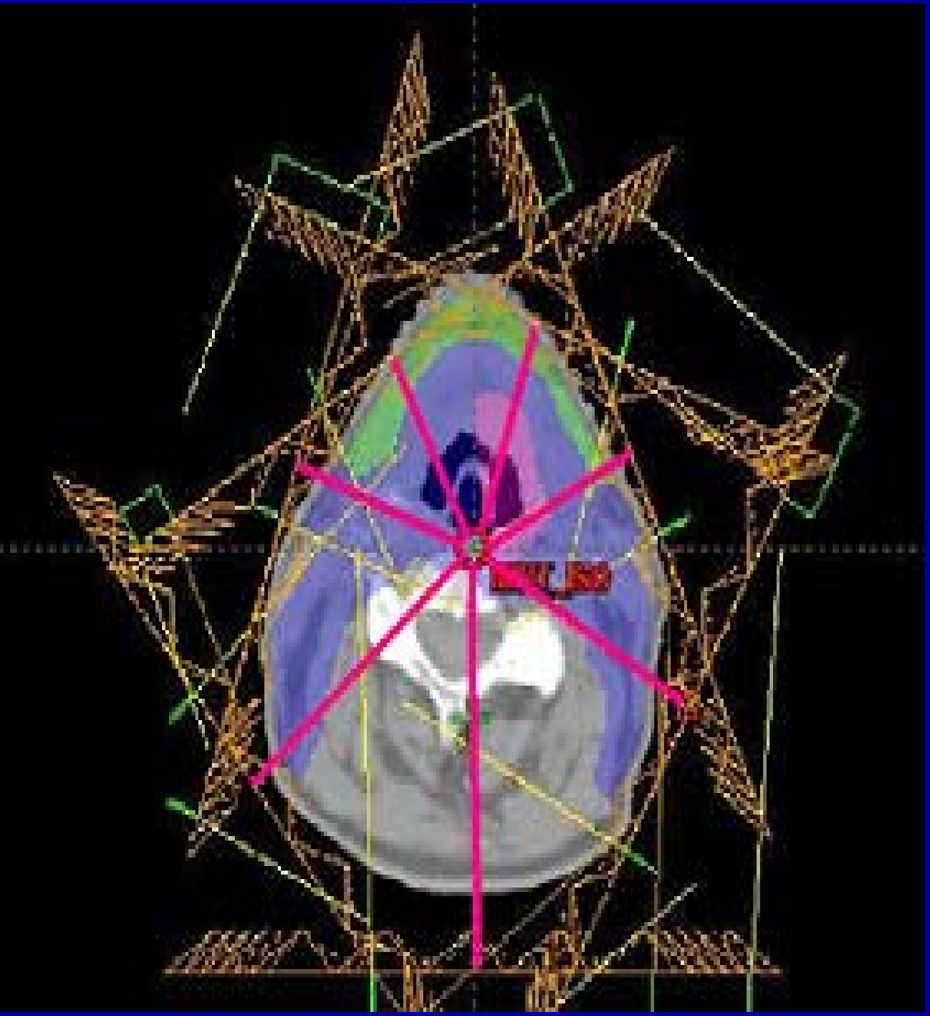
(1) Treat full extent with IMRT

(2) Single isocenter IMRT matched to LAN

(3) IMRT matched to a stepped wedge LAN (UAB Technique)

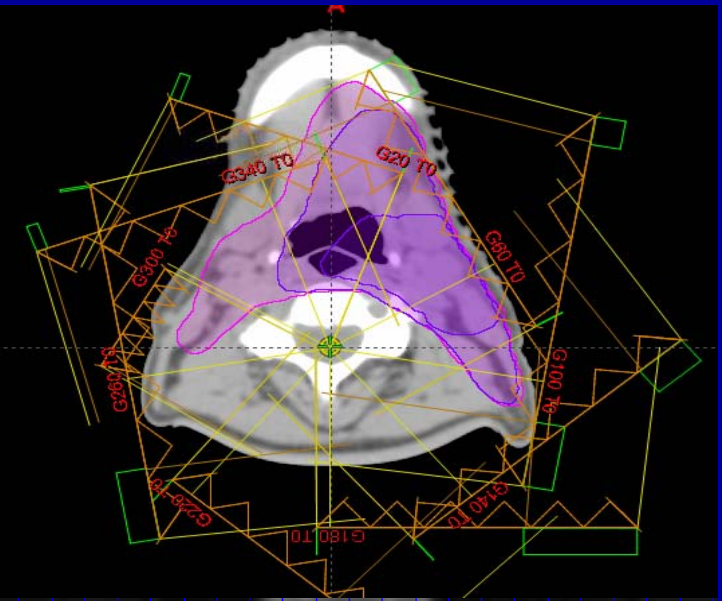
(4) Larynx sparing extended field IMRT

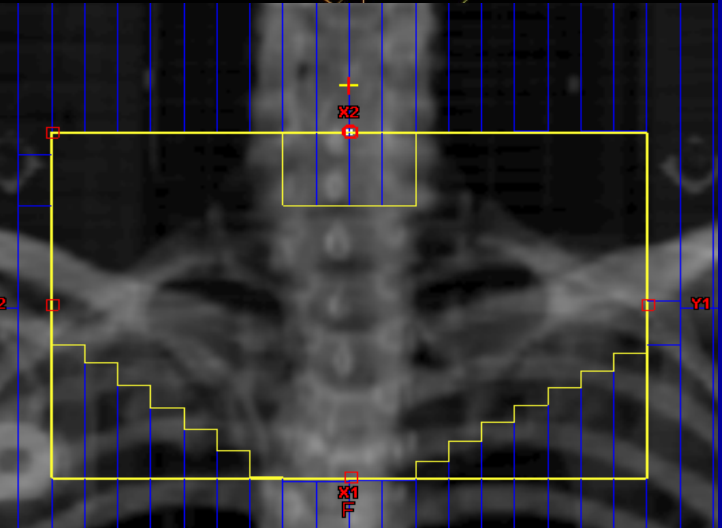
Full Field IMRT



- No matchline issues
- Excellent coverage of deep seated neck nodes
- increased dose to the uninvolved larynx
- brachial plexus

Single Isocenter Matched to Static LAN Field

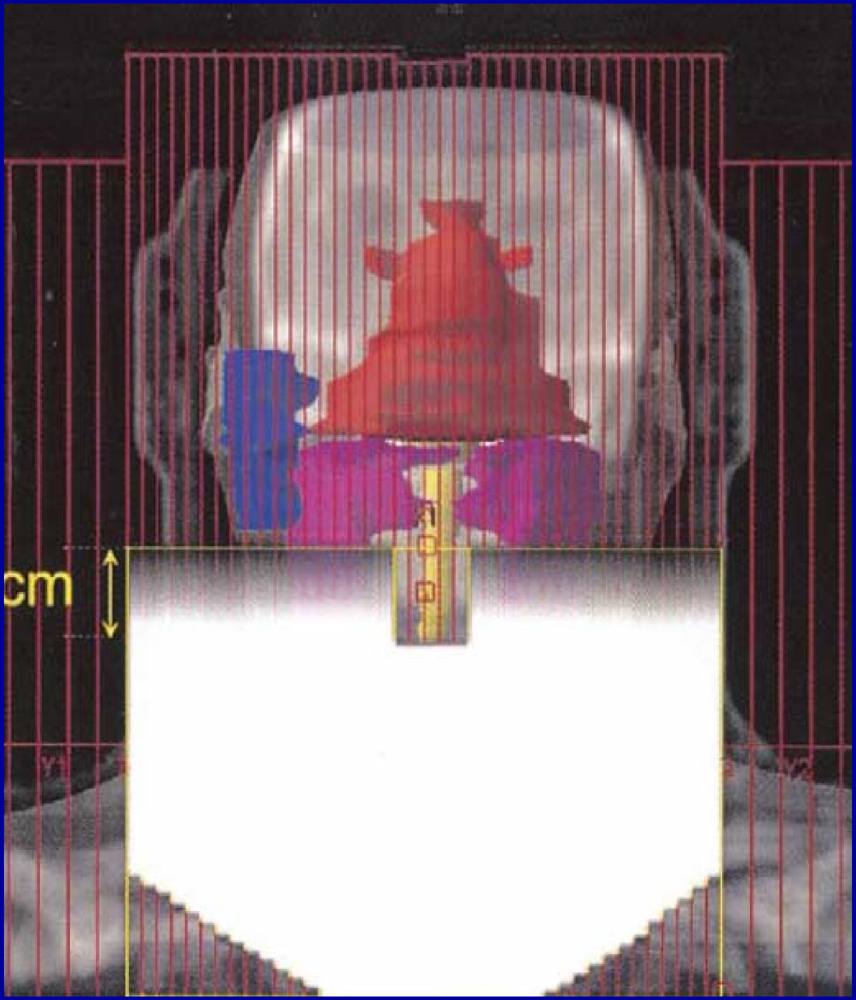




- IMRT in the superior region
- LAN field for inferior region
- Limitations in the field size (Nasopharynx)
- In homogeneities at matchline
- Study from Wash U, found that 19% of their failures occurred at the matchline*

**Thorstad, et al., IJROBP, V63(2), p.S74, 2005.*

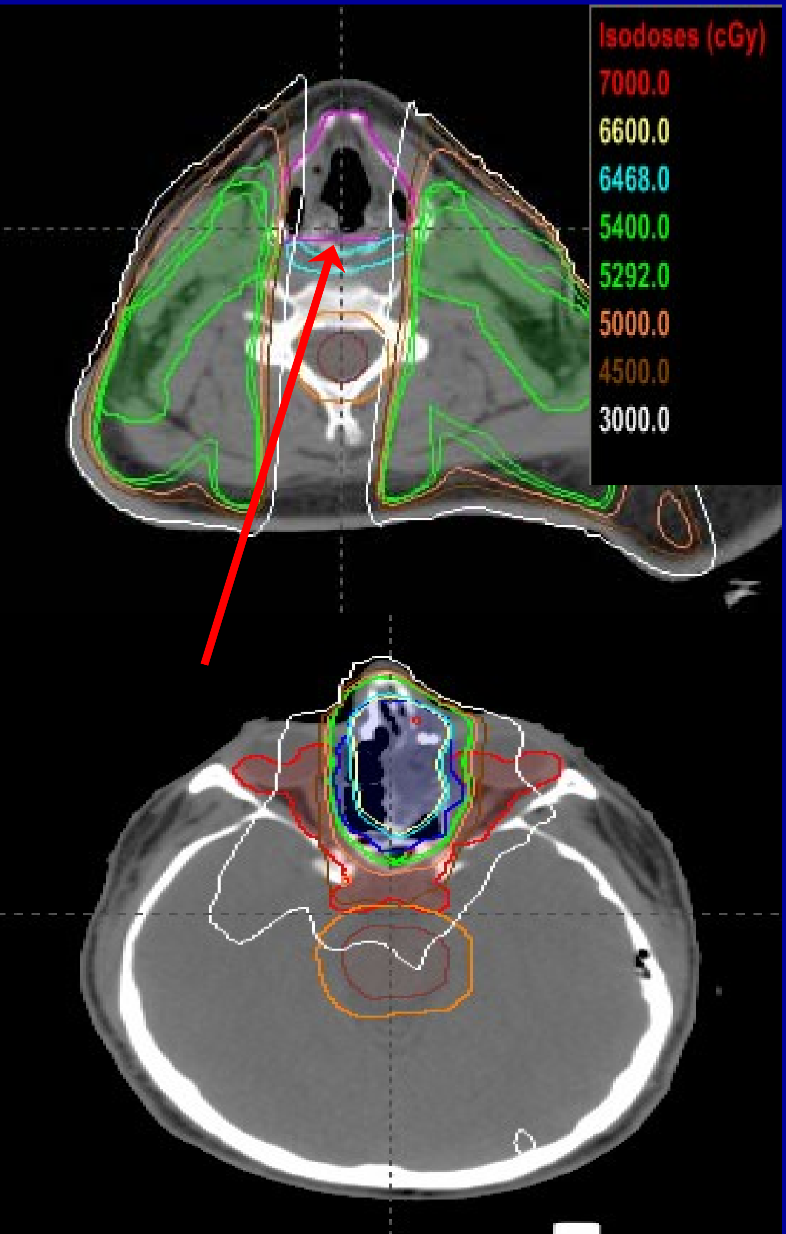
IMRT Matched To A Stepped Wedge LAN Field (UAB Technique)



- stepped wedge approach in the superior 3cm of LAN
- External program generates stepped wedge feature
- Single LAN can't treat deep seated S/C nodes

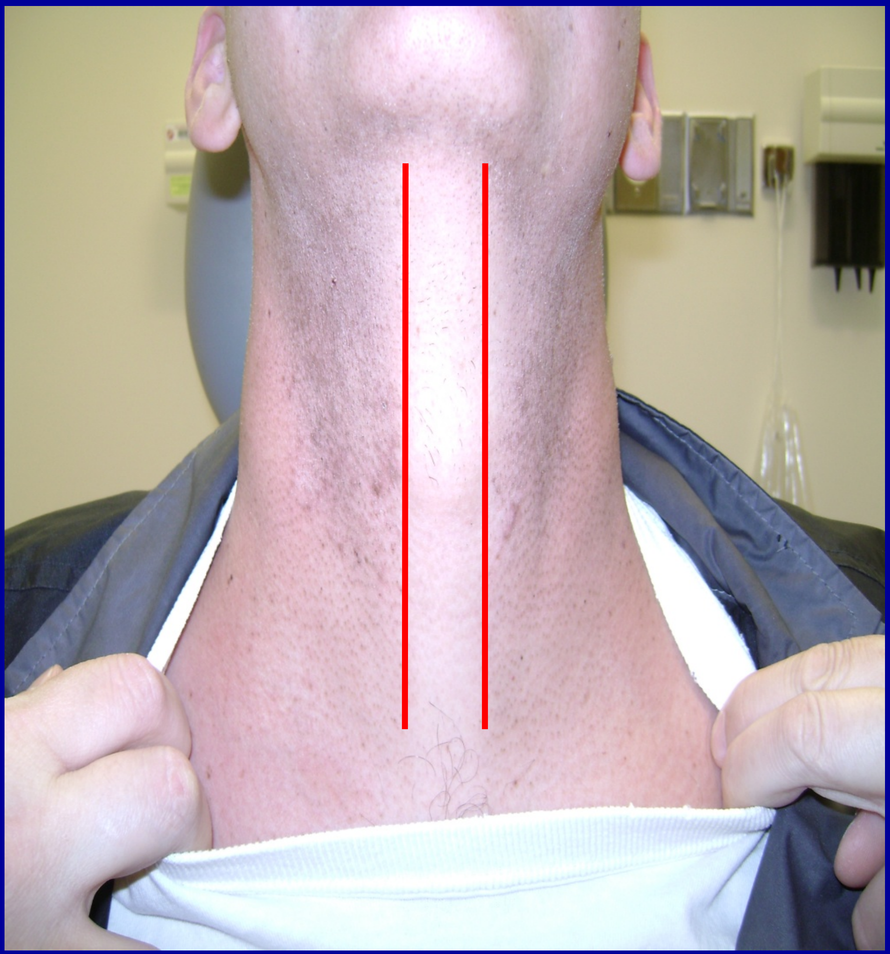
Duan, et al., A dynamic supraclavicular field matching technique for head And neck cancer patients treated with IMRT. IJROBP, 60(3), 2004.

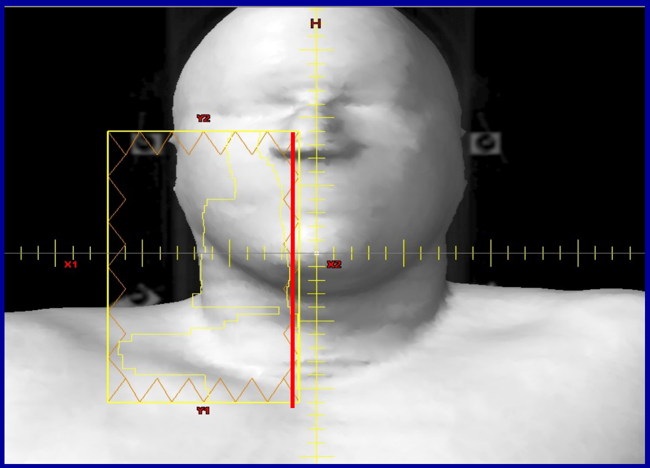
Larynx Sparing IMRT (DFCI)

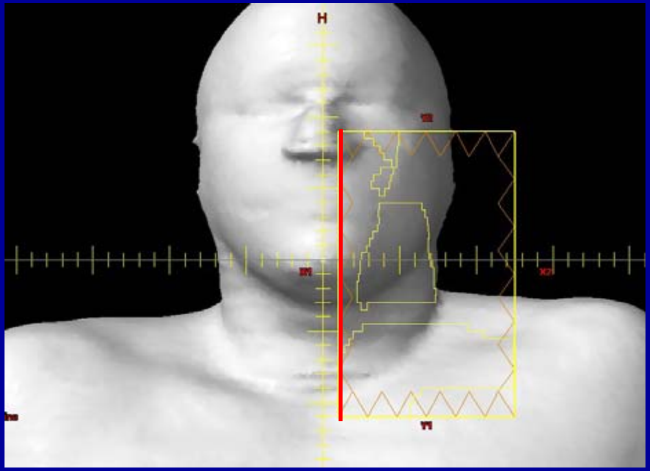


- AP/PA type fields treat disease at/below larynx - split into LT and RT components
- inferior edge of other beams are fixed at the top of the larynx
- No field Size limitation or matchline issues
- Can treat deep seated nodes

Larynx Sparing IMRT*







*Schofield, D., Tishler, R., Balboni, T., Court, L., Sher, D. Reduction of Larynx Dose in Head and Neck IMRT: A Restricted Field Approach. AAPM National Meeting, 2009. Anaheim, California

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Differential Smoothing IMRT for Thyroid/ H&N Disease with extension into Mediastinum*

Low smoothing

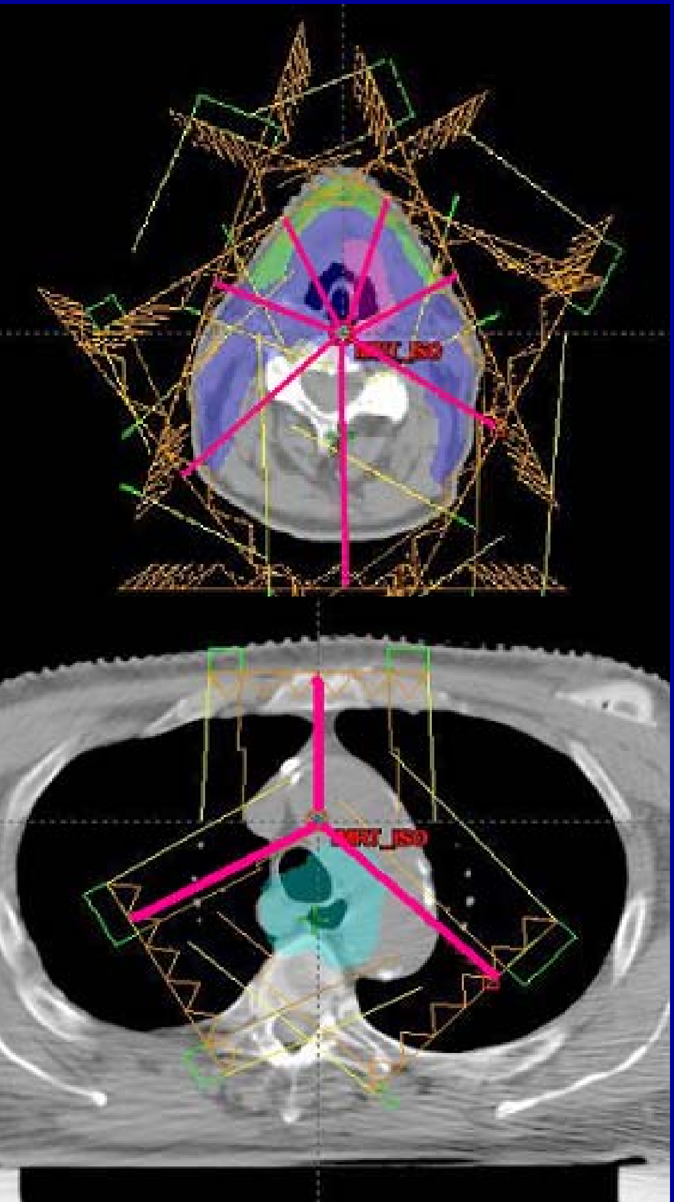
- yields more complex fluence
- smaller leaf gaps

High Smoothing

- yields less complex fluences
- larger leaf gaps
- not as conformal for complex geometries
- less susceptible to interplay effects

*Schofield, D., Tishler, R., Court, L. Differential Smoothing IMRT Planning for Head and Neck Cancer Patients with Mediastinal Involvement. AAPM National Meeting, July, 2006. Orlando, Florida.

Planning Strategy



Single Isocenter

Neck:

- 7-9 low smoothing rate beams
- 5mm PTV expansions

Mediastinum:

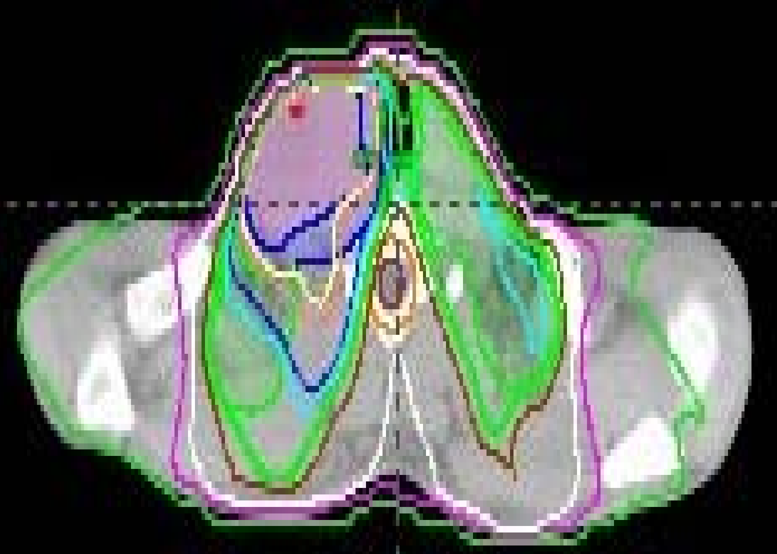
- 3-4 high smoothing rate beams
- PTV expansions based on respiratory motion

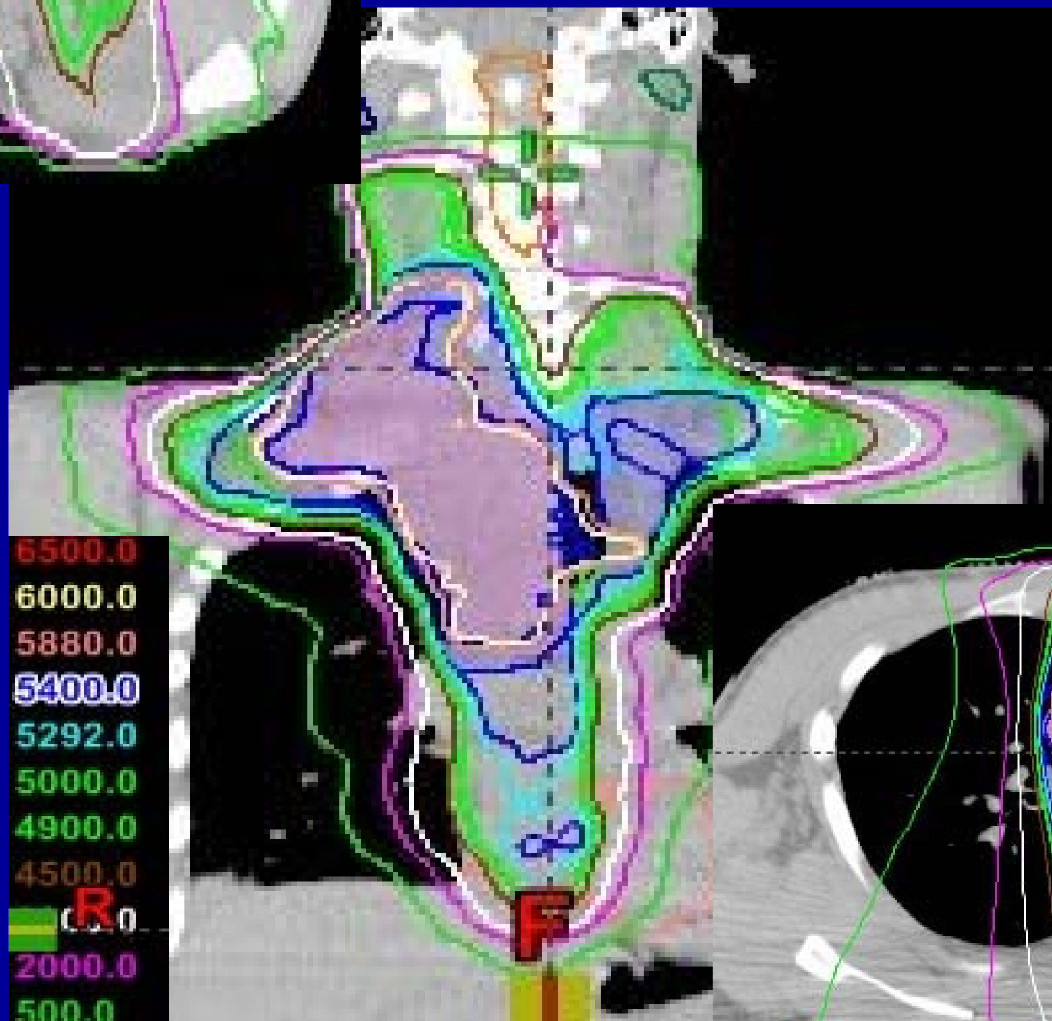
Lung Doses

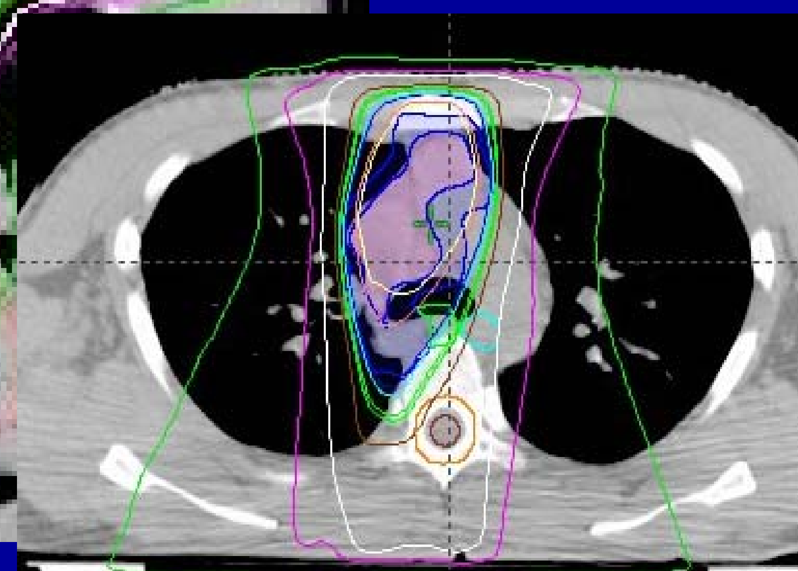
MLD: 11.9Gy

V20: 20.5%

V5: 49.8%







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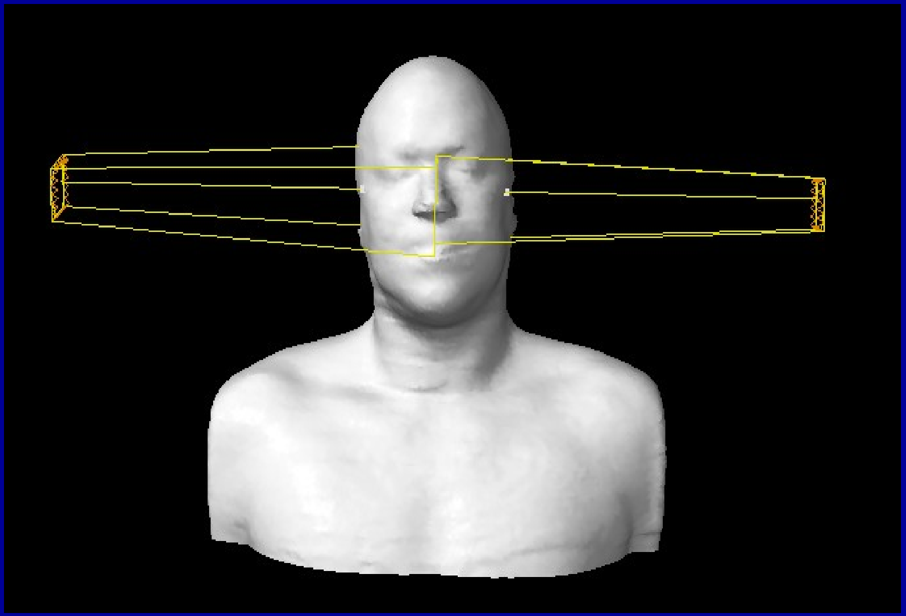
Sinus / Nasal Cavity

- This site can be difficult to treat because of the proximity of the target volumes to the optic structures.

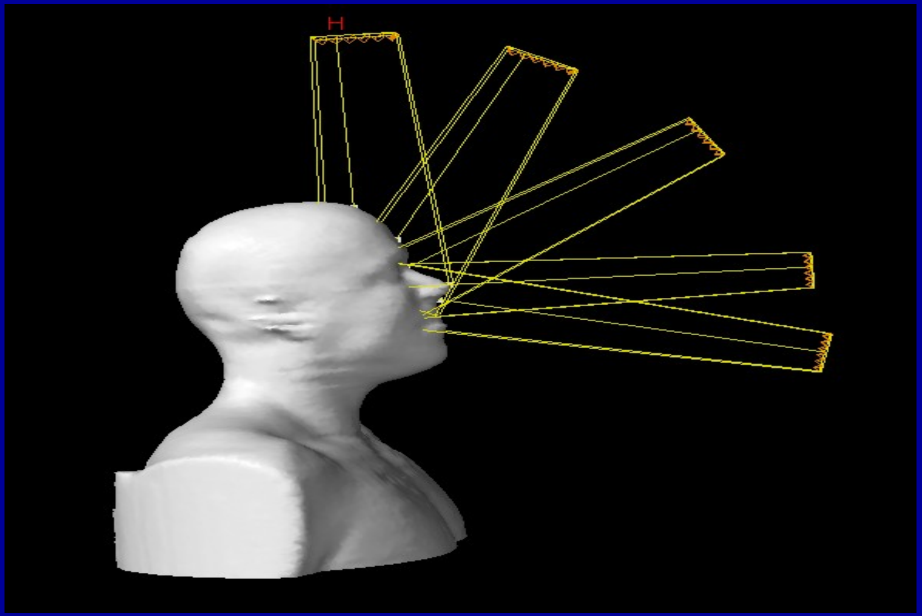
- OAR's
  - Globes and Optic Nerves
  - Chiasm
  - lacrimal glands
  - brainstem

Technique



Gantry Angles: 90°, 270°

Couch: 0°

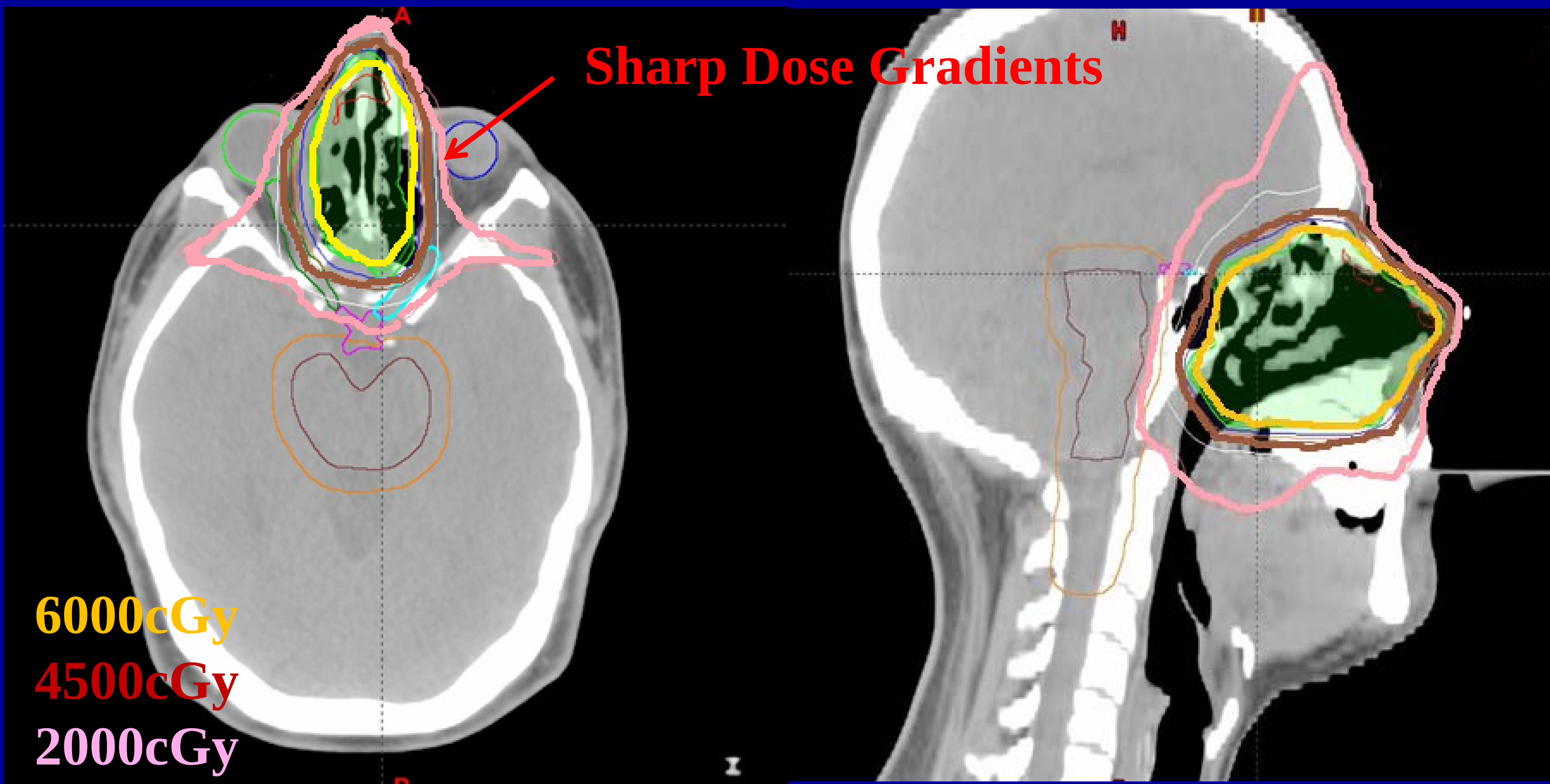


Gantry Angles: 340°, 0°, 30°, 60°, 90°

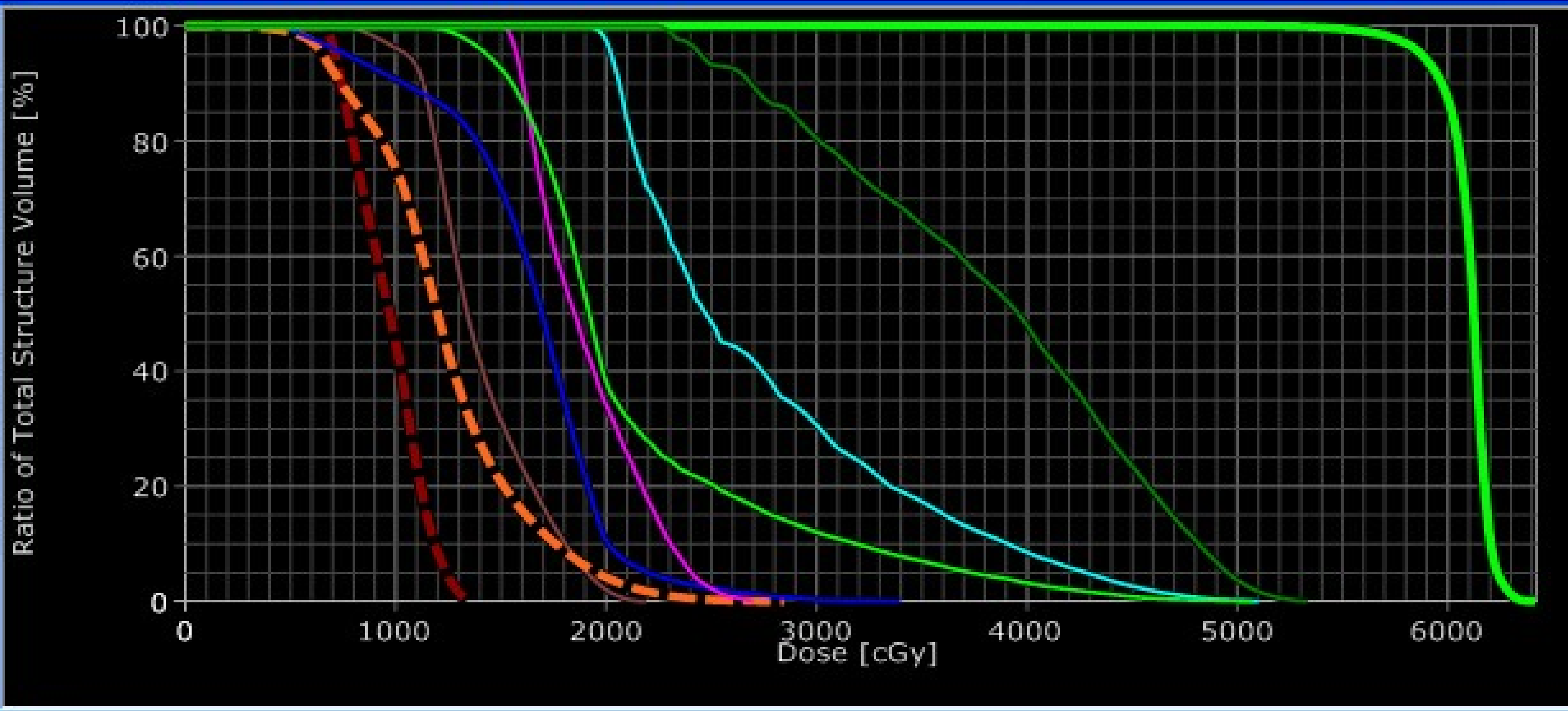
Couch: 90°

IMRT for paranasal sinus and Nasal Cavity Tumors. Duthoy and De Neve, ‘IMRT for paranasal sinus and nasal cavity (sino-nasal) tumors’, Image Guided IMRT

Example



Rx: 6000 cGy



Structure	Max	Mean
CORD	1353.6	965.4
EXP CORD	2862.5	1234.1
PTV_60	6422.9	6099.0
OPTIC CHIASM	2708.6	1906.6
R OPTIC NERVE	5340.2	3829.5
L OPTIC NERVE	5107.5	2742.6
R GLOBE	5076.6	2139.7
L GLOBE	3399.8	1635.6
BRAINSTEM	2191.1	1402.1

Overview

- Immobilization and Localization

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    - Sinus
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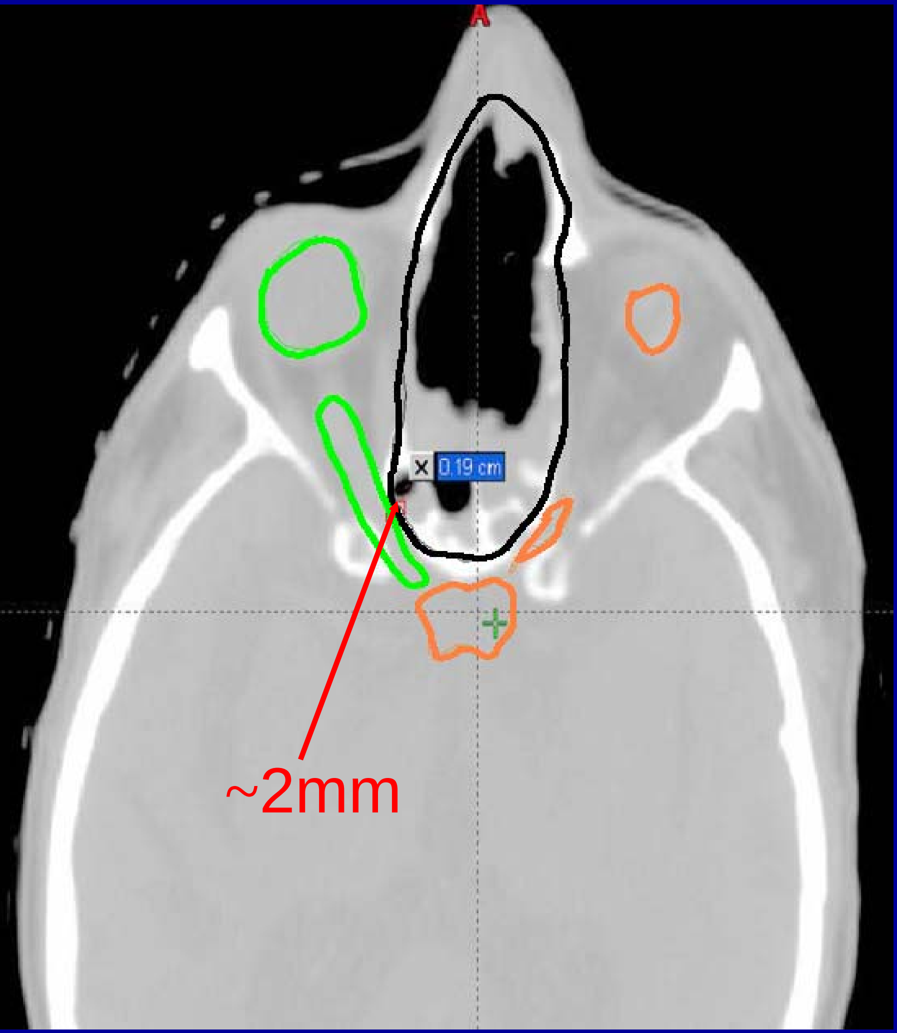
Retreatments

- Retreatments are difficult
- Often have to deliver high dose (>50Gy) in close proximity to OAR's that have already received (up to) tolerance dose
- Often need high number of beam/couch angles
- Use fixed jaws to protect OAR's
- Cord / expanded cord dose limits:

  Cord: 10-12Gy

  Expanded cord: 15Gy

Example: Sinus Retreat

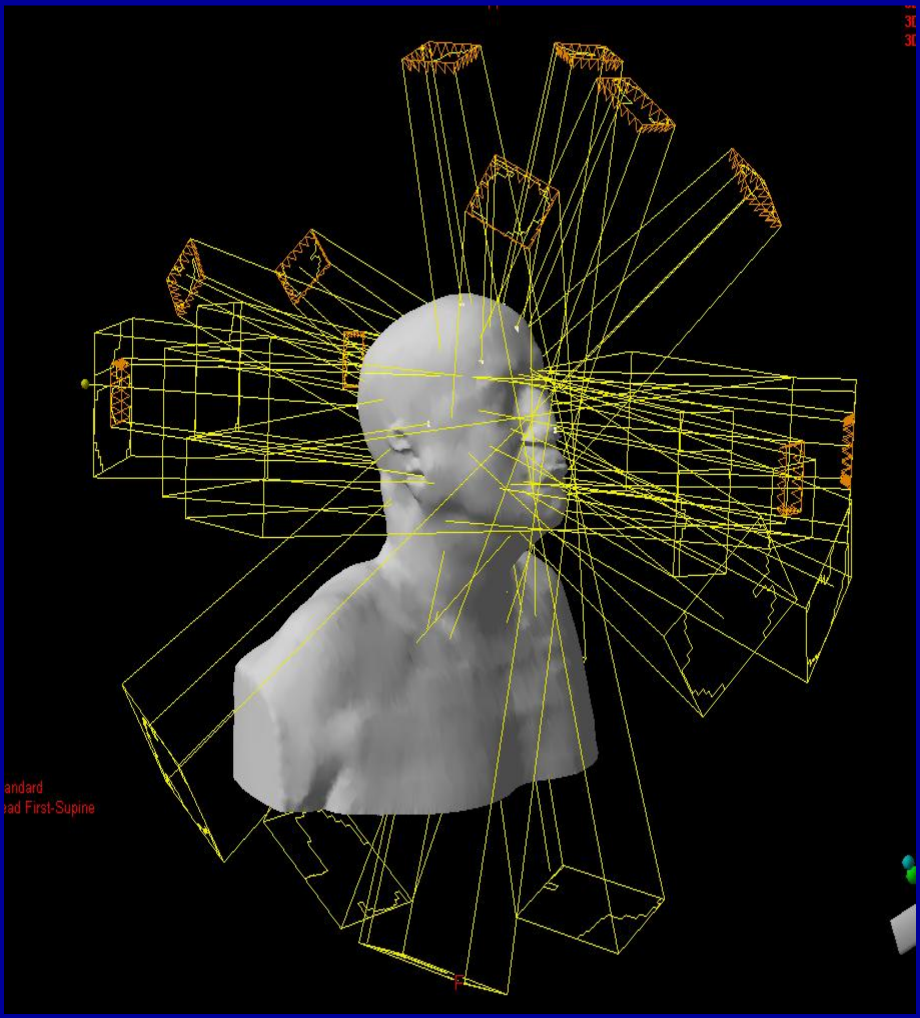


Patient had been previously
Treated to the sinus

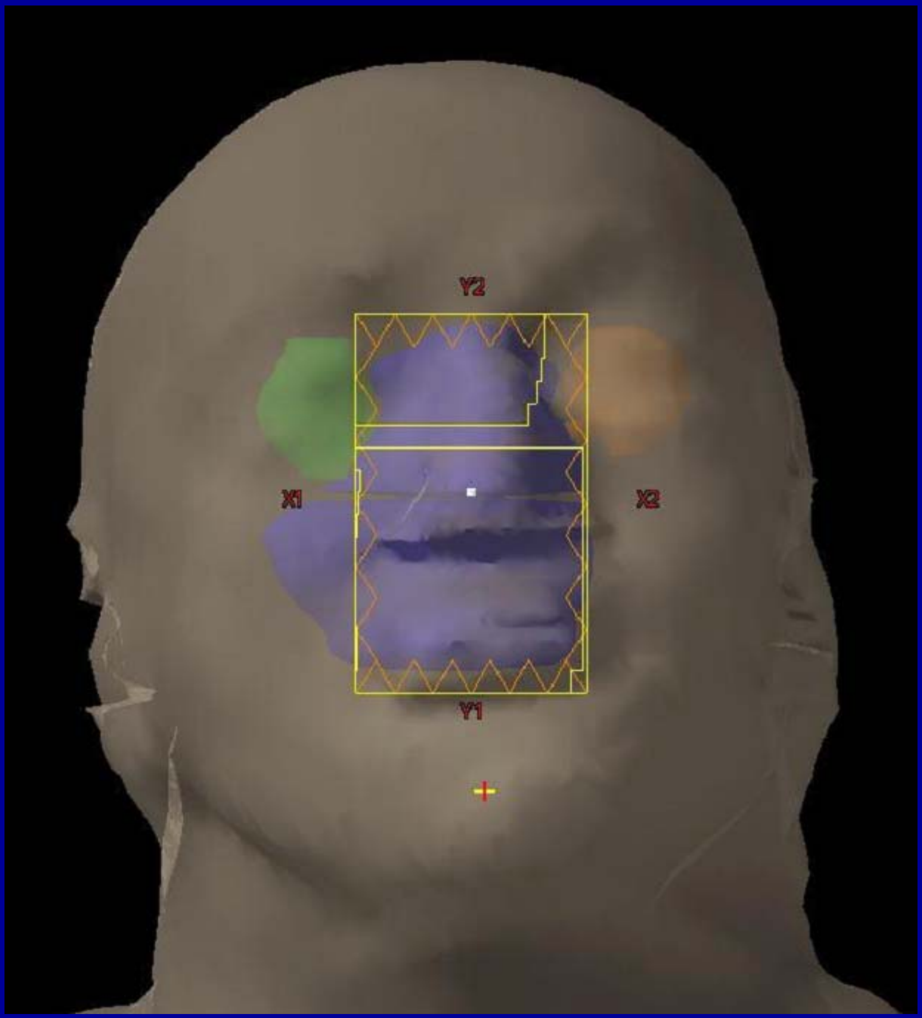
Optics: Previously treated to
Full tolerance

Recurrence: ~ 1yr after radiation
GTV ~ 2mm from
optics

Beam Configuration

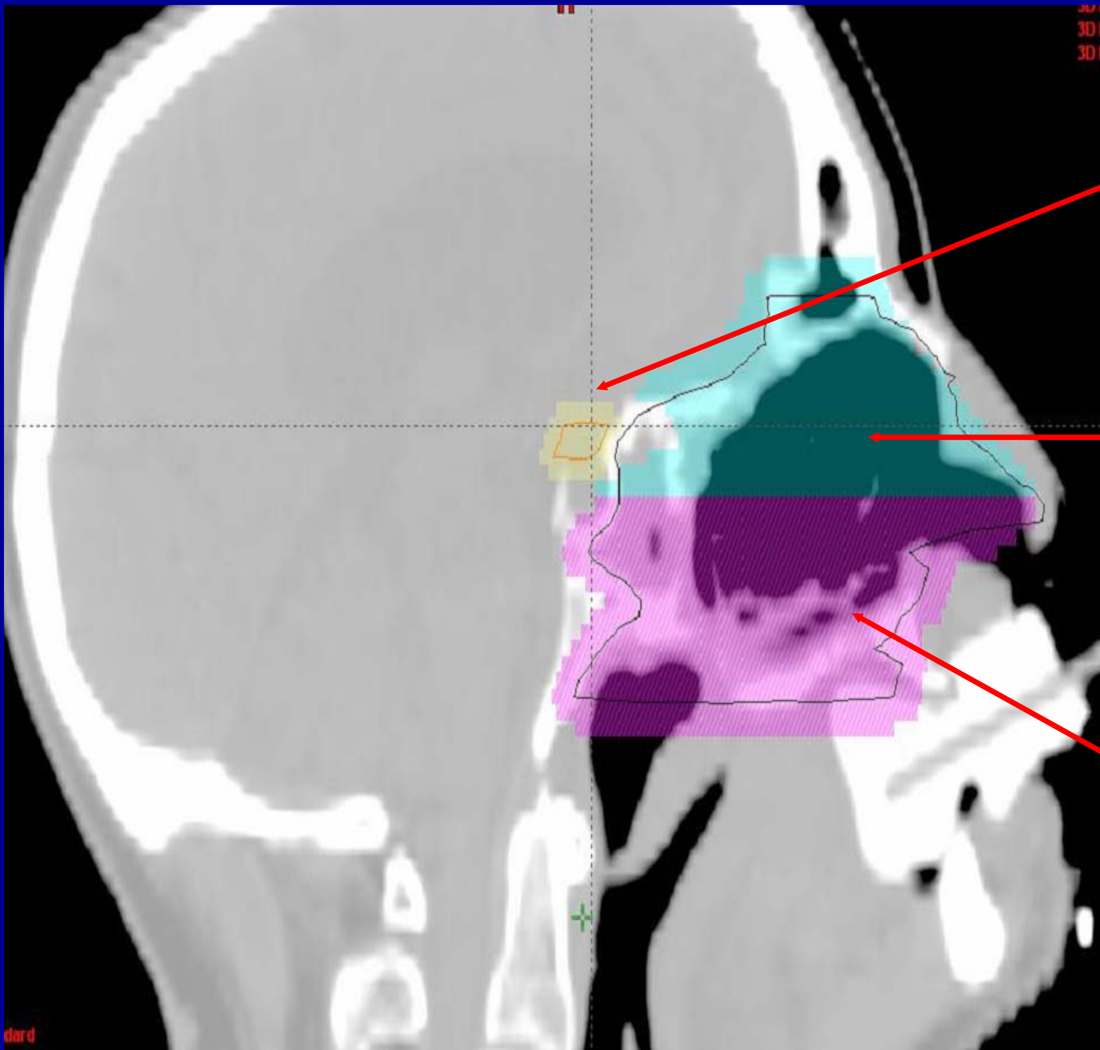


11 Beams, 7 couch angles



Fixed Beams

For Optimization

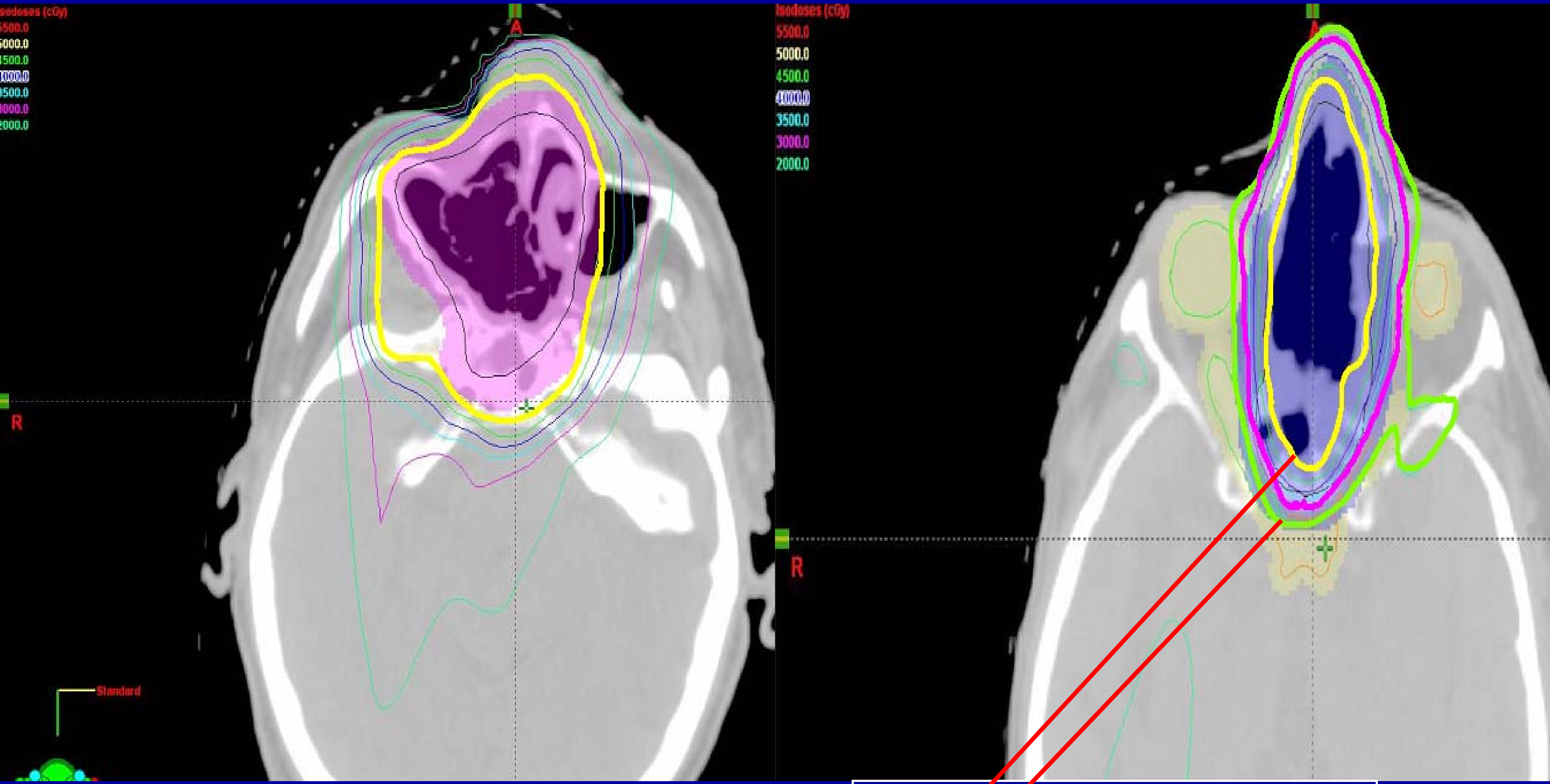


3mm margins on Optics

Sup dummy “PTV” pulled away from optic structures

Unmodified inferior PTV

Results



Dose fall off:
50Gy to 20 Gy < 1cm

Educational Objective

Discuss different approaches for the use of IMRT for treating head and neck tumors.

We discussed:

- immobilization and localization
- routine cases including 4 approaches for the treatment of the S/C
- H&N with extension into the mediastinum
- sinus
- re-irradiation

Review and guidelines for treating head and neck tumors using IMRT and VMAT

Volume-Modulated Arc Therapy

Charles Mayo, Ph.D.

Mayo Clinic

Rochester, MN

WE-B-203-1
Wednesday 8:30 am -9:25 am Room 203

MAYO CLINIC

Disclosure

- Grant support from Varian Medical Systems

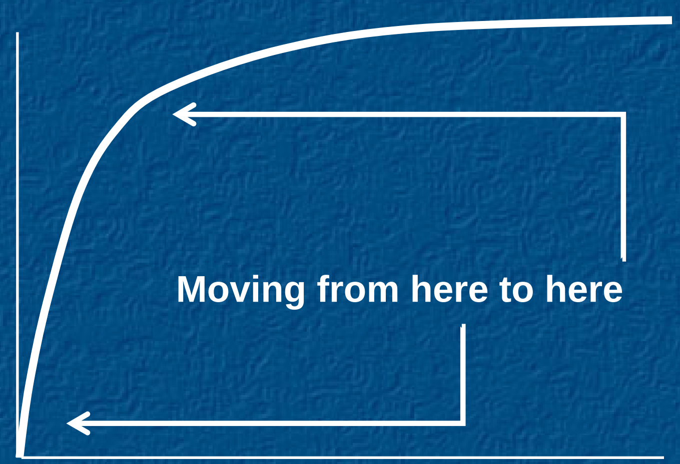
Outline

- Brief review of VMAT
- Advantages / disadvantages of VMAT vs. IMRT
- Tips on planning VMAT cases
- Comparison of VMAT and IMRT plans (including some special cases covered in IMRT portion)
- Table attenuation correction
- QA for RapidArc (? Depends on time)

Where we thought the challenges would lie and where they actually did emerge.

The Learning Curve

Probability of getting the desired plan



What is Volumetric Modulate Arc Therapy (VMAT)?

- IMRT modulates MLC's during beam on to shape the 2D beam profile on a fixed angle beam. Combine beams for a 3D dose distribution.
- VMAT modulates MLC's, gantry speed, dose rate during beam on to shape the 3D dose distribution from arc beams.
- Available in most treatment planning systems
  - **Eclipse (RapidArc)** examples in this presentation
  - Pinnacle (Smart Arc)
  - CMS (Monaco with VMAT)

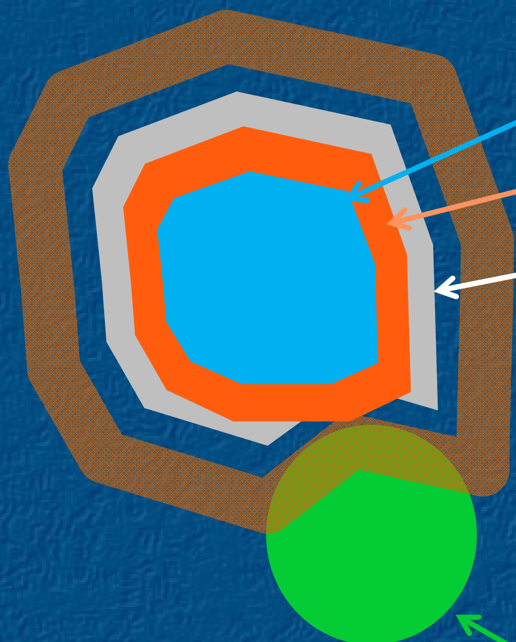
Why VMAT?

- Fewer Beams
  - 2-3 Arcs vs 9-18 (carriage splits)
  - Improves QA process
    - Improves 2nd check process on plans
    - Reduces time for QA measurements
  - Shorter Treatment Time
    - Patient satisfaction
    - Reduced potential for intra-fraction motion
    - Better utilization of FTE and technology resources
    - Create more available time for IGRT

Why VMAT?

- Potential for improved planning
  - Arc distributions help reduce intermediate dose level exposures.
  - Difficult to over modulate a RapidArc beam. Less likely to fail in QA measurements when normal tissue constraints are pushed.
  - Templated approach to planning that may raise the bar on base plan quality.

Basic planning approach: we use the same <u>contouring based</u> approach to planning for RapidArc that we developed and reported for IMRT many years ago.



CTV

Important to follow ICRU definitions

PTV

IMRT PTV

- Optimize on the IMRT PTV
- Margin to compensate for shoulders on profile
- Modify to reflect normal tissue compromises

Dose Limiting Annulus

- To control intermediate dose levels

Normal Tissue to Avoid

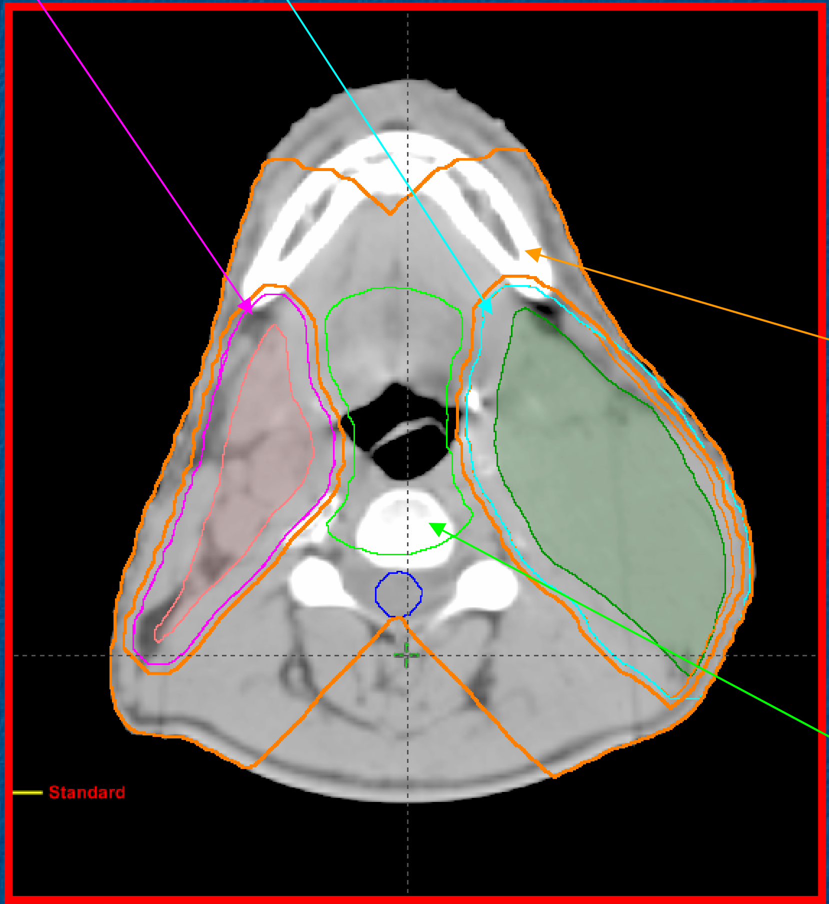
- Contour actual anatomy
- Add separate buffer structures as needed

In several of the clinical examples to follow you will see extensions of this basic contour orient approach to planning.

Dose Sculpting Structures

PTV 54 Gy

PTV 60 Gy



IMRT PTVs are cropped back from surface by 4 mm.

- ✓ Optimize to IMRT PTV
- ✓ Normalize/Evaluate PTV

DLA: Defines intermediate dose region for dose reduction

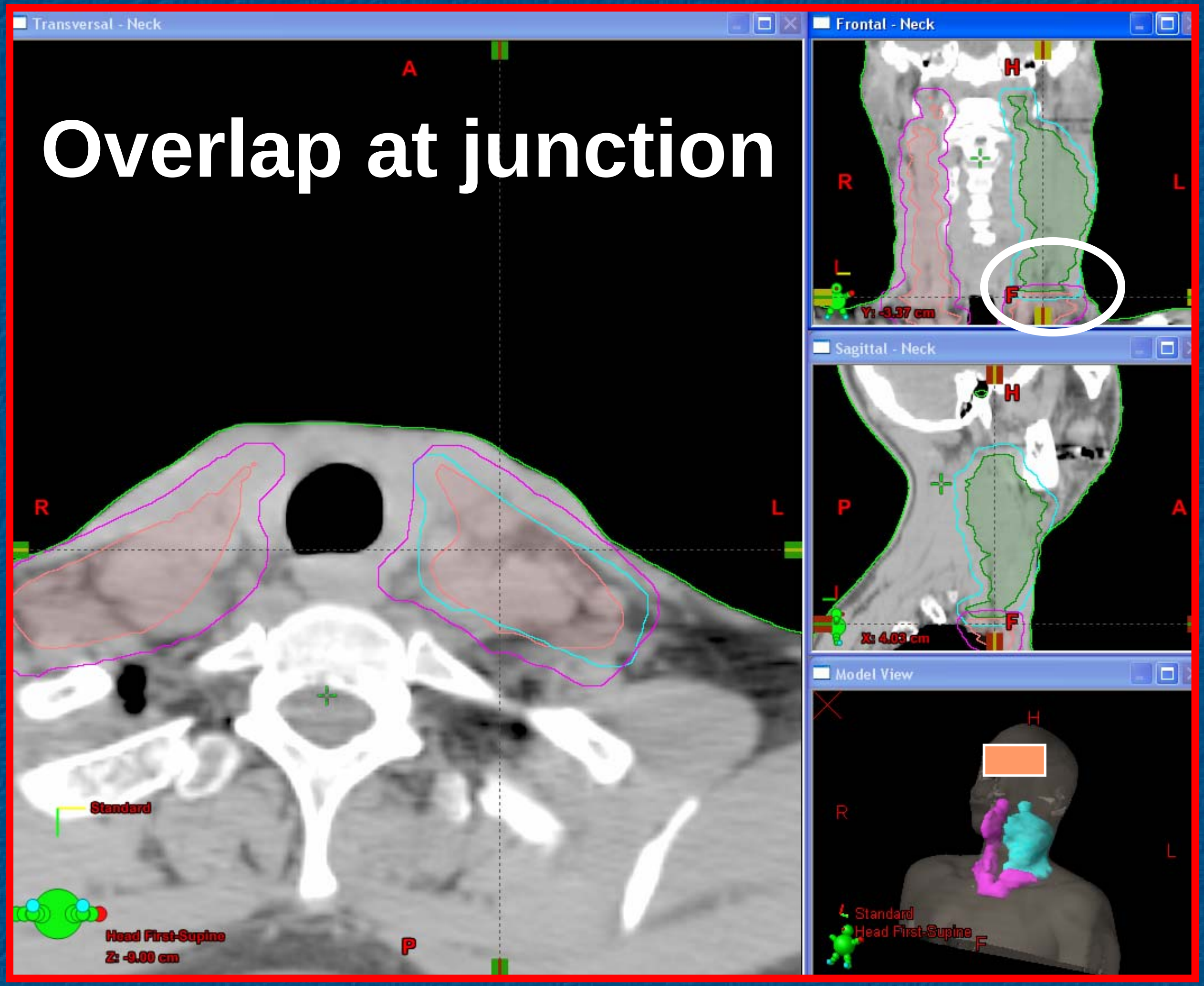
Buff: Specifies sub-region between target volumes to drive out "hot" spots

Contouring – Targets

Overlap at junction

GTV
CTV
PTV

IMRT-PTV

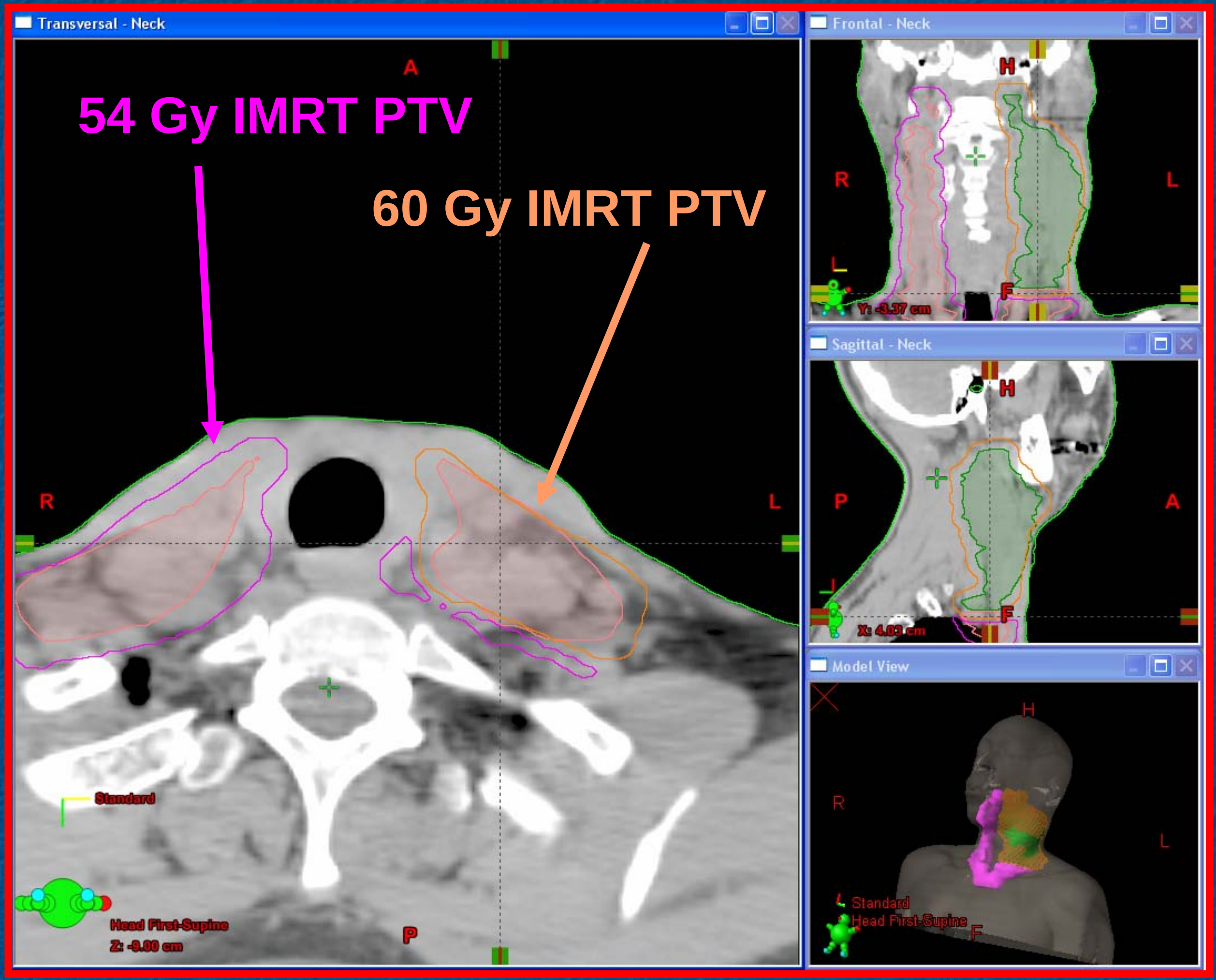


MAYO CLINIC

Contouring – Targets

Fix with IMRT PTV

Crop IMRT PTVs in overlap region to reflect which gets the higer priority for coverage. More intuitive than trying to do this in the optimizer with overlapping structures.

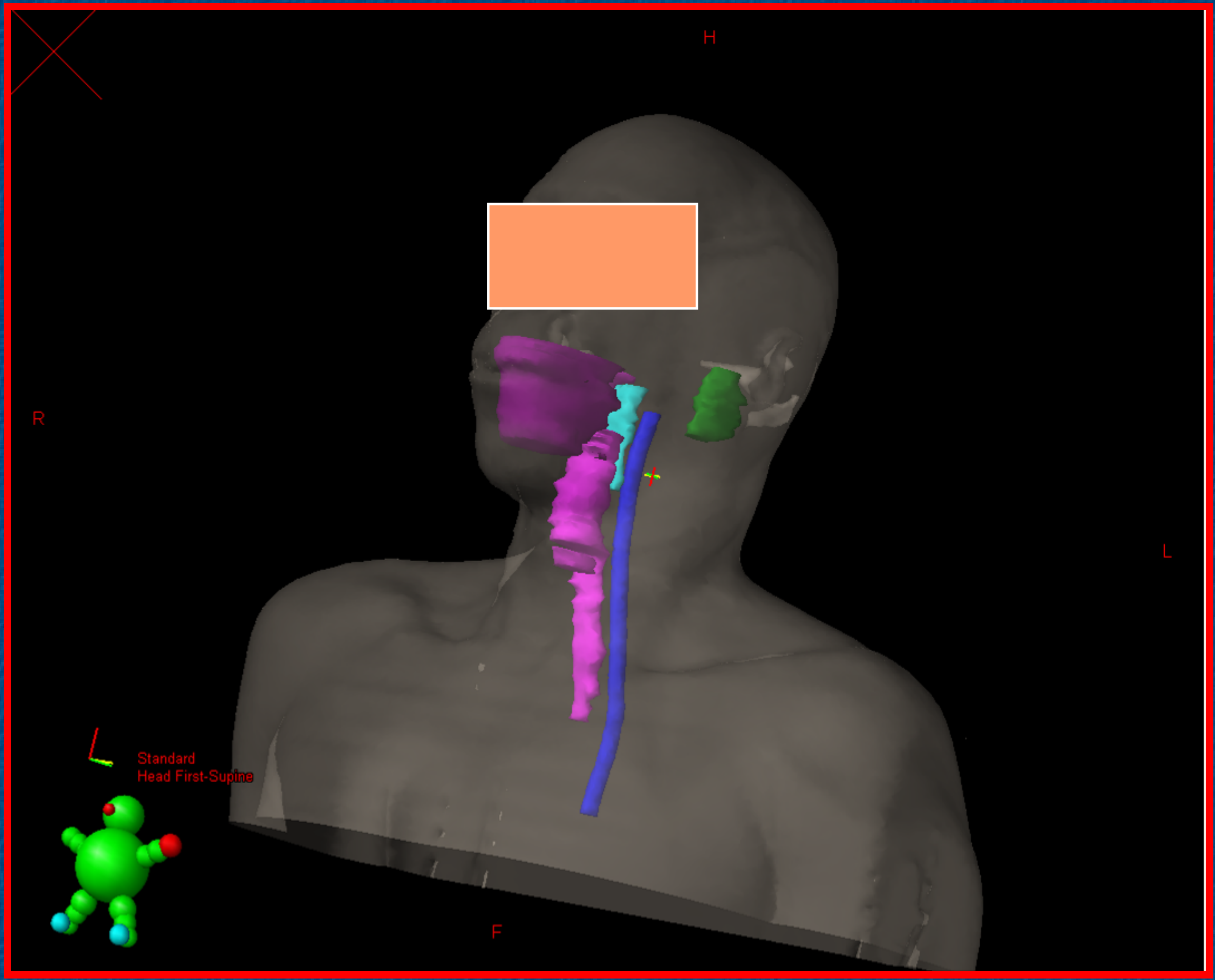


MAYO CLINIC

Normal Structures

It is important to try to contour the actual anatomic structures, in order to make meaningful comparisons of normal tissue constraints or complications.

Use buffer or sculpting structures to control dose gradients.

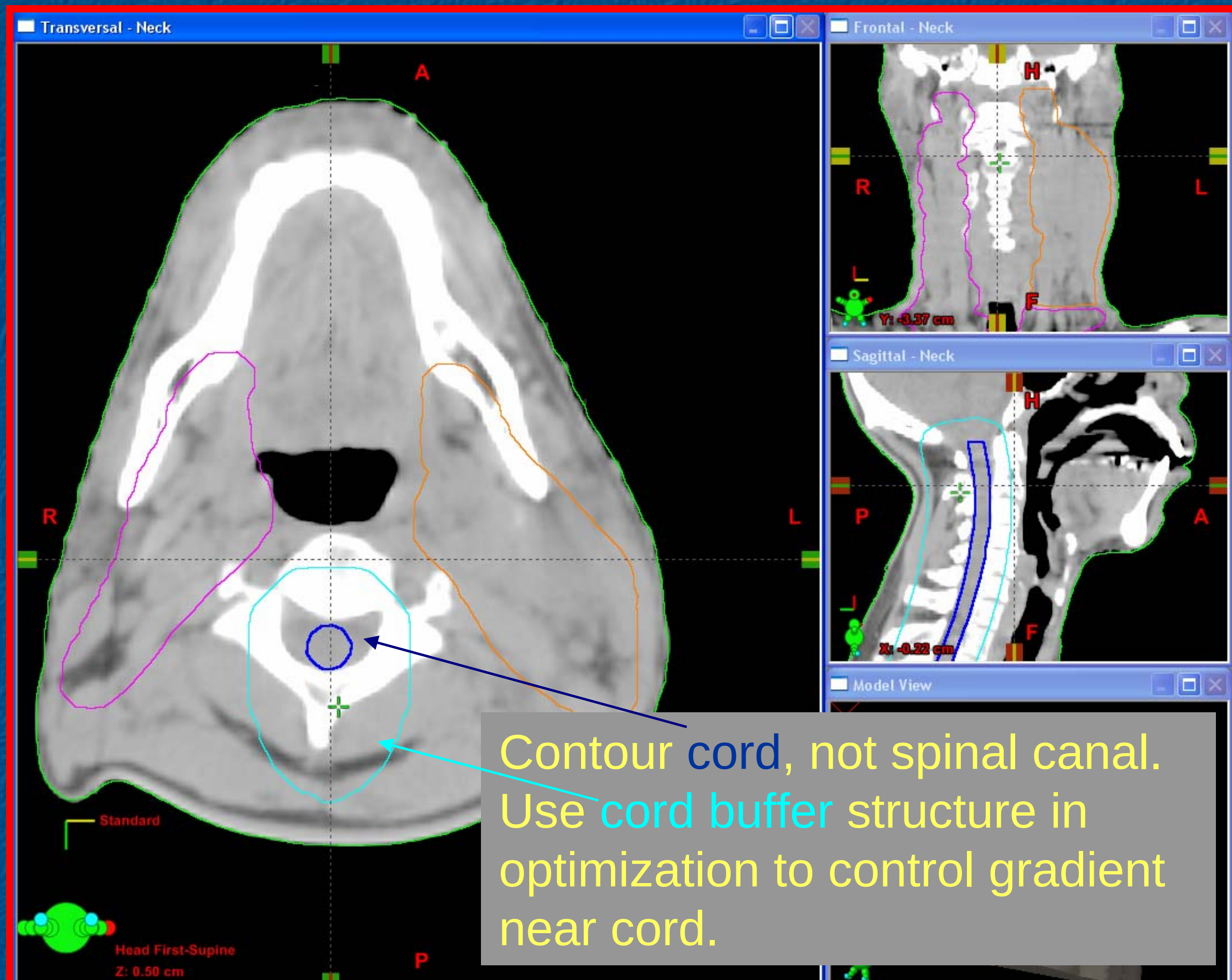


MAYO CLINIC

Dose Sculpting Structures

Cord Buffer

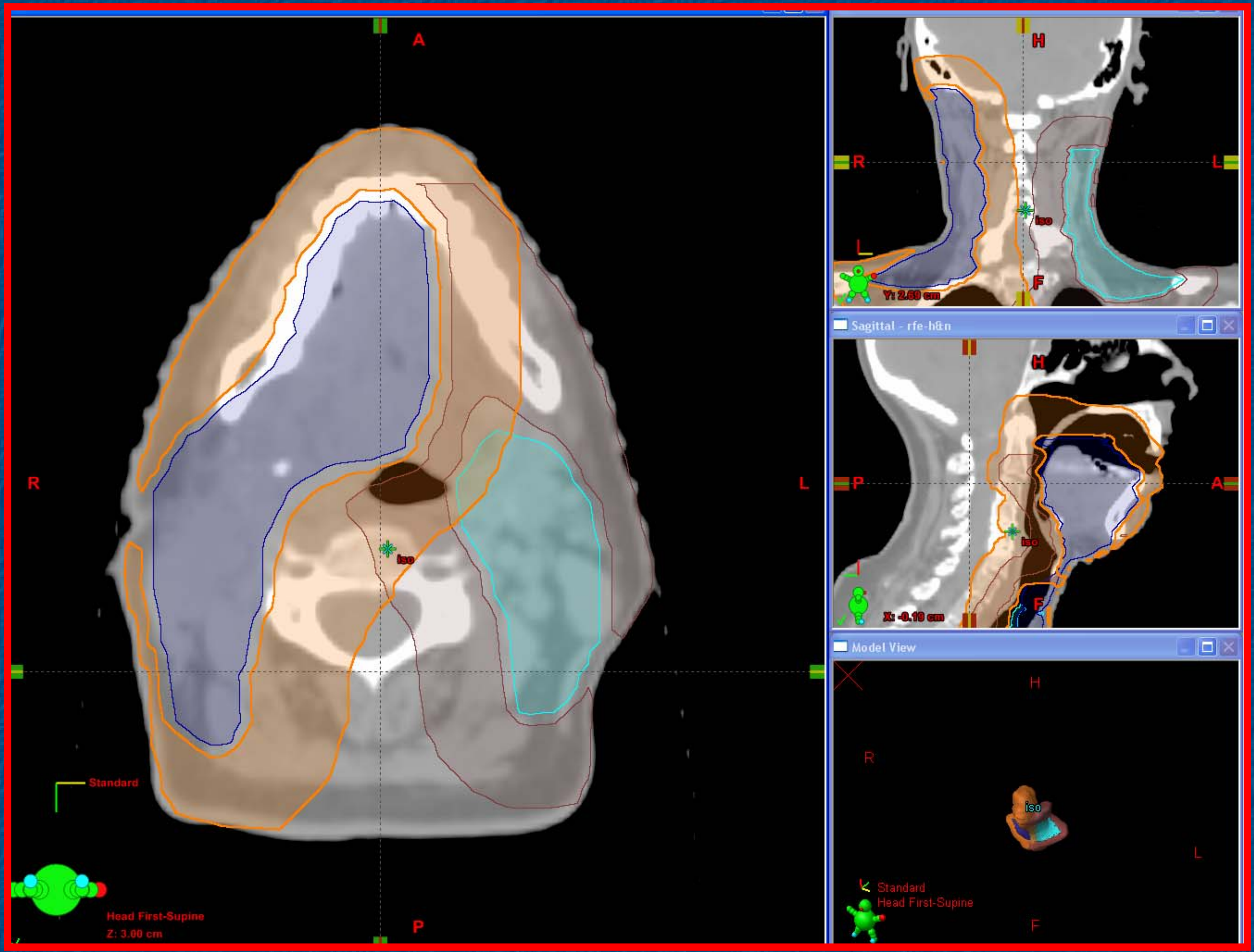
Contour normal structures to be anatomically correct. Include a buffer on normal tissues to control gradient of dose near to normal tissue.



Contour cord, not spinal canal. Use cord buffer structure in optimization to control gradient near cord.

2 Level DLA

For dose painting (e.g. 60 Gy and 54 Gy targets) two DLA's may be helpful.

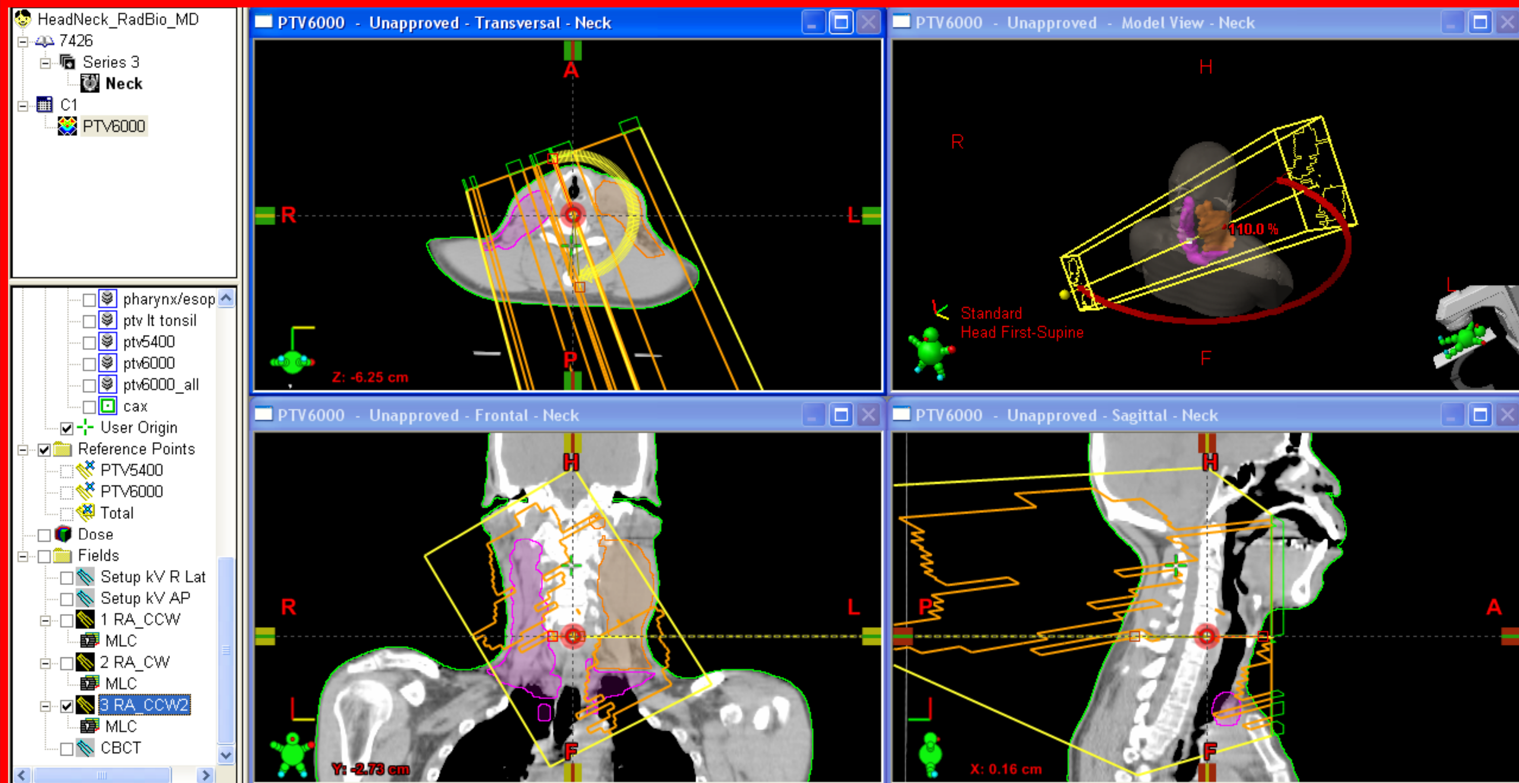


MAYO CLINIC

Beam Selection

Group	Field ID	Technique	Machine/Energy	MLC	Field Weight	Scale	Gantry Rtn [deg]	Coll Rtn [deg]	Couch Rtn [deg]	Wedge	Field X [cm]	X1 [cm]	X2 [cm]	Field Y [cm]	Y1 [cm]	Y2 [cm]	X [cm]	Y [cm]	Z [cm]	SSD [cm]	MU	Ref. D [cGy]
✓	Setup kV R Lat	STATIC-I	T1 Trilogy - 6X		1.000	Varian IEC	270.0	0.0	0.0	None	15.0	+7.5	+7.5	22.0	+9.0	+13.0	0.2	-2.7	-6.3	94.0		
✓	Setup kV AP	STATIC-I	T1 Trilogy - 6X		1.000	Varian IEC	0.0	0.0	0.0	None	15.0	+7.5	+7.5	22.0	+9.0	+13.0	0.2	-2.7	-6.3	95.6		
✓	1 RA_CCW	ARC-I	T1 Trilogy - 6X	Dose Dyn. Arc	1.000	Varian IEC	175.0	30.0	0.0	None	15.0	+7.5	+7.5	22.0	+9.0	+13.0	0.2	-2.7	-6.3	92.0	194	
✓	2 RA_CW	ARC-I	T1 Trilogy - 6X	Dose Dyn. Arc	1.000	Varian IEC	185.0	330.0	0.0	None	15.0	+7.5	+7.5	22.0	+9.0	+13.0	0.2	-2.7	-6.3	92.0	206	
✓	3 RA_CCW2	ARC-I	T1 Trilogy - 6X	Dose Dyn. Arc	1.000	Varian IEC	340.0	30.0	0.0	None	15.0	+7.5	+7.5	22.0	+9.0	+13.0	0.2	-2.7	-6.3	95.7	133	
✓	CBCT	STATIC-I	T1 Trilogy - 6X		1.000	Varian IEC	0.0	0.0	0.0	None	15.0	+7.5	+7.5	22.0	+9.0	+13.0	0.2	-2.7	-6.3	95.6		

Beam Selection

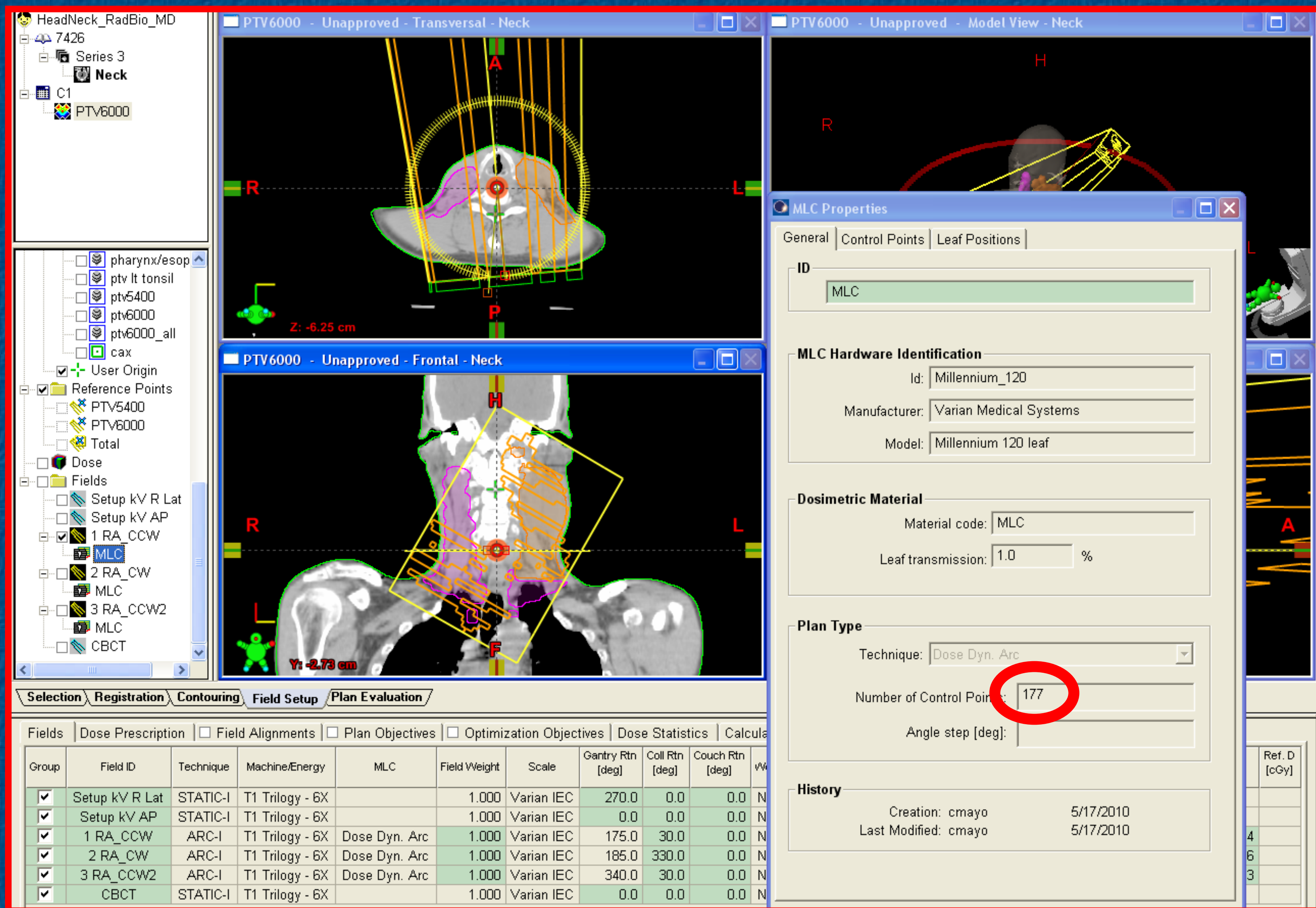


Selection | Registration | Contouring | Field Setup | Plan Evaluation

Fields | Dose Prescription | Field Alignments | Plan Objectives | Optimization Objectives | Dose Statistics | Calculation Models | Plan Sum

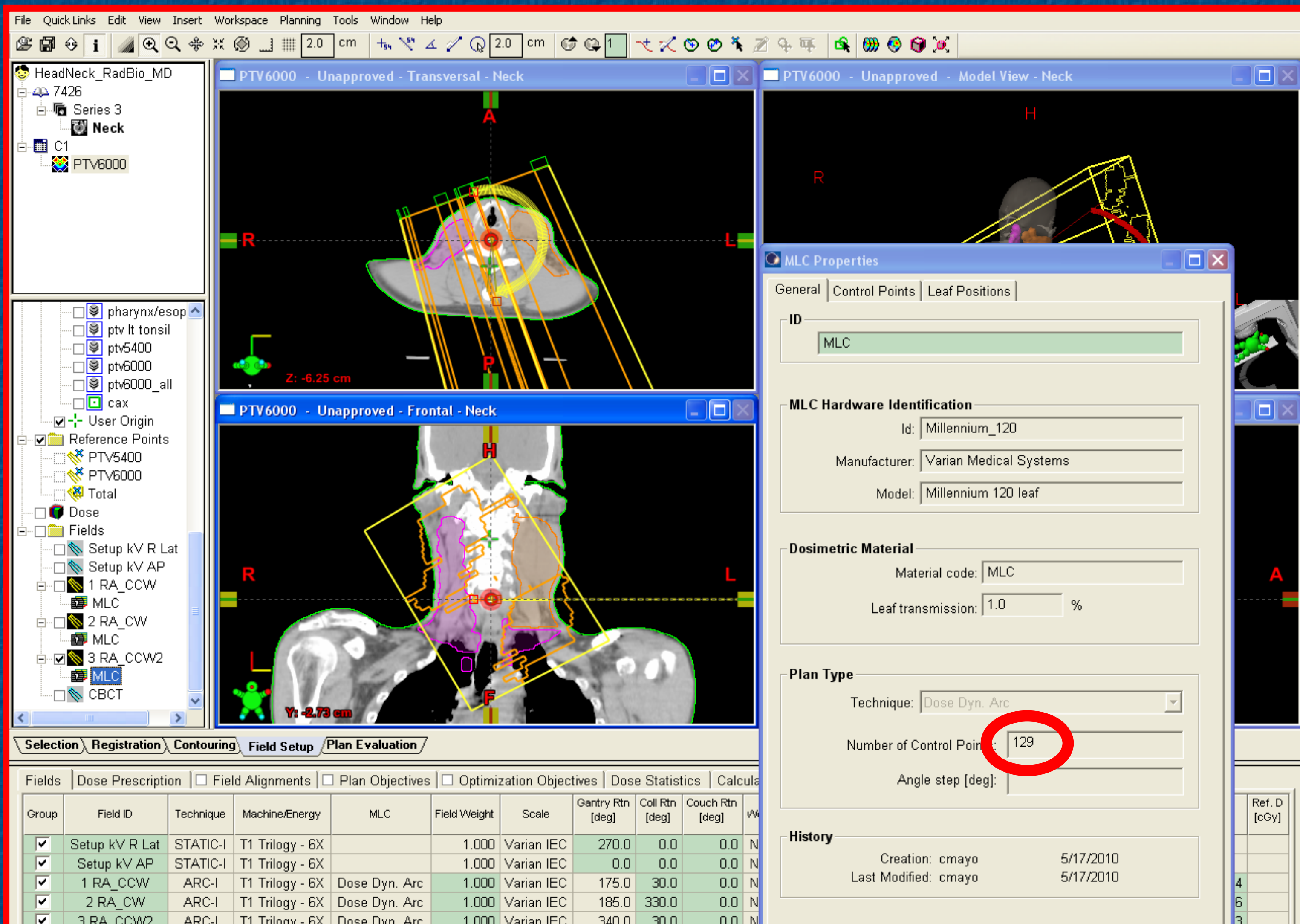
Group	Field ID	Technique	Machine/Energy	MLC	Field Weight	Scale	Gantry Rtn [deg]	Coll Rtn [deg]	Couch Rtn [deg]	Wedge	Field X [cm]	X1 [cm]	X2 [cm]	Field Y [cm]	Y1 [cm]	Y2 [cm]	X [cm]	Y [cm]	Z [cm]	SSD [cm]	MU	Ref. D [cGy]
✔	Setup kV R Lat	STATIC-I	T1 Trilogy - 6X		1.000	Varian IEC	270.0	0.0	0.0	None	15.0	+7.5	+7.5	22.0	+9.0	+13.0	0.2	-2.7	-6.3	94.0		
✔	Setup kV AP	STATIC-I	T1 Trilogy - 6X		1.000	Varian IEC	0.0	0.0	0.0	None	15.0	+7.5	+7.5	22.0	+9.0	+13.0	0.2	-2.7	-6.3	95.6		
✔	1 RA_CCW	ARC-I	T1 Trilogy - 6X	Dose Dyn. Arc	1.000	Varian IEC	175.0	30.0	0.0	None	15.0	+7.5	+7.5	22.0	+9.0	+13.0	0.2	-2.7	-6.3	92.0	194	
✔	2 RA_CW	ARC-I	T1 Trilogy - 6X	Dose Dyn. Arc	1.000	Varian IEC	185.0	330.0	0.0	None	15.0	+7.5	+7.5	22.0	+9.0	+13.0	0.2	-2.7	-6.3	92.0	206	
✔	3 RA_CCW2	ARC-I	T1 Trilogy - 6X	Dose Dyn. Arc	1.000	Varian IEC	340.0	30.0	0.0	None	15.0	+7.5	+7.5	22.0	+9.0	+13.0	0.2	-2.7	-6.3	95.7	133	
✔	CBCT	STATIC-I	T1 Trilogy - 6X		1.000	Varian IEC	0.0	0.0	0.0	None	15.0	+7.5	+7.5	22.0	+9.0	+13.0	0.2	-2.7	-6.3	95.6		

Control Points

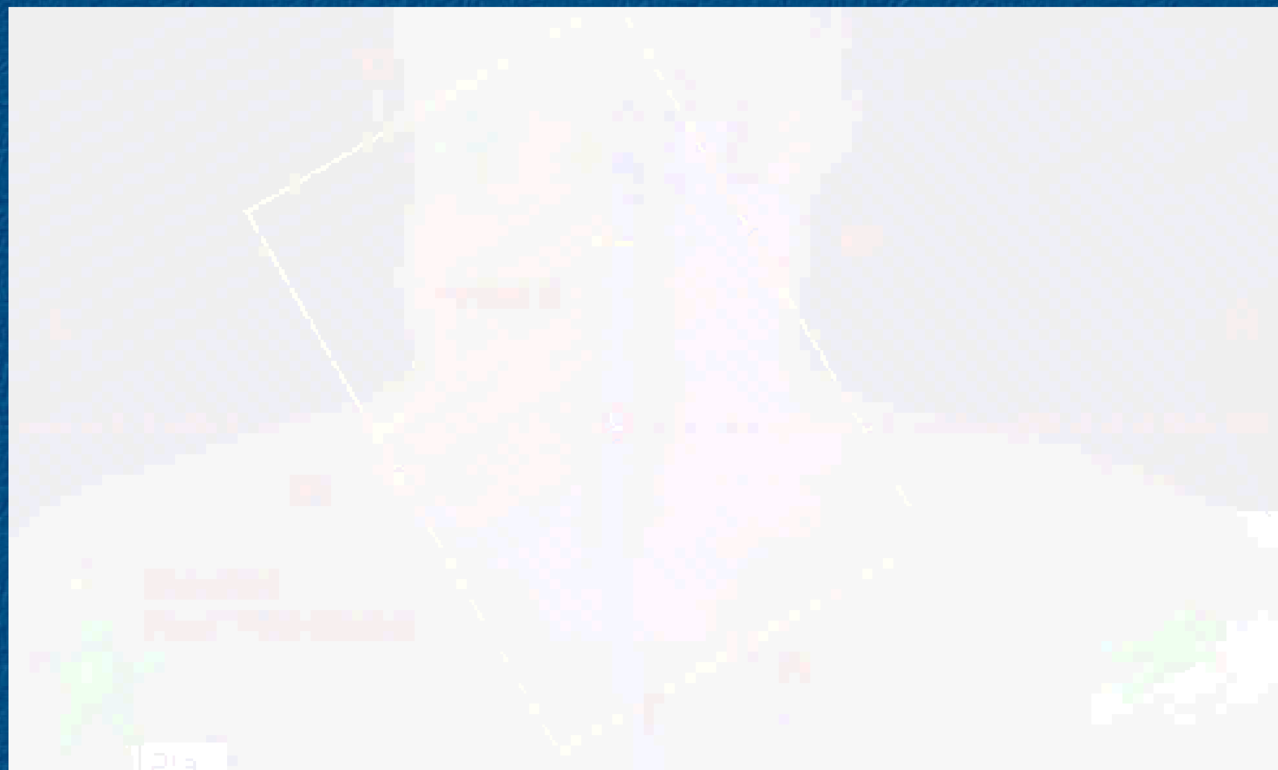


Control Points

Get other beam 126 vs 177



Beam Selection
Two Dose Levels (60Gy/54Gy)



1) Clockwise
2) Counter Clockwise
3) Partial On High Dose Volume

Total of 732 MU and 483 control points with RapidArc vs.1260 MU and 2020 control points for 9 field IMRT with carriage splits. More efficient use of MU's and MLC's to deliver the same dose.

MAYO CLINIC

Is it complicated to design the constraints?

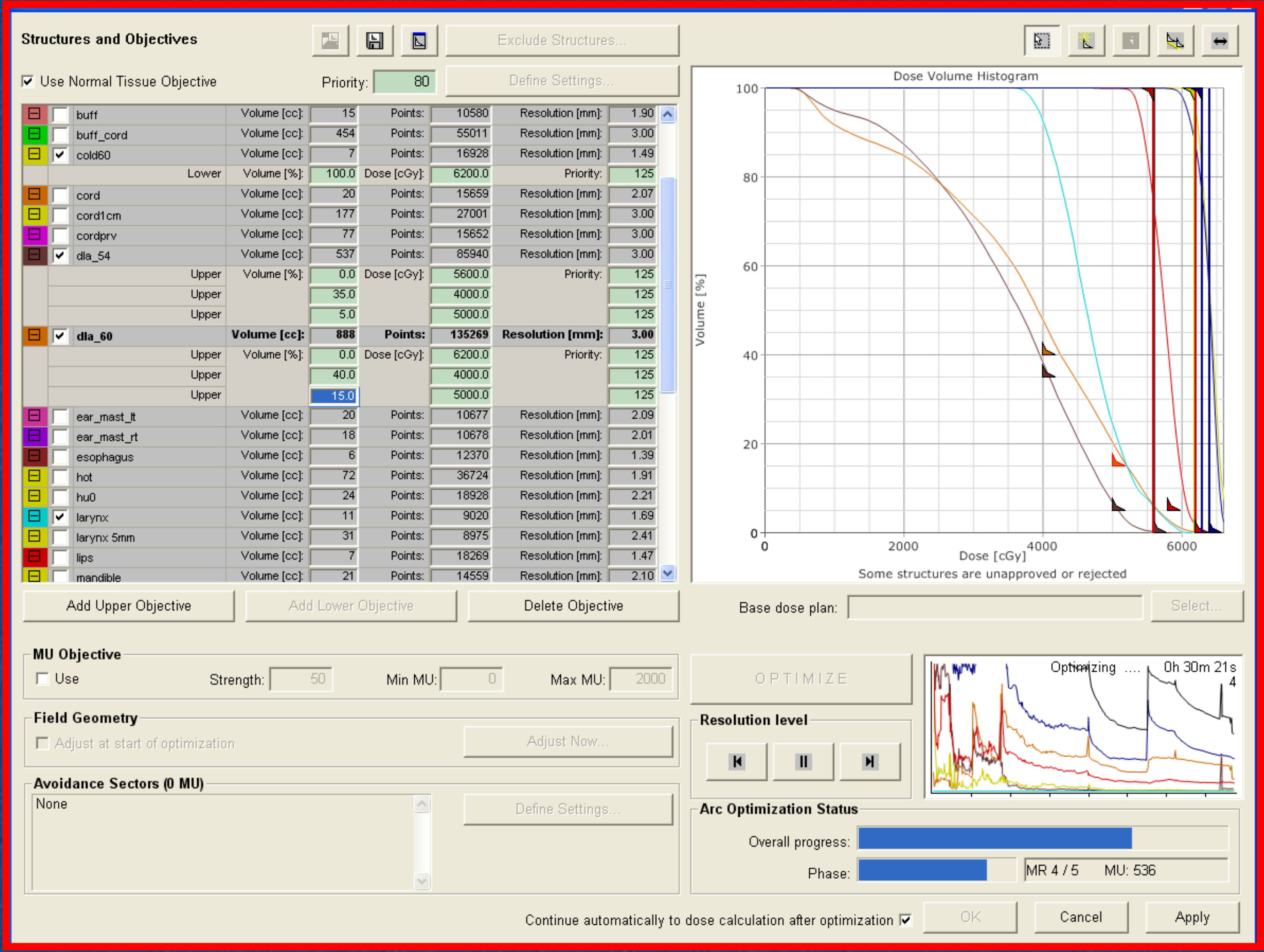
Start simple to understand the behavior then refine.

Is it complicated to design the constraints?

Minimal Optimization

If you just push on the constraints to have a conformal dose distribution, how do the dose levels in the normal structures turn out?

✓Cover IMRT PTV's
✓Minmize High dose in DLA's
✓Use NTO



MAYO CLINIC

Is it complicated to design the constraints?

Minimal Optimization

Original IMRT plan was designed with specific constraints for the normal tissues.

Simple approach to VMAT produced lower dose in

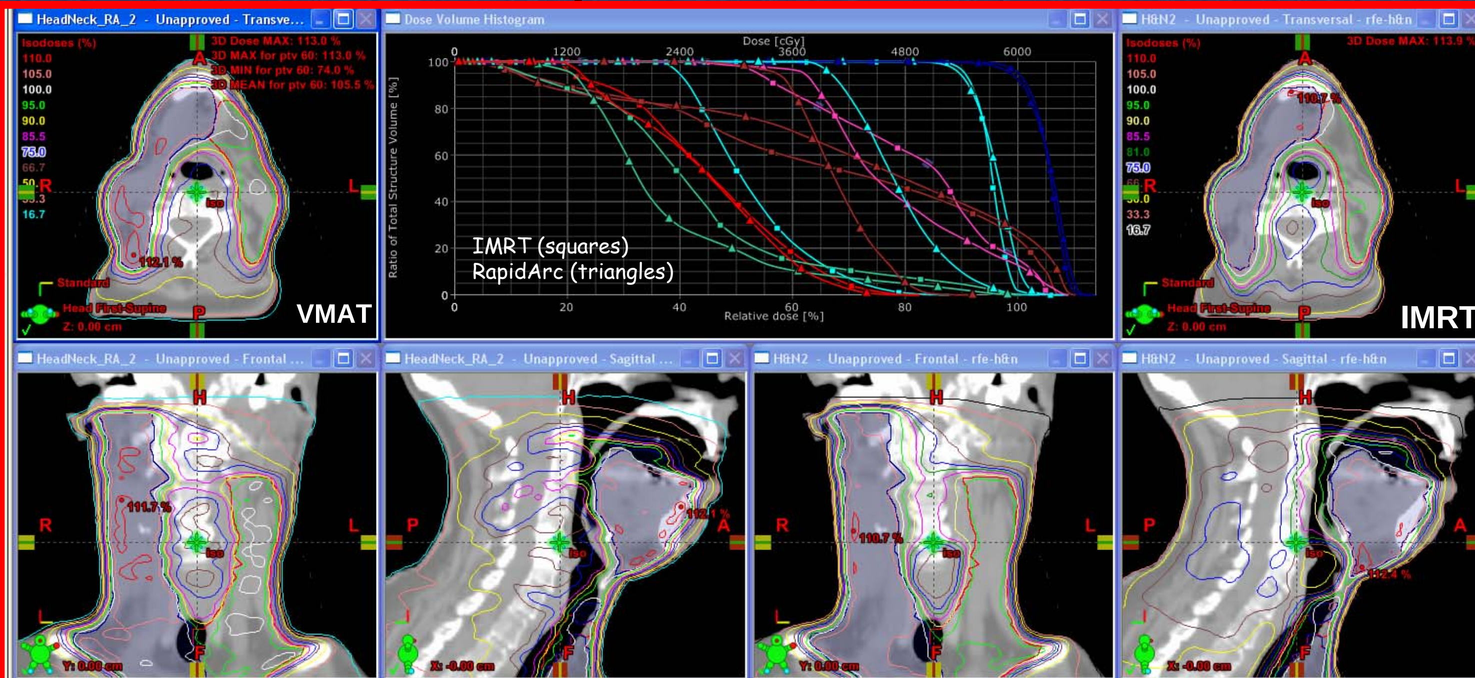
- L Parotid
- Phar Constrictors

Higher dose in

- Cord
- R Parotid

We can do better with more and specific constraints, but this simplistic approach takes us well along the way to a desirable plan.

MAYO CLINIC



Registration | Contouring | Field Setup | Plan Evaluation

ose Prescription | Dose Statistics | Plan Sum

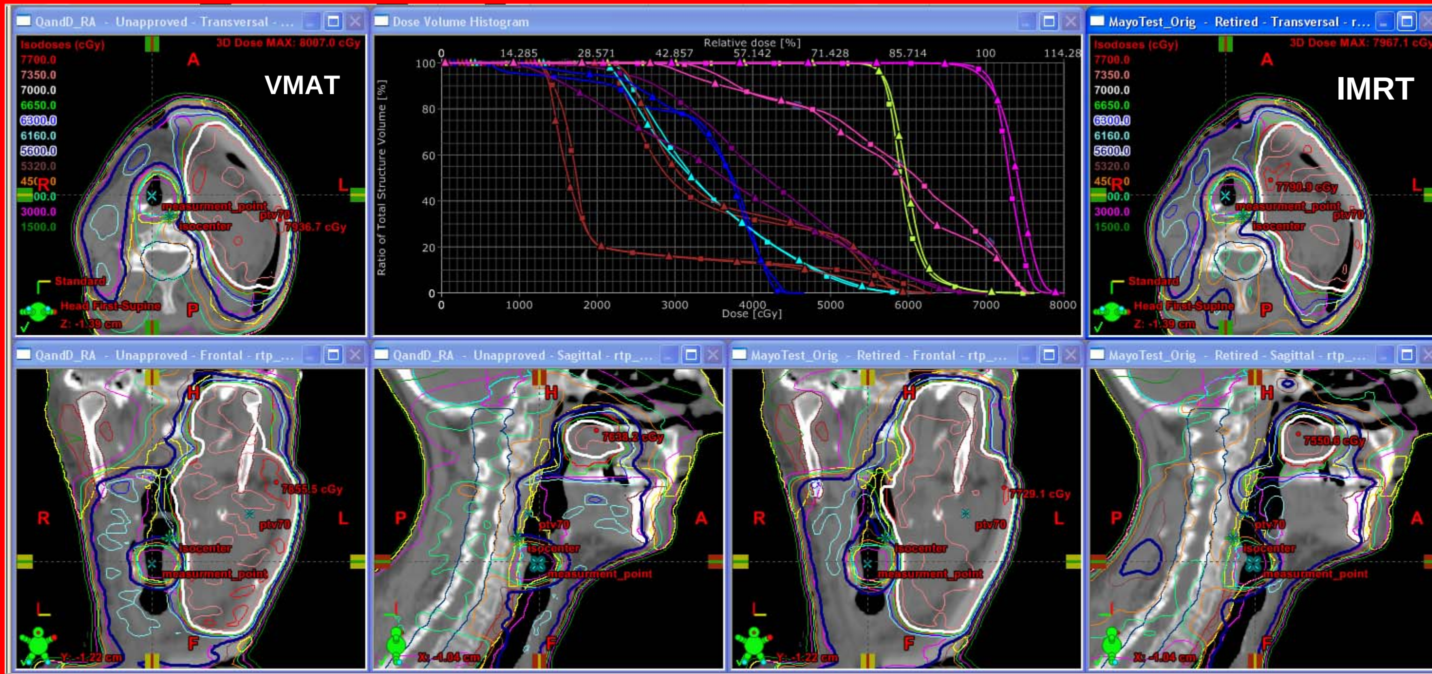
VH Line	Structure	Approval Status	Plan	Course	Volume [cm³]	Dose Cover.[%]	Sampling Cover.[%]	Min Dose [%]	Max Dose [%]	Mean Dose [%]
	ptv 60	Approved	H&N2	Planning	406.9	100.0	100.1	77.8	113.9	105.4
	ptv 60	Approved	HeadNeck_RA_2	Planning	406.9	100.0	100.1	74.0	113.0	105.5
	ptv 54	Approved	H&N2	Planning	213.9	100.0	100.1	73.1	109.1	95.3
	ptv 54	Approved	HeadNeck_RA_2	Planning	213.9	100.0	100.1	75.8	108.2	96.1
	pharyng_constr	Approved	H&N2	Planning	6.0	100.0	105.5	40.5	106.4	82.2
	pharyng_constr	Approved	HeadNeck_RA_2	Planning	6.0	100.0	105.5	36.3	109.1	78.7
	parotid_rt	Approved	H&N2	Planning	14.7	100.0	100.7	4.4	107.5	68.4
	parotid_rt	Approved	HeadNeck_RA_2	Planning	14.7	100.0	100.7	6.7	110.3	72.5
	parotid_lt	Approved	H&N2	Planning	17.0	100.0	100.4	5.1	98.3	42.9
	parotid_lt	Approved	HeadNeck_RA_2	Planning	17.0	100.0	100.4	11.0	100.6	38.0
	lips	Approved	H&N2	Planning	7.1	100.0	101.3	14.7	82.6	46.0
	lips	Approved	HeadNeck_RA_2	Planning	7.1	100.0	101.3	16.7	82.7	44.6
	larynx	Approved	H&N2	Planning	10.8	100.0	100.3	36.8	88.0	52.9
	larynx	Approved	HeadNeck_RA_2	Planning	10.8	100.0	100.3	61.2	104.1	78.7
	esophagus	Approved	HeadNeck_RA_2	Planning	5.9	100.0	100.6	40.8	92.6	67.9

Is it complicated to design the constraints?

Try IMRT constraints on a first pass at a VMAT plan

Should we consider a VMAT plan instead of the current IMRT plan?

As a first pass, try re-optimizing with the same constraint set and the set of 3 VMAT beams.



se Prescription | Dose Statistics | Plan Sum

H Line	Structure	Approval Status	Plan	Course	Volume [cm³]	Dose Cover.[%]	Sampling Cover.[%]	Min Dose [cGy]	Max Dose [cGy]	Mean Dose [cGy]
	pharyng_constr	Approved	MayoTest_Orig	MayoTesting	9.1	100.0	100.8	2880.5	7554.2	5864.0
	pharyng_constr	Approved	QandD_RA	MayoTesting	9.1	100.0	100.8	2599.4	7586.9	5680.1
	parotid_rt	Approved	MayoTest_Orig	MayoTesting	17.4	100.0	100.2	1260.1	6316.8	2258.0
	parotid_rt	Approved	QandD_RA	MayoTesting	17.4	100.0	100.2	1216.4	6309.0	2140.5
	oral_nas_cav	Approved	MayoTest_Orig	MayoTesting	108.6	100.0	100.0	977.9	7138.1	4222.5
	oral_nas_cav	Approved	QandD_RA	MayoTesting	108.6	100.0	100.0	714.2	6946.5	3668.5
	larynx	Approved	MayoTest_Orig	MayoTesting	10.4	100.0	100.0	2161.1	6224.5	3454.7
	larynx	Approved	QandD_RA	MayoTesting	10.4	100.0	100.0	2088.1	6089.5	3418.1
	esophagus	Approved	MayoTest_Orig	MayoTesting	8.5	100.0	100.1	1987.0	6191.9	3527.6
	esophagus	Approved	QandD_RA	MayoTesting	8.5	100.0	100.1	2122.7	6114.0	3677.5
	cordN	Approved	MayoTest_Orig	MayoTesting	44.0	100.0	100.1	561.3	4664.5	3408.8
	cordN	Approved	QandD_RA	MayoTesting	44.0	100.0	100.1	790.9	4483.4	3501.7
	PTV 70 -3mm	Approved	MayoTest_Orig	MayoTesting	642.9	100.0	100.0	5362.2	7967.1	7303.8
	PTV 70 -3mm	Approved	QandD_RA	MayoTesting	642.9	100.0	100.0	5545.6	8007.0	7379.6
	PTV 56 -3mm	Approved	MayoTest_Orig	MayoTesting	491.1	100.0	100.0	4822.6	7634.9	5953.1
	PTV 56 -3mm	Approved	QandD_RA	MayoTesting	491.1	100.0	100.0	4388.9	7635.3	6008.2

MAYO CLINIC

Thanks to Shelly Ward

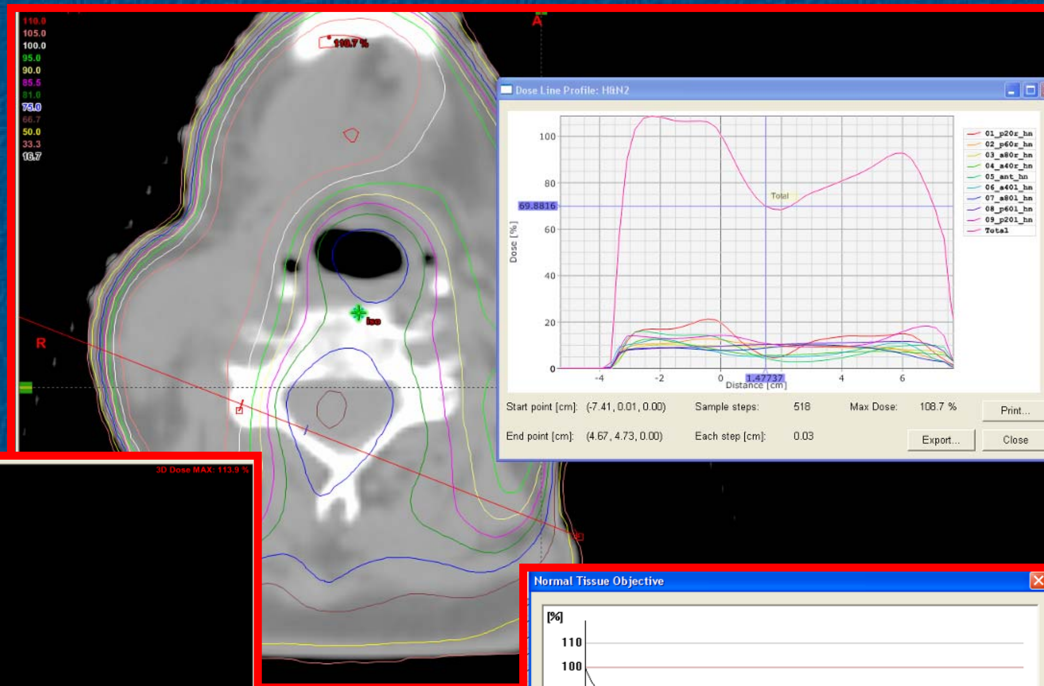
Setting the Normal Tissue Objective (NTO)

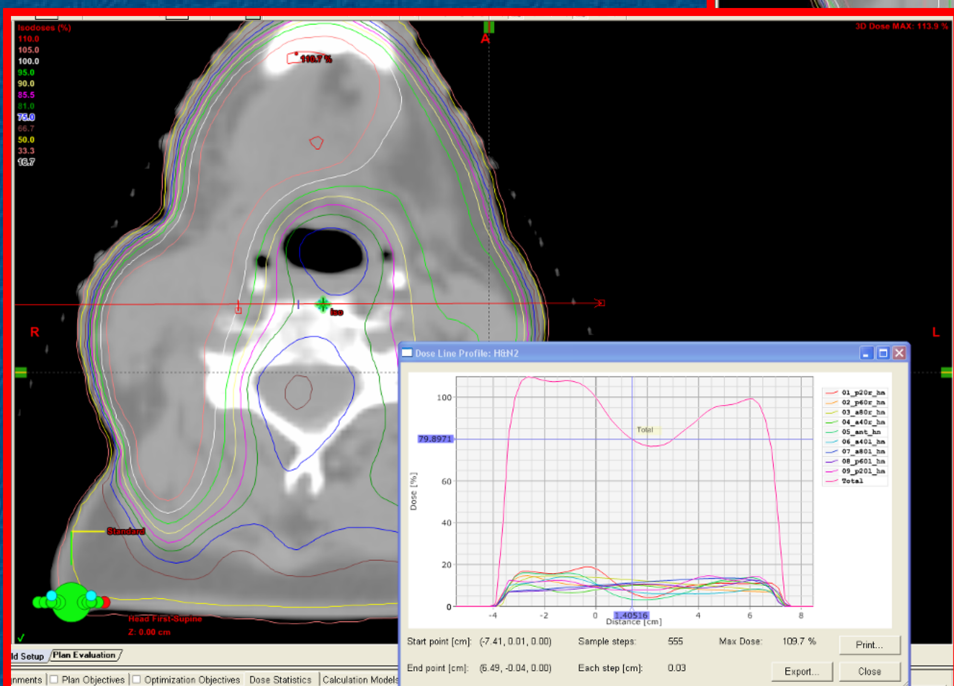
If you are not sure what parameters to use

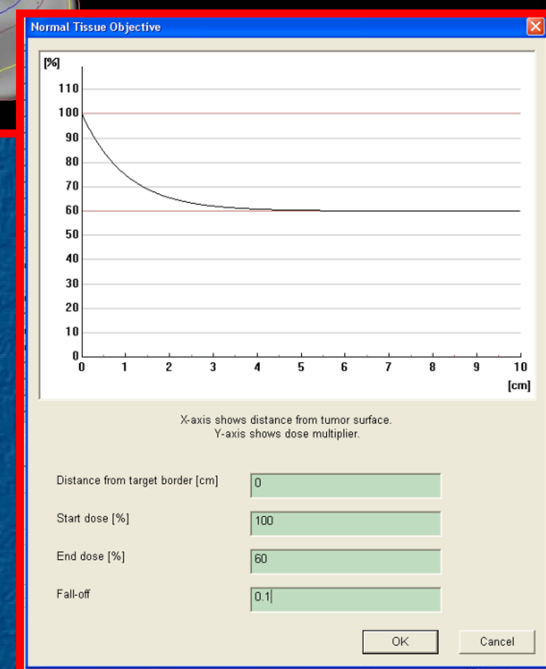
- Optimize without the NTO
- Use the dose profile tool discover what fall off is reasonable

•Set NTO parameters to push it reasonably

• If the NTO is over constrained (i.e. physically unreasonable dose distribution) the results can be poor.





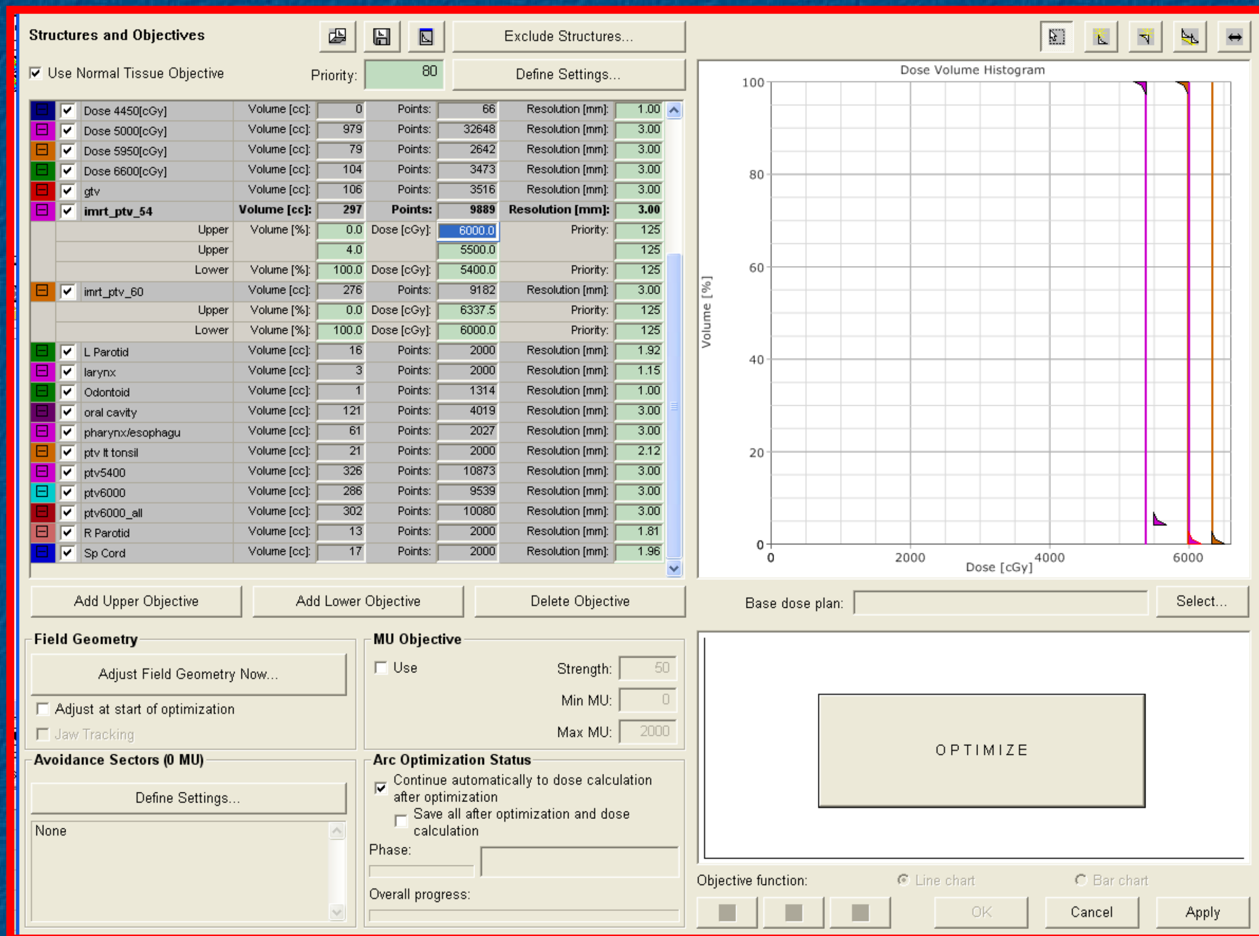


MAYO CLINIC

Optimization Constraints

IMRT PTV

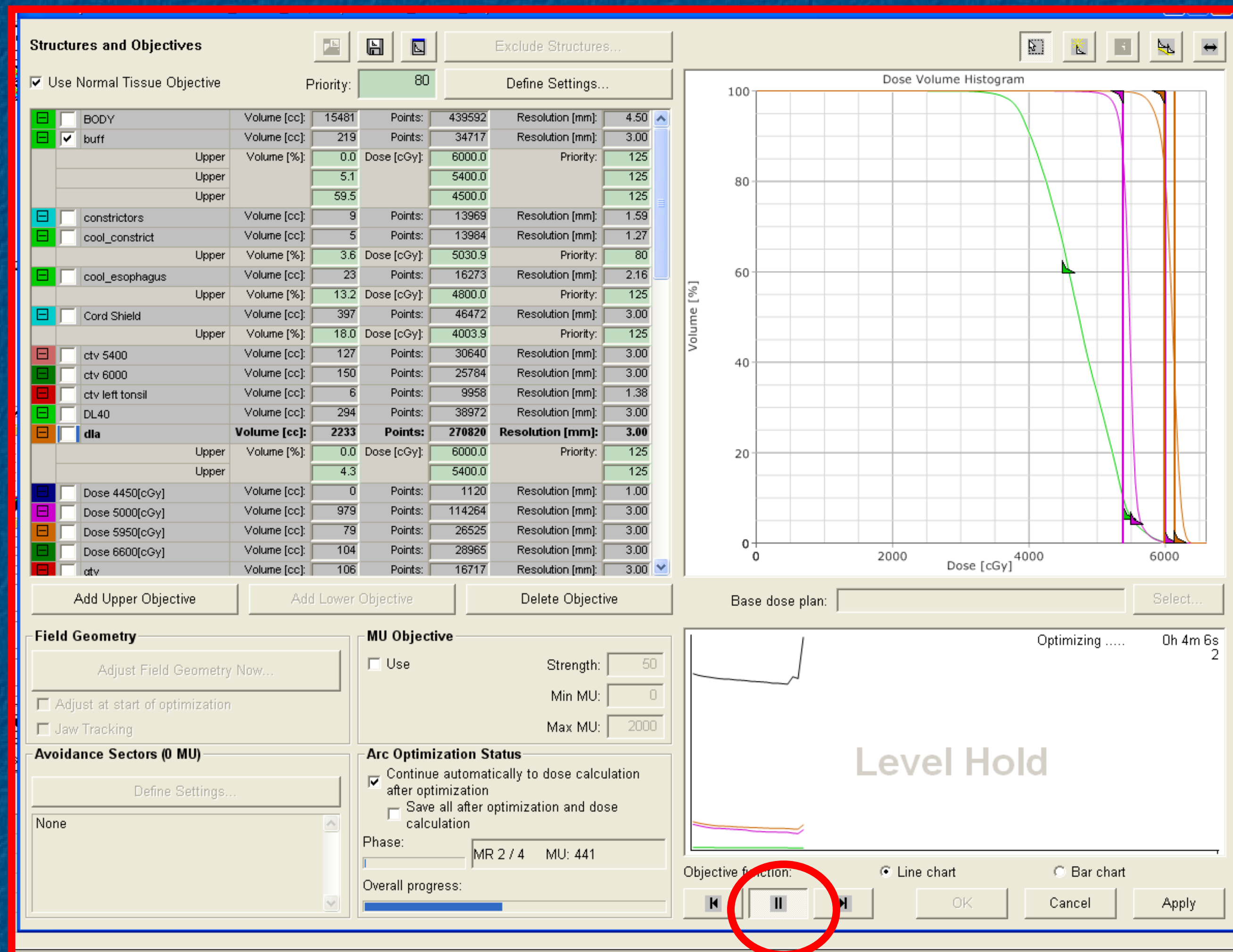
Since IMRT PTV has been contoured to reflect reasonable expectation of high dose (avoid buildup near skin, avoid overlap of normal tissues to be spared, differing dose levels, etc) set constraints to cover IMRT PTV.



Optimization Constraints

Buff

Leverage ability, to hold RapidArc optimization at an early level (e.g. 2), to take your time to look at specific structure constraints one by one and avoid a cluttered screen.

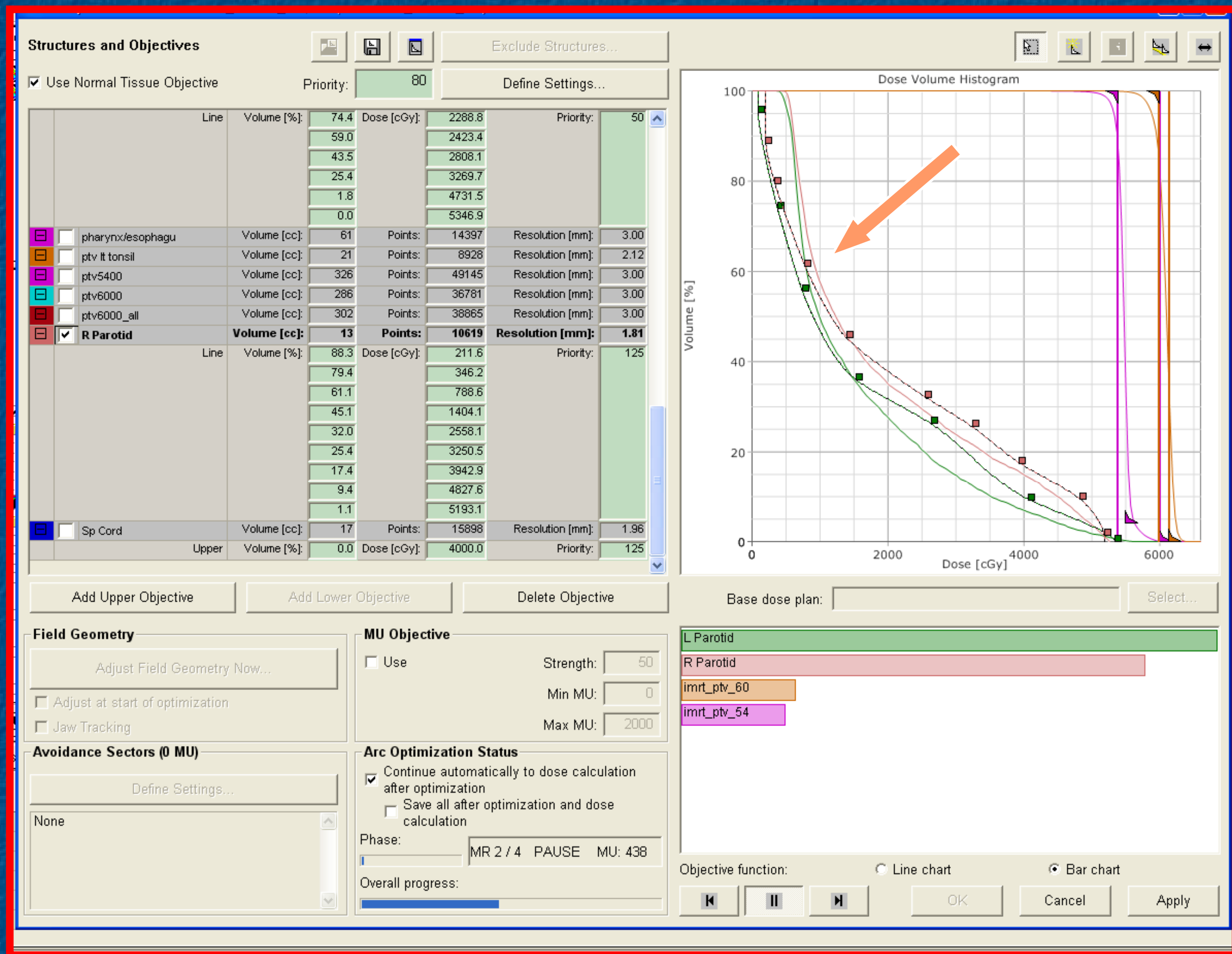


MAYO CLINIC

Optimization Constraints

Parotid

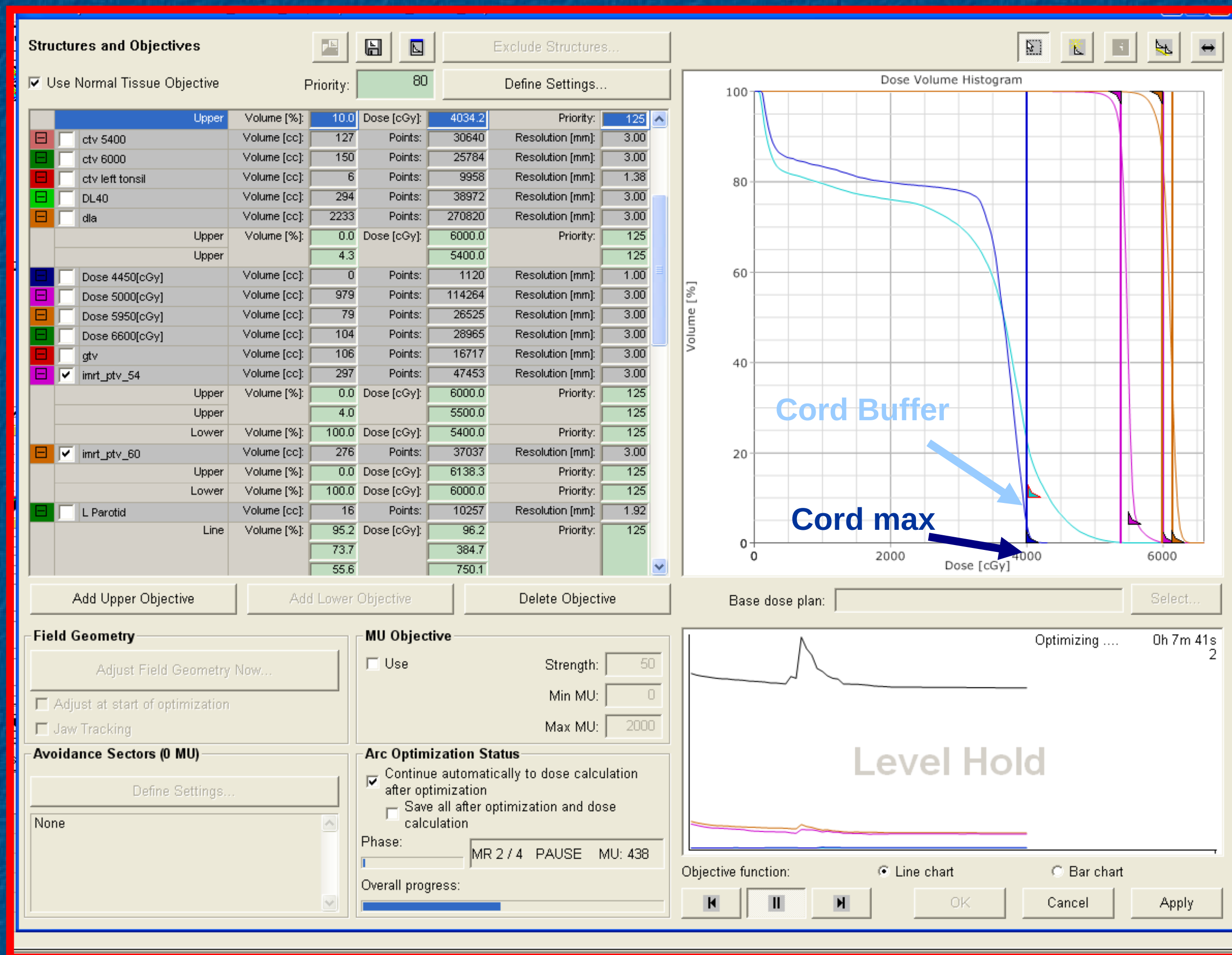
Drive mean parotid dose low, by pushing on the low dose portion of the DVH curve.



MAYO CLINIC

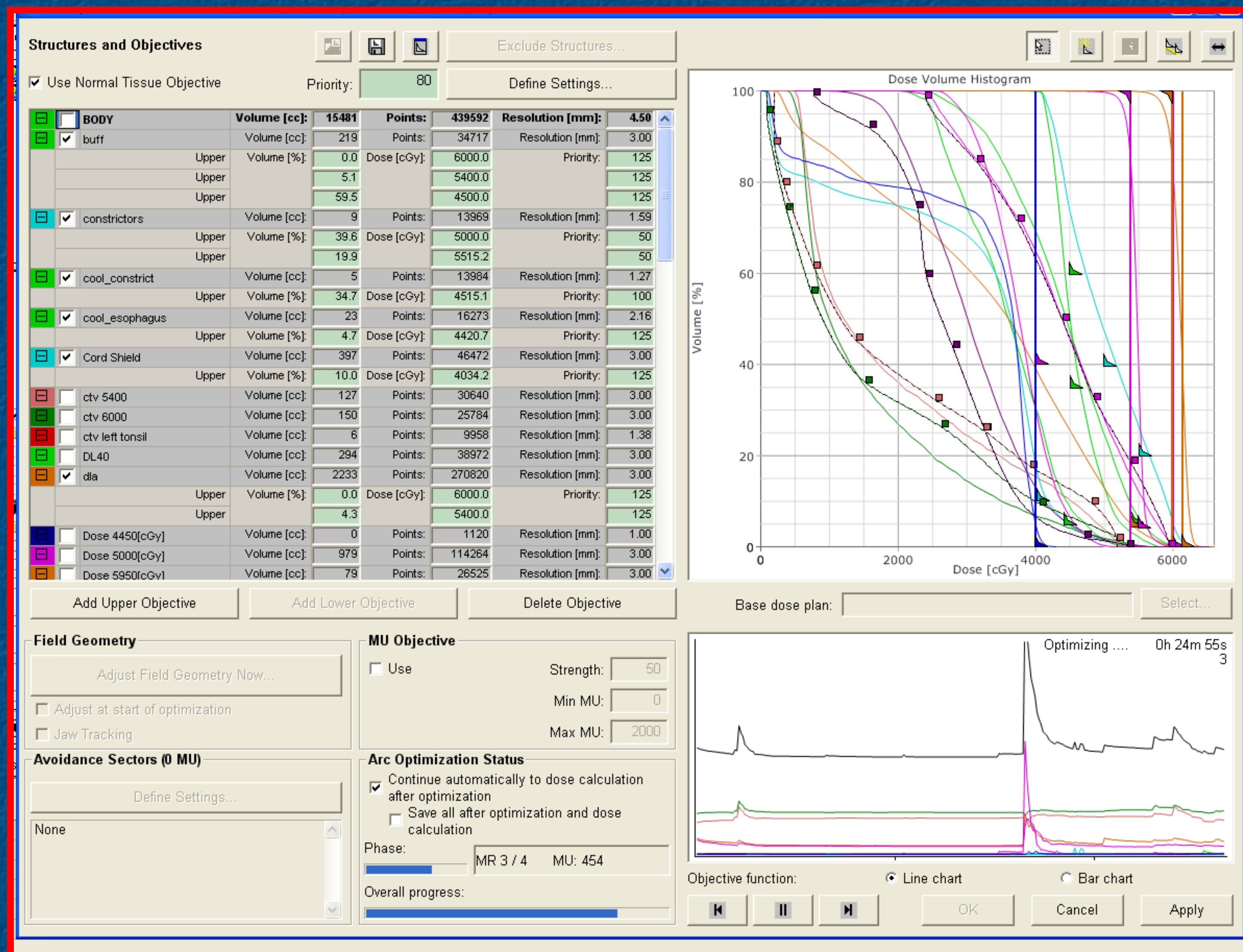
Optimization Constraints
Spinal Cord

Set max on cord, then drive volume of cord buffer structure at that dose level to a lover volume.



Optimization Constraints

All Together



Comparison of IMRT and RapidArc

How quickly to planners climb the learning curve?

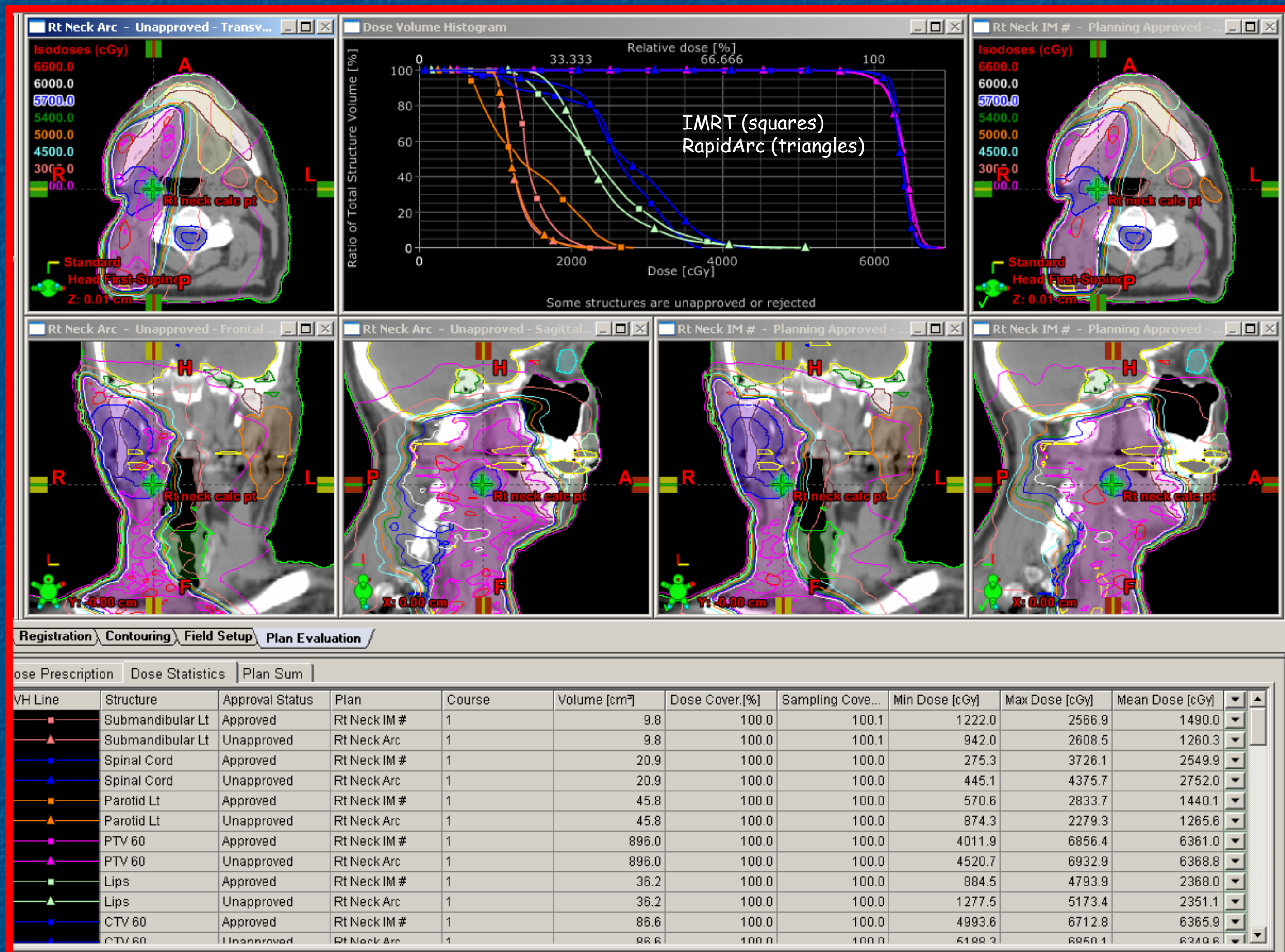
Clinical examples of cases where planners decided that they preferred the VMAT dose distribution.

IMRT vs RapidArc

Needed to reduce dose to contralateral parotids and submandibular glands.

L Parotid Mean

IMRT: 28.3 GY
RA: 22.8 GY



VH Line	Structure	Approval Status	Plan	Course	Volume [cm³]	Dose Cover.[%]	Sampling Cove...	Min Dose [cGy]	Max Dose [cGy]	Mean Dose [cGy]
	Submandibular Lt	Approved	Rt Neck IM #	1	9.8	100.0	100.1	1222.0	2566.9	1490.0
	Submandibular Lt	Unapproved	Rt Neck Arc	1	9.8	100.0	100.1	942.0	2608.5	1260.3
	Spinal Cord	Approved	Rt Neck IM #	1	20.9	100.0	100.0	275.3	3726.1	2549.9
	Spinal Cord	Unapproved	Rt Neck Arc	1	20.9	100.0	100.0	445.1	4375.7	2752.0
	Parotid Lt	Approved	Rt Neck IM #	1	45.8	100.0	100.0	570.6	2833.7	1440.1
	Parotid Lt	Unapproved	Rt Neck Arc	1	45.8	100.0	100.0	874.3	2279.3	1265.6
	PTV 60	Approved	Rt Neck IM #	1	896.0	100.0	100.0	4011.9	6856.4	6361.0
	PTV 60	Unapproved	Rt Neck Arc	1	896.0	100.0	100.0	4520.7	6932.9	6368.8
	Lips	Approved	Rt Neck IM #	1	36.2	100.0	100.0	884.5	4793.9	2368.0
	Lips	Unapproved	Rt Neck Arc	1	36.2	100.0	100.0	1277.5	5173.4	2351.1
	CTV 60	Approved	Rt Neck IM #	1	86.6	100.0	100.0	4993.6	6712.8	6365.9
	CTV 60	Unapproved	Rt Neck Arc	1	86.6	100.0	100.0	5188.3	6850.1	6349.6

MAYO CLINIC

Thanks to Jeffrey Kuball

IMRT vs RapidArc

Needed to keep cord dose as low as possible.

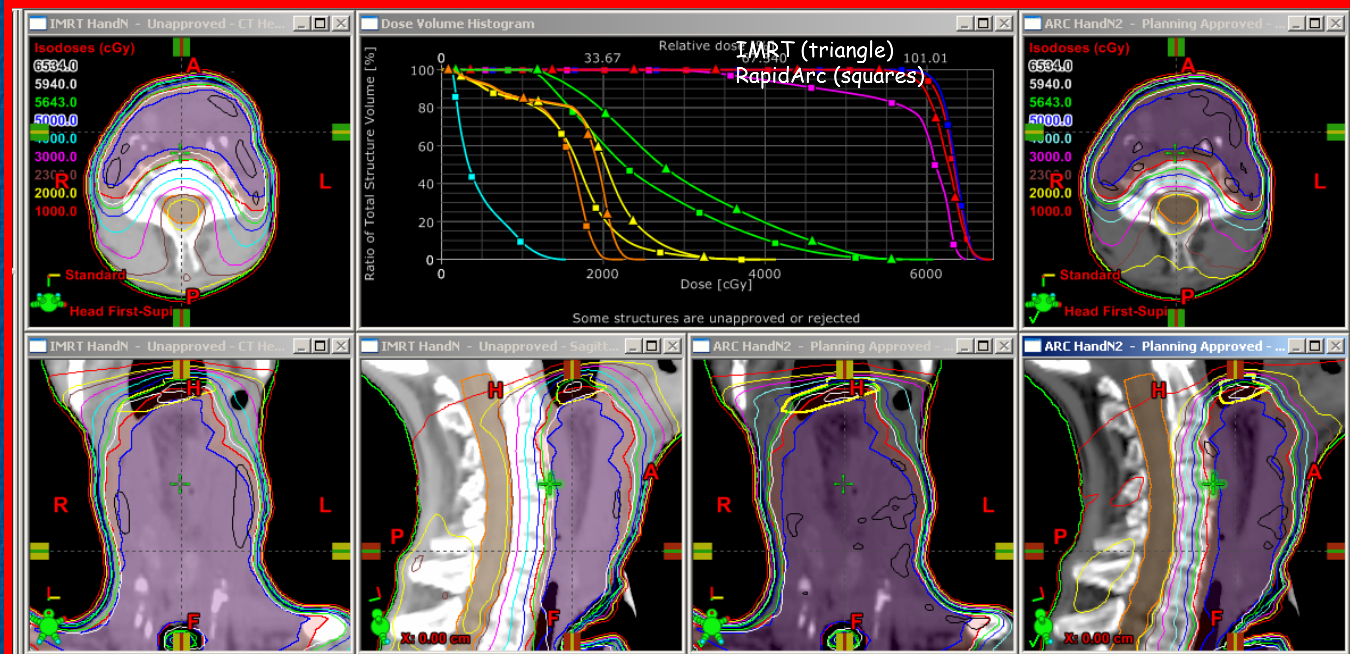
Cord Max

IMRT: 25.3 Gy
RA: 22.5 Gy

Cord PRV mean
IMRT: 18.9 Gy
RA: 16.0 Gy

As bonus, oral cavity

IMRT: 28.3 GY
RA: 22.8 GY

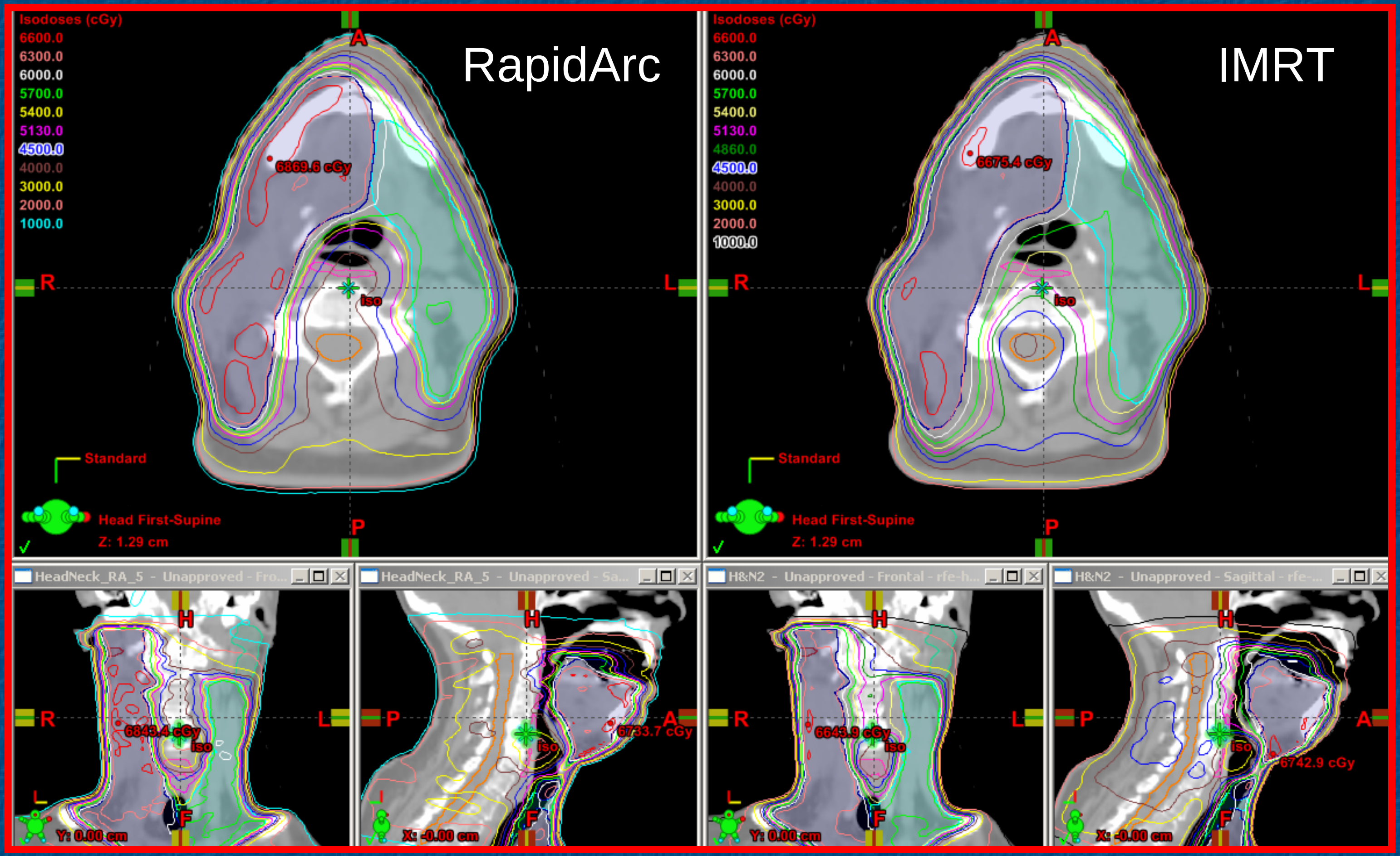


Line	Structure	Approval Status	Plan	Course	Volume [cm³]	Dose Cover.[%]	Sampling Cove...	Min Dose [cGy]	Max Dose [cGy]	Mean Dose [cGy]
	ptv	Approved	ARC HandN2	1	455.8	100.0	100.0	5193.5	6779.8	6314.3
	ptv	Unapproved	IMRT HandN	1	456.4	100.0	100.1	5047.1	6821.7	6241.1
	oral_cavity	Approved	ARC HandN2	1	46.7	100.0	100.0	916.5	6090.6	2509.8
	oral_cavity	Unapproved	IMRT HandN	1	46.8	100.0	100.0	1157.7	5710.8	2928.8
	lips	Approved	ARC HandN2	1	12.7	100.0	99.9	122.9	1553.8	460.5
	esophagus	Approved	ARC HandN2	1	10.4	100.0	100.1	2613.9	6488.9	5849.8
	ctv	Approved	ARC HandN2	1	280.4	100.0	100.0	5494.2	6710.3	6340.0
	cordPRV	Approved	ARC HandN2	1	100.8	100.0	99.9	172.4	4149.6	1602.8
	cordPRV	Unapproved	IMRT HandN	1	100.8	100.0	100.0	131.0	3939.3	1899.0
	cord	Approved	ARC HandN2	1	33.5	100.0	99.9	185.5	2252.9	1455.4
	cord	Unapproved	IMRT HandN	1	33.6	100.0	100.0	142.1	2527.0	1725.1

Thanks to Kevin Kisrow

IMRT vs Rapid Arc

RapidArc gave very conformal dose distribution with significant reduction in dose to contralateral parotid and pharyngeal constrictors

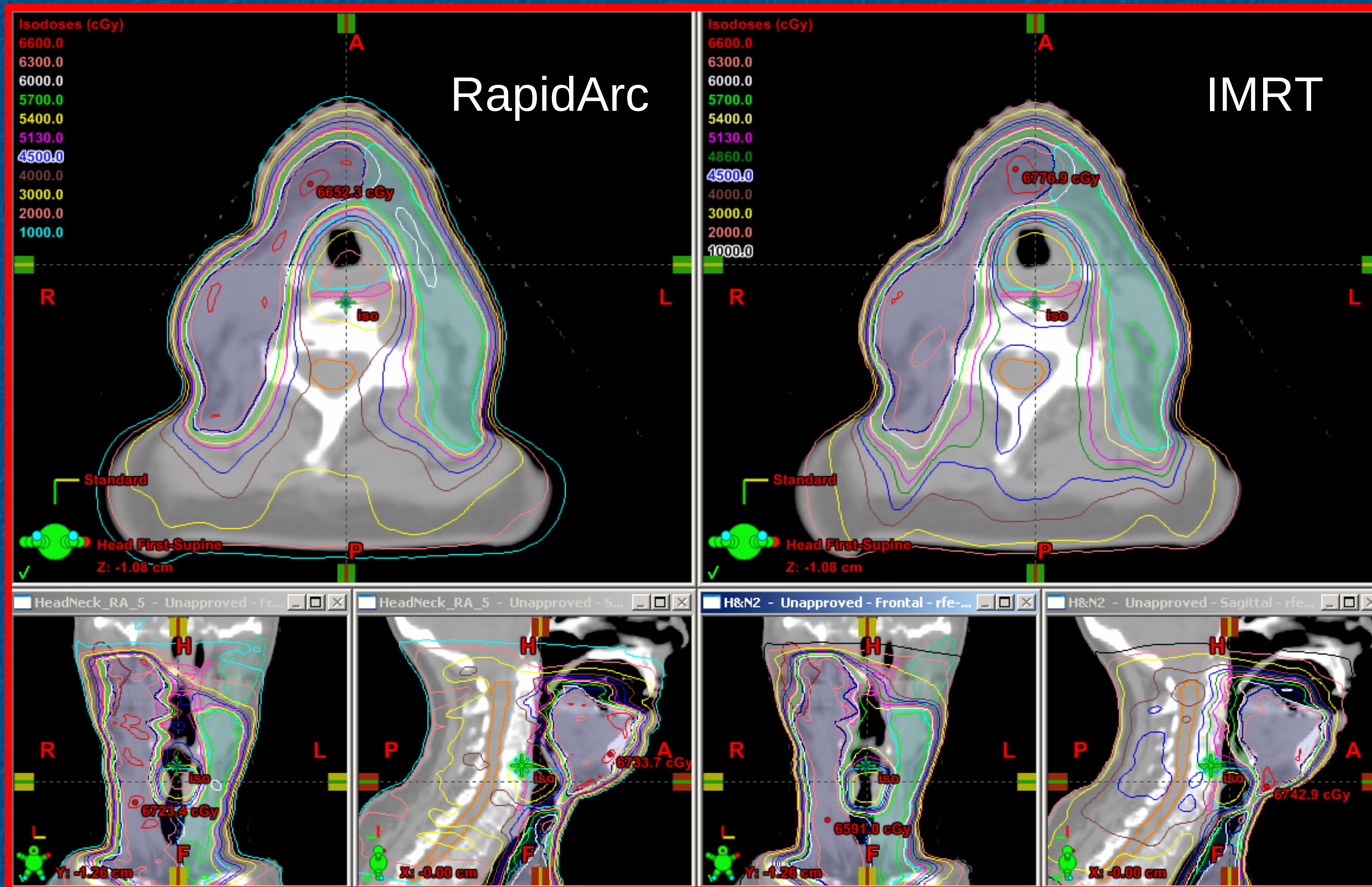


MAYO CLINIC

Thanks to Janelle Miller, Dr Louis Fong de los Santos, Jeffrey Kuball

IMRT vs Rapid Arc

IMRT did better on reducing max larynx dose. For overall larynx dose distribution, RapidArc is lower



MAYO CLINIC

IMRT vs Rapid Arc

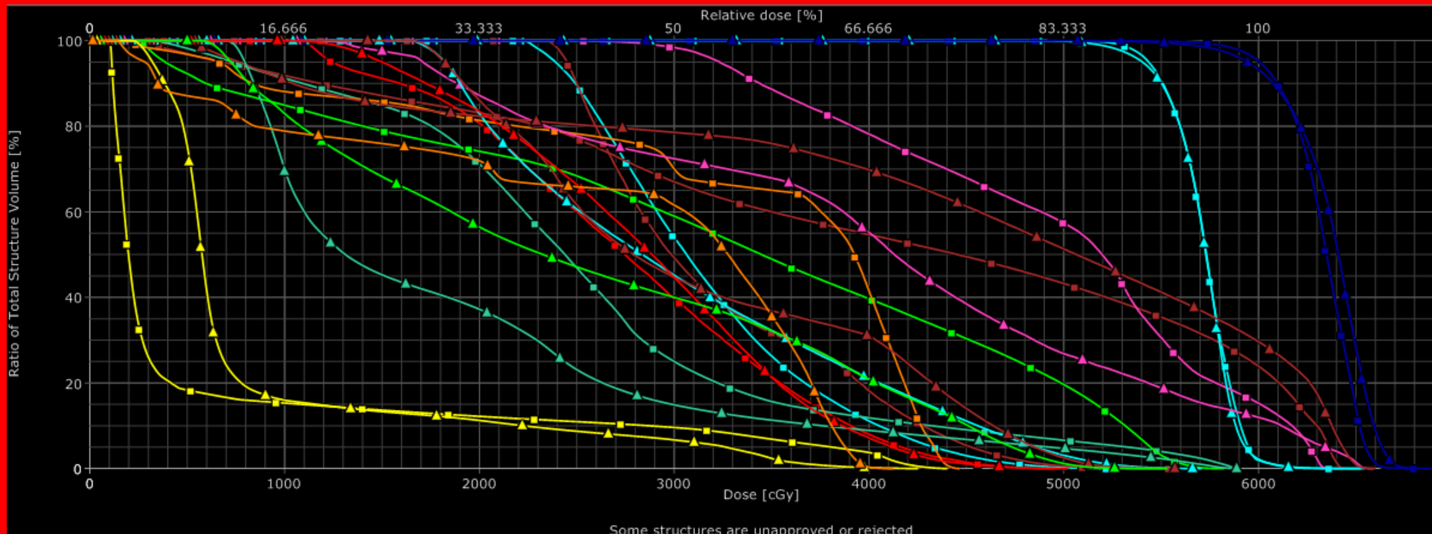
RapidArc (triangles) IMRT (squares)

Significant gains with RapidArc for

L Parotid
Constrictors
Cord

IMRT better for

Esophagus
Larynx max



n | Registration | Contouring | Field Setup | Plan Evaluation

Dose Prescription | Dose Statistics | Plan Sum

DVH Line	Structure	Approval Status	Plan	Course	Volume [cm³]	Dose Cover.[%]	Sampling Cove...	Min Dose [cGy]	Max Dose [cGy]	Mean Dose [cGy]
	ptv 60	Approved	H&N2	Planning	406.9	100.0	100.1	4667.3	6831.4	6326.1
	ptv 60	Approved	HeadNeck_RA_5	Planning	406.9	100.0	100.1	4315.5	6913.0	6365.4
	ptv 54	Approved	H&N2	Planning	213.9	100.0	100.1	4388.6	6546.1	5719.5
	ptv 54	Approved	HeadNeck_RA_5	Planning	213.9	100.0	100.1	4671.4	6530.7	5710.1
	pharyng_constr	Approved	H&N2	Planning	6.0	100.0	105.5	2430.8	6384.5	4930.0
	pharyng_constr	Approved	HeadNeck_RA_5	Planning	6.0	100.0	105.5	1099.9	6598.4	4030.8
	parotid_rt	Approved	H&N2	Planning	14.7	100.0	100.7	264.5	6452.9	4106.8
	parotid_rt	Approved	HeadNeck_RA_5	Planning	14.7	100.0	100.7	466.3	6603.1	4500.2
	parotid_lt	Approved	H&N2	Planning	17.0	100.0	100.4	306.7	5896.2	2572.9
	parotid_lt	Approved	HeadNeck_RA_5	Planning	17.0	100.0	100.4	695.1	5903.7	1890.4
	lips	Approved	H&N2	Planning	7.1	100.0	101.3	884.9	4956.1	2759.2
	lips	Approved	HeadNeck_RA_5	Planning	7.1	100.0	101.3	963.7	5026.2	2844.8
	larynx	Approved	H&N2	Planning	10.8	100.0	100.3	2209.7	5281.4	3172.6
	larynx	Approved	HeadNeck_RA_5	Planning	10.8	100.0	100.3	1654.2	5714.1	3039.9
	esophagus	Approved	H&N2	Planning	5.9	100.0	100.6	2336.9	5570.6	3225.1
	esophagus	Approved	HeadNeck_RA_5	Planning	5.9	100.0	100.6	1593.7	5592.6	3141.0
	cord	Approved	H&N2	Planning	19.6	100.0	100.4	183.9	4467.3	3287.6
	cord	Approved	HeadNeck_RA_5	Planning	19.6	100.0	100.4	141.0	4129.1	2640.5

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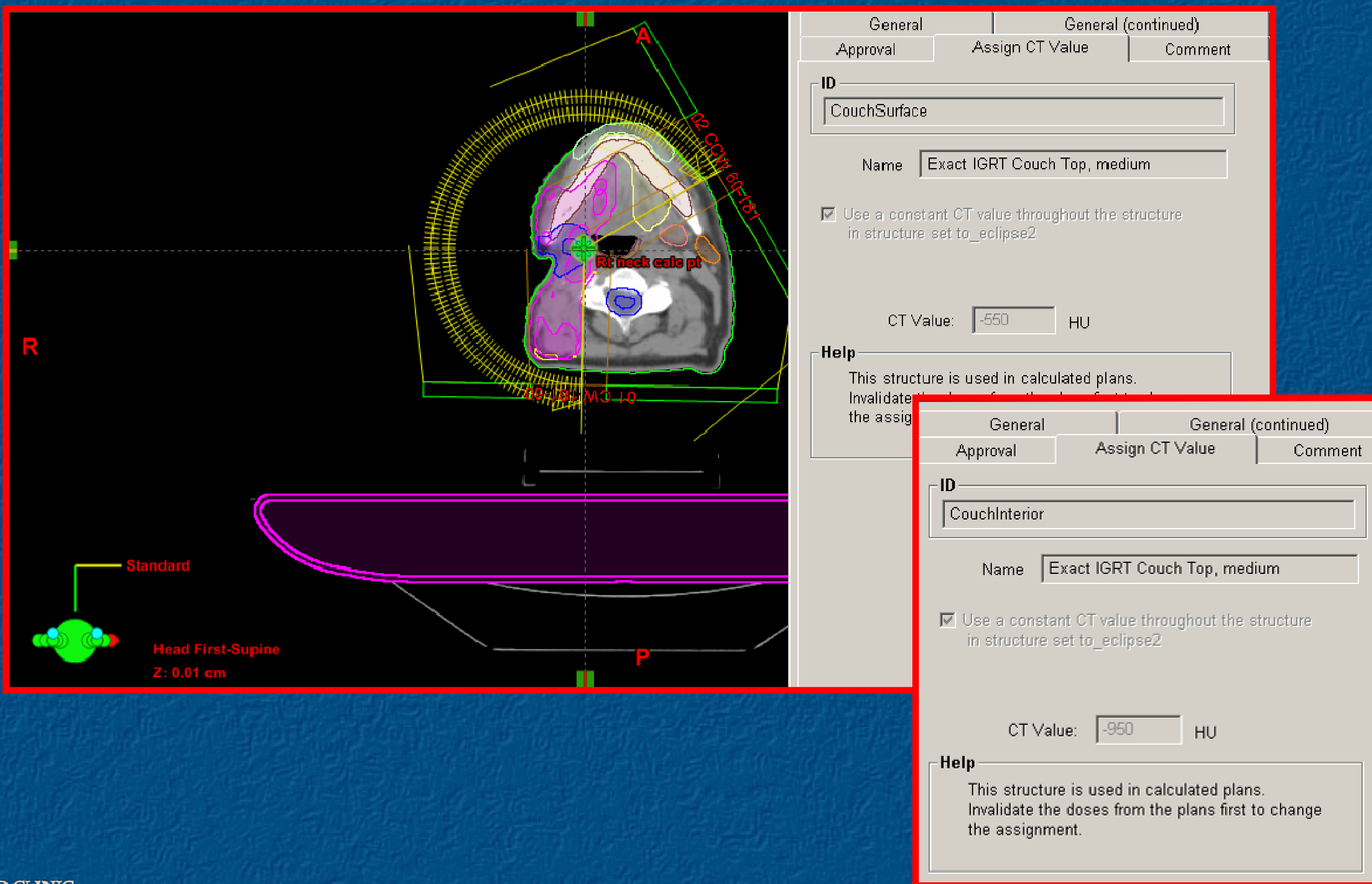
Couch Top

For CT couch tops attenuation is on the order of 4%. Including the couch top in the plan, to have this attenuation automatically factored into the plan, is optimal.



On the learning curve

Remember a lesson learned during IMRT about perceptions of new technology

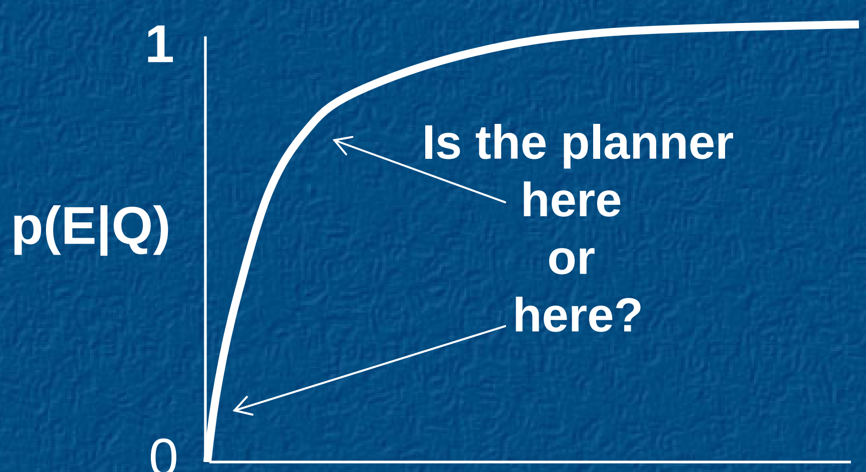
Probability that the planner gets a better Rapid Arc Plan

Given that the technology is capable, probability that the planner gets a better Rapid Arc Plan

Probability that VMAT technology is capable of a better plan

$$p(E) = p(E|Q)\ p(Q)$$

The Learning **Curve**



Not getting the plan we want could be p(Q) but it could also be p(E|Q).

Avoid temptation to judge a new technology, before staff have time to master it.

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Summary

VMAT is emerging as a main stream treatment planning/delivery option

- Supported by multiple vendors
- Expanding number of facilities making use of the technology

VMAT does not have to mean compromise in sparing of normal tissues

VMAT planning can build upon IMRT planning approaches to facilitate transition, however additional "tricks" may be needed to get the most out of it.

There is a learning curve for getting good VMAT plans. Once there it becomes the preferred approach.

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