



Advent Health

**Moving Towards SGRT for
Sim, Plan, Treat and Dose.
Early Clinical Results with
MapRT**

Adi Robinson Ph.D., DABR

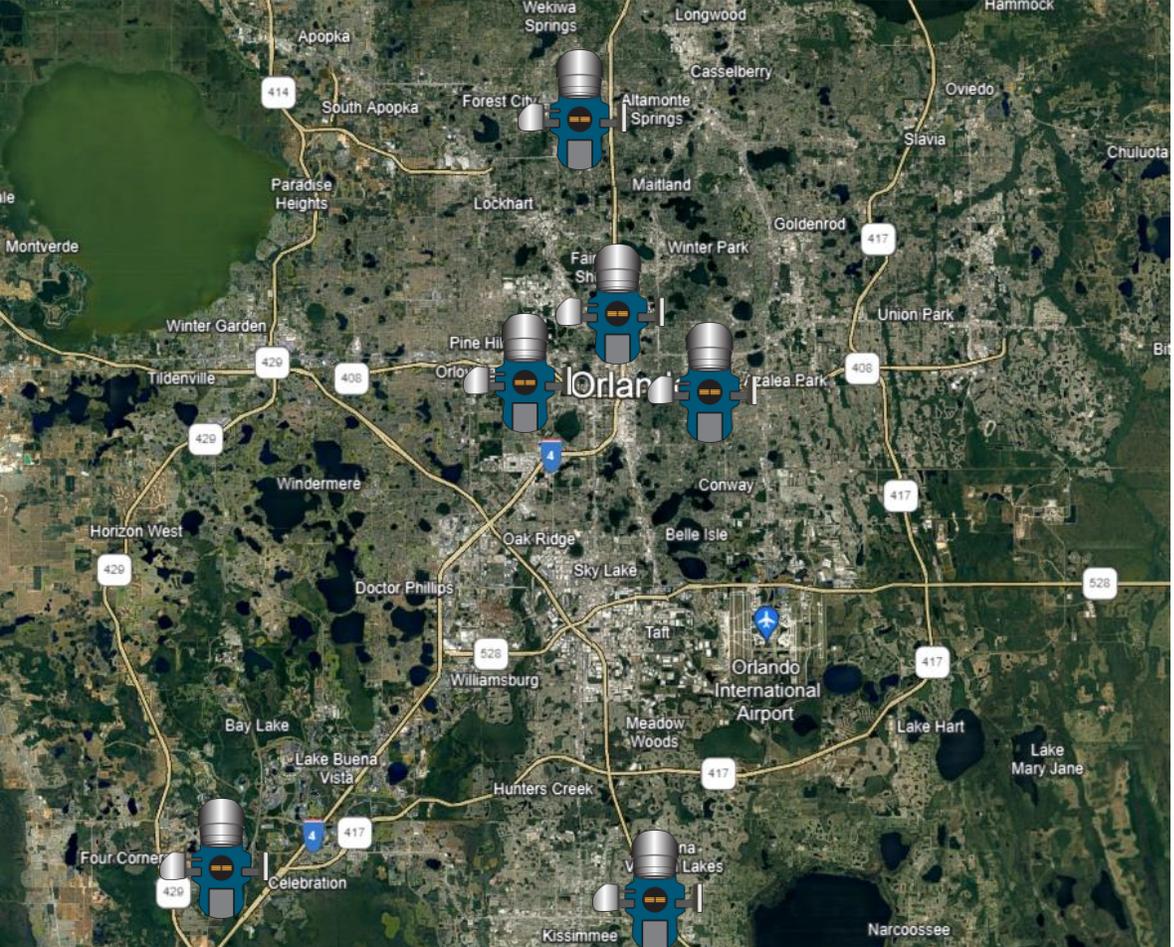
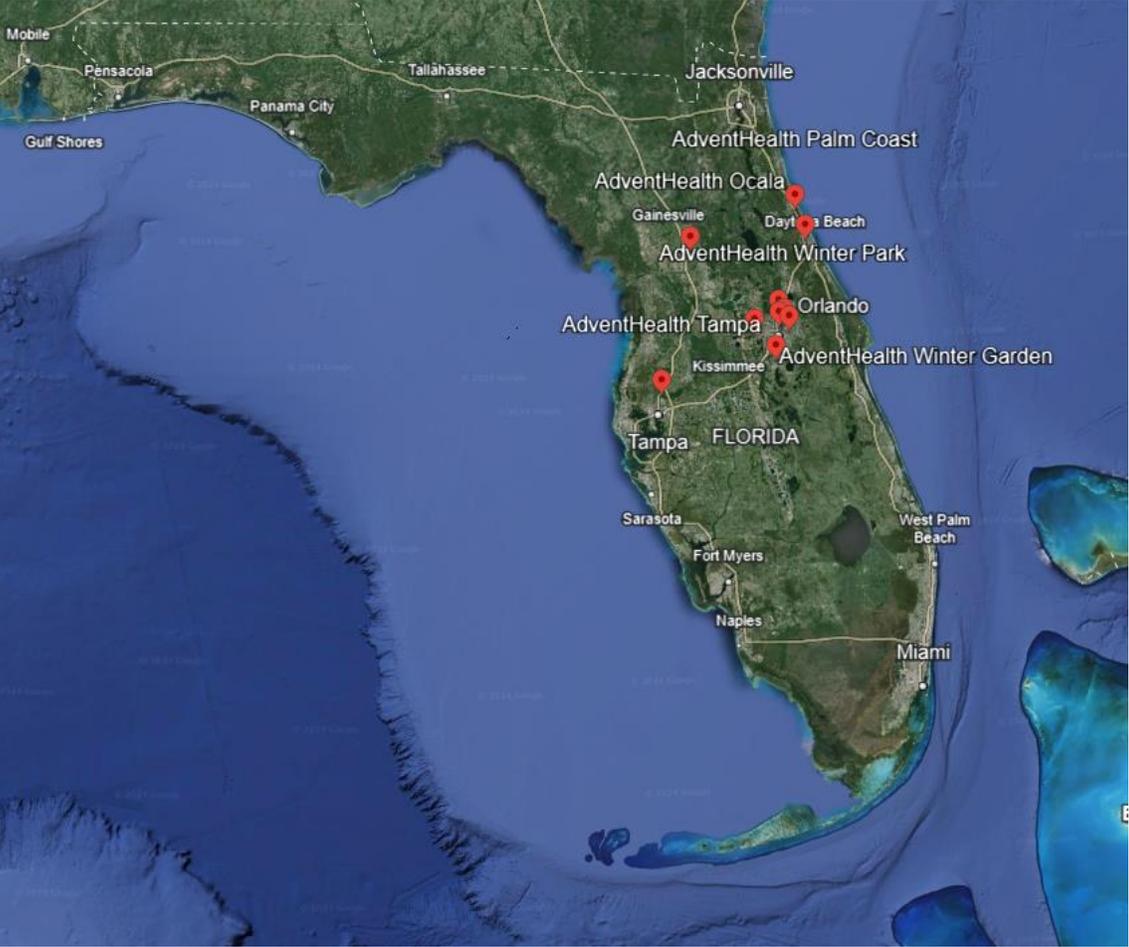
Disclosures

- None

Outline

- What is MapRT?
 - Clearance Mapping
 - Surface Guided Planning
- Why Non-Coplanar treatments
 - Advantages and Importance
 - Examples
- Clinical Examples
 - Brain
 - Breast
- Conclusions

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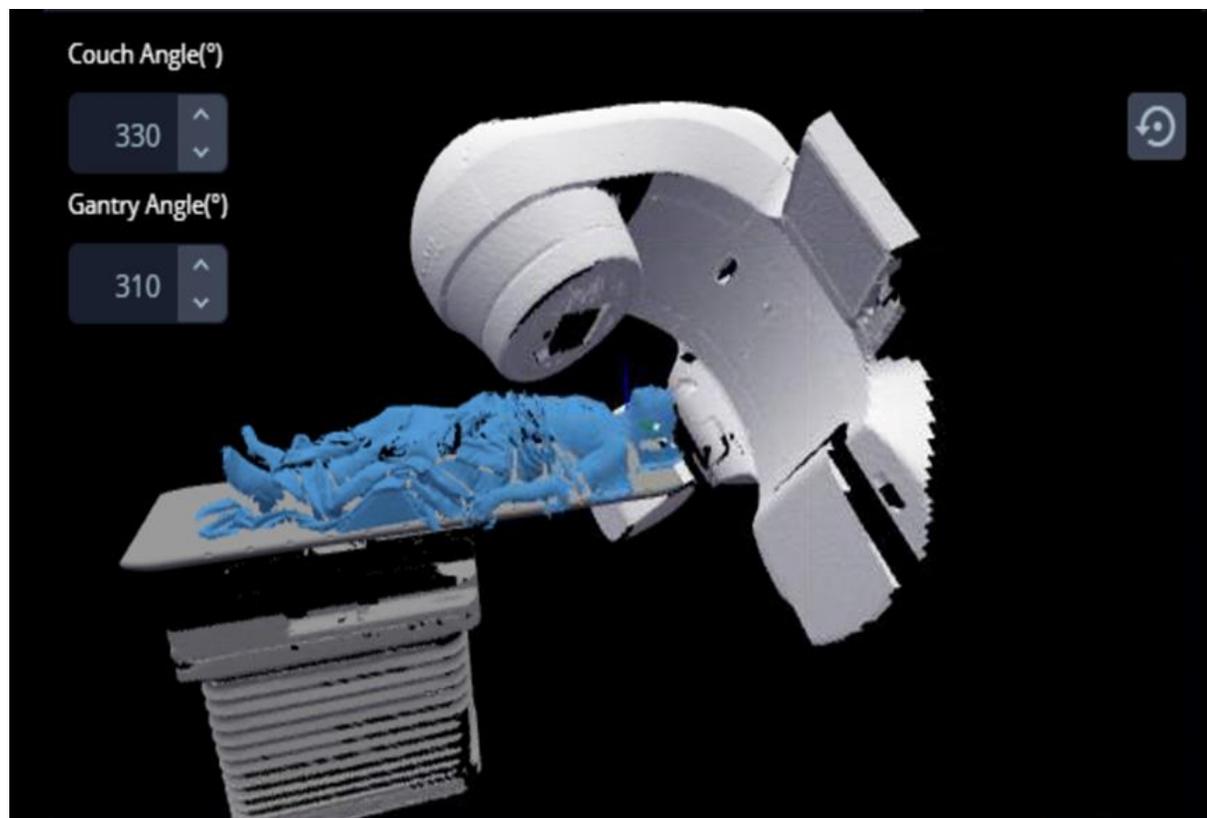
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- 15 Radiation Oncology Centers
- 20 Varian Linacs (2 added this year)
- GammaKnife (Esprit), 3 HDRs, IORT
- SGRT systems
 - 6 AlignRT (2 more planned)
 - SimRT (2 more planned)
 - MapRT
 - DoseRT
 - PatientID
- Single server Aria and Eclipse system



What is MapRT?

- SGRT cameras capture the entire 3D surface of the patient and provide a clearance map to detect collisions.
- The clearance map will also check for safe plan delivery.

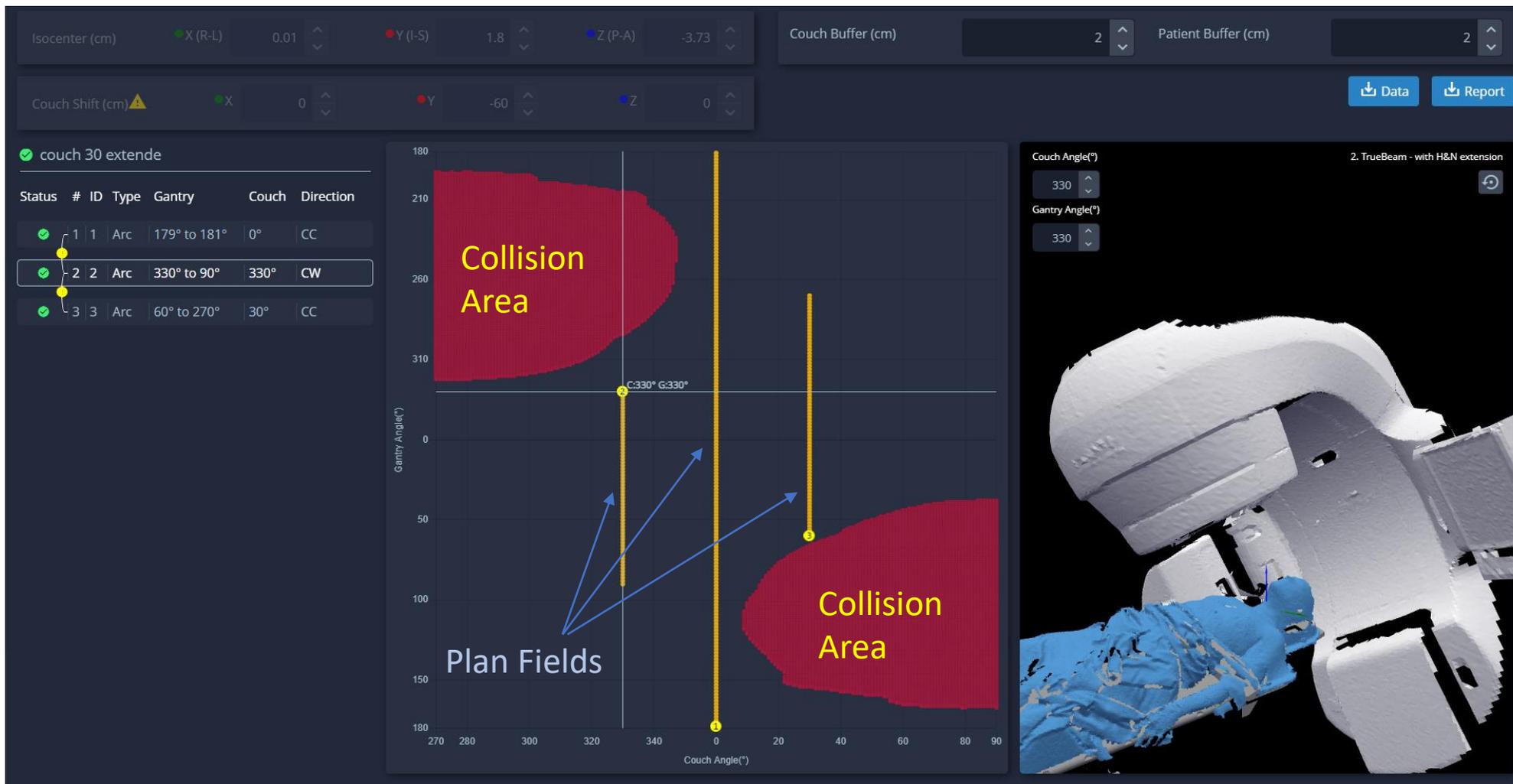


MapRT in the Sim Room



The Clearance Map

Imported Plan



Traditional Treatment Planning

- Traditional treatment planning relies on CT/MR images. Images are taken during the pre-treatment simulation have little correlation to the treatment environment.
- Some treatment plans are complex and can require dry runs to ensure patient and/or accessories will clear the linac or imagers.
- Failing a dry run will result in re-planning which leads to delays in treatment.

Surface guided Planning

- Clearance map at time of sim.
 - Patient and immobilization device collision check
- Planner can use the clearance map data to optimize planning
 - Plan with “allowed” fields
 - Non-coplanar treatment
- No need for dry run or collision check

Non-Coplanar Treatments

- Non-Coplanar radiotherapy involves using treatment fields at a non-zero couch angle.
- Non-coplanar beam arrangement can help improve tumor coverage and/or lower dose to OARs
- However, it introduces the risk of collisions and requires clearance verification prior to delivery.

Non-Coplanar Treatments - Examples

REVIEW ARTICLE

Recent developments in non-coplanar radiotherapy

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ABSTRACT

This paper gives an overview of recent developments in non-coplanar intensity modulated radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT). Modern linear accelerators are capable of automating motion around multiple axes, allowing efficient delivery of highly non-coplanar radiotherapy techniques. Novel techniques developed for C-arm and non-standard linac geometries, methods of optimization, and clinical applications are reviewed. The additional degrees of freedom are shown to increase the therapeutic ratio, either through dose escalation to the target or dose reduction to functionally important organs at risk, by multiple research groups. Although significant work is still needed to translate these new non-coplanar radiotherapy techniques into the clinic, clinical implementation should be prioritized. Recent developments in non-coplanar radiotherapy demonstrate that it continues to have a place in modern cancer treatment.

Dosimetric Comparison of Coplanar versus Noncoplanar Volumetric Modulated Arc Therapy for Treatment of Bilateral Breast Cancers

[Avinav Bharati](#), [Satyajjeet Rath](#),¹ [Rohini Khurana](#),² [Madhup Rastogi](#),² [Susama R. Mandal](#),³ [Ajeet Kumar Gandhi](#),² [Rahat Hadi](#),² [Anoop K. Srivastava](#),² and [Surendra Prasad Mishra](#)²

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Abstract

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Introduction:

The purpose of this study was to compare the dosimetric parameters of volumetric modulated arc therapy (VMAT) treatment plans using coplanar and noncoplanar beams in patients with bilateral breast cancer/s (BBCs) in terms of organ at risk sparing and target volume coverage. The hypothesis was to test whether VMAT with noncoplanar beams can result in lesser dose delivery to critical organs such as heart and lung, which will result in lesser overall toxicity.

Non-coplanar volumetric modulated arc therapy for locoregional radiotherapy of left-sided breast cancer including internal mammary nodes

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This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Background. Non-coplanar volumetric modulated arc therapy (ncVMAT) is proposed to reduce toxicity in heart and lungs for locoregional radiotherapy of left-sided breast cancer, including internal mammary nodes (IMN).

Patients and methods. This retrospective study included 10 patients with left-sided breast cancer who underwent locoregional radiotherapy after breast-conserving surgery. For each patient, the ncVMAT plan was designed with four partial arcs comprising two coplanar arcs and two non-coplanar arcs, with a couch rotating to 90°. The prescribed dose was normalized to cover 95% of planning target volume (PTV), with 50 Gy delivered in 25 fractions. For each ncVMAT plan, dosimetric parameters were compared with the coplanar volumetric modulated arc therapy (coVMAT) plan.

Results. There were improvements in conformity index, homogeneity index and V_{95} of total target volume (PTV) comparing ncVMAT to coVMAT ($p < 0.001$). Among the organs at risk, the average V_{20} , V_{30} , V_{40} , and mean dose (D_{mean}) of the heart decreased significantly ($p < 0.001$). Furthermore, ncVMAT significantly reduced the mean V_{20} , V_{30} , V_{40} , and D_{mean} of left lung and the mean V_{20} and V_{30} of contralateral lung ($p < 0.001$). An improved sparing of the left anterior descending coronary artery and right breast were also observed with ncVMAT ($p < 0.001$).

Conclusions. Compared to coVMAT, ncVMAT provides improved conformity and homogeneity of whole PTV, better dose sparing of the heart, bilateral lungs, left anterior descending coronary artery (LAD), and right breast for locoregional radiotherapy of left-sided breast cancer with IMN, potentially reducing the risk of normal tissue damage.

Key words: non-coplanar; volumetric modulated arc therapy; left-sided breast cancer; internal mammary nodes

Locoregional breast radiotherapy including IMN: optimizing the dose distribution using an automated non-coplanar VMAT-technique

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PMID: 37812070 DOI: 10.1080/0284186X.2023.2264488

Abstract

Background: Volumetric Modulated Arc Therapy (VMAT) offers better conformity, homogeneity and sparing of the heart and ipsilateral lung for locoregional radiotherapy in left-sided breast cancer compared to three-dimensional conformal radiotherapy (3D-CRT). However, conventional coplanar VMAT (cVMAT) can result in higher doses to the normal tissue on the contralateral side. This study investigates a non-coplanar VMAT-technique (ncVMAT) to mitigate this issue.

Material and methods: CT series of 20 left-sided breast cancer patients were included for planning of locoregional breast radiotherapy including internal mammary nodes (IMN). Three treatment plans: 3D-CRT, cVMAT and ncVMAT, were generated for each patient with a prescription dose of 40.05 Gy in 15 fractions. Both VMAT-techniques consisted of a single arc in the axial plane, while ncVMAT included an additional arc in the sagittal plane. All plans were optimized to cover the clinical target volume (CTV) by 38.05 Gy for the breast and 36.05 Gy for lymph nodes, with as low as possible dose to organs at risk.

Results: Full CTV coverage was achieved for all plans. Both cVMAT and ncVMAT delivered more conformal and homogeneous target doses than 3D-CRT. Doses to the heart and ipsilateral lung were significantly lower with ncVMAT compared to both cVMAT and 3D-CRT. ncVMAT reduced doses to both the contralateral breast and lung compared to cVMAT and achieved levels similar to 3D-CRT for the contralateral breast and moderately higher doses for the contralateral lung. Delivery of high doses (>30 Gy) to the contralateral side was completely avoided with ncVMAT, contrary to the results for cVMAT and 3D-CRT.

Conclusion: ncVMAT reduced doses to the heart and ipsilateral lung as compared to both cVMAT and 3D-CRT. All contralateral dose metrics were reduced with the novel ncVMAT technique compared to cVMAT, and the mean contralateral breast doses were similar to 3D-CRT.

Non-Coplanar Treatments - Examples

NEXT >>

SGRT in Treatment Planning:
Surface Guided Clearance Mapping



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SGRT
COMMUNITY

A new view of
SGRT

Improving efficiencies with MapRT

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A new view of
SGRT

Use of MapRT to optimise noncoplanar
planning for head and neck patients



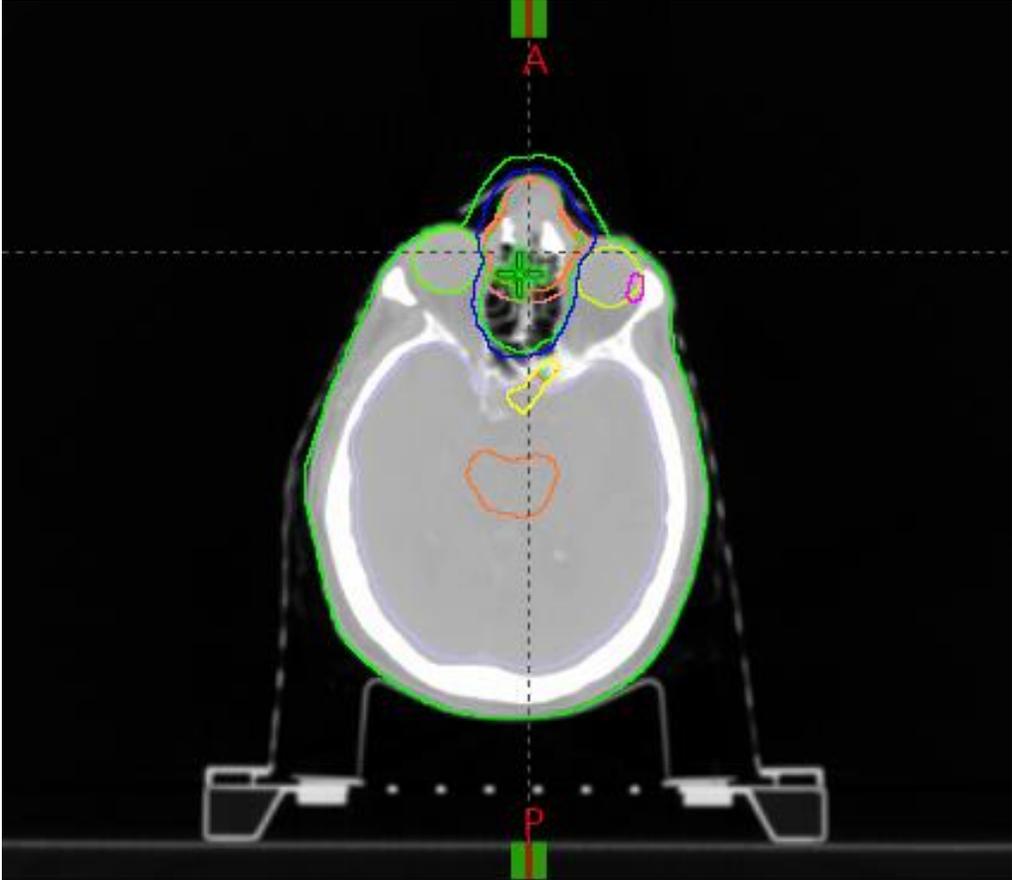
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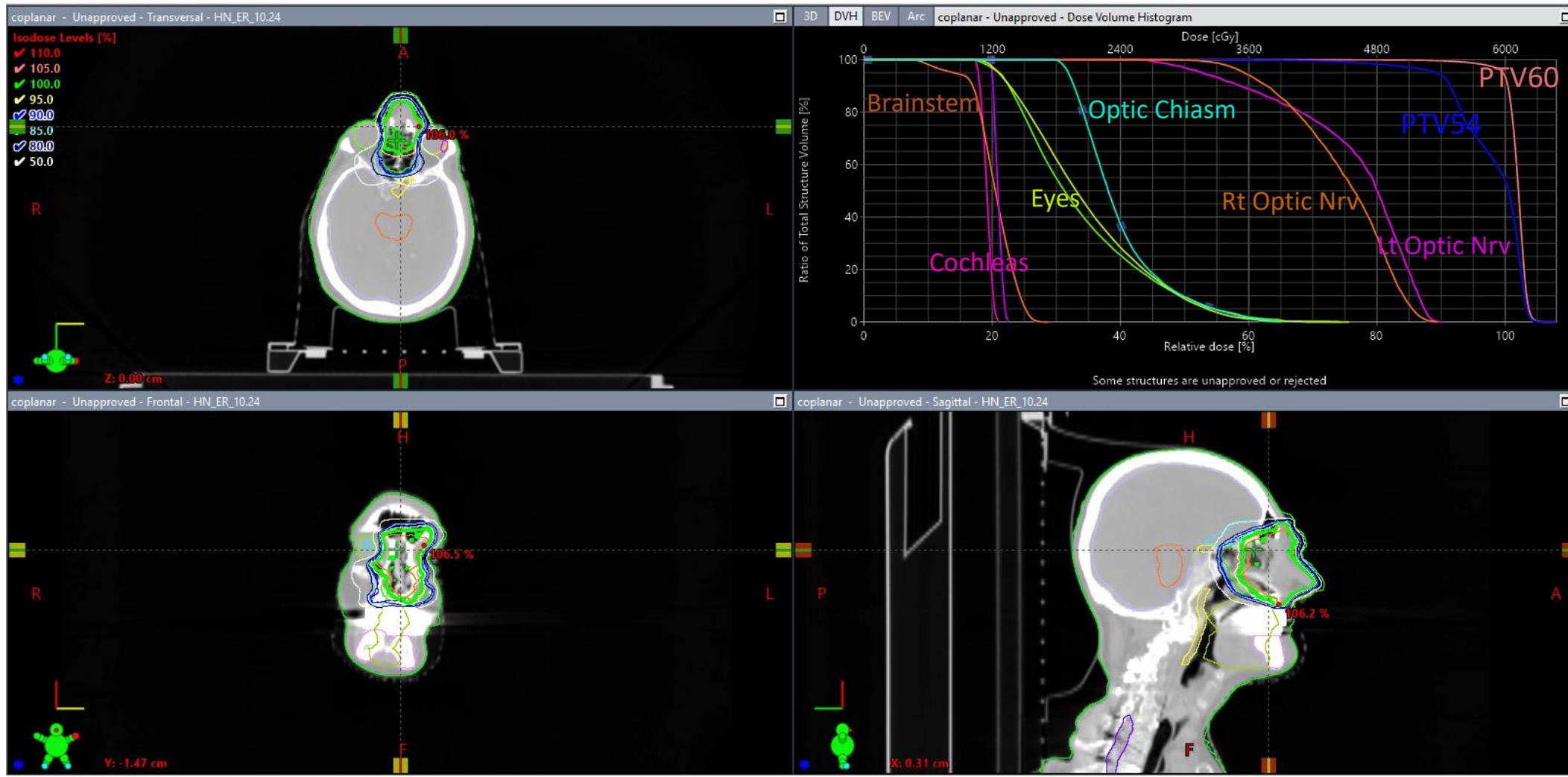
Workflow

- In the CT sim room
 - Capture surface prior to CT sim
 - Check for collisions
 - Adjust patient position or immobilization device accordingly.
- Treatment Planning
 - Use clearance map to optimize the plan
- Treatment
 - Plan can be safely delivered

Surface Guided Planning - HN



Standard Coplanar Plan

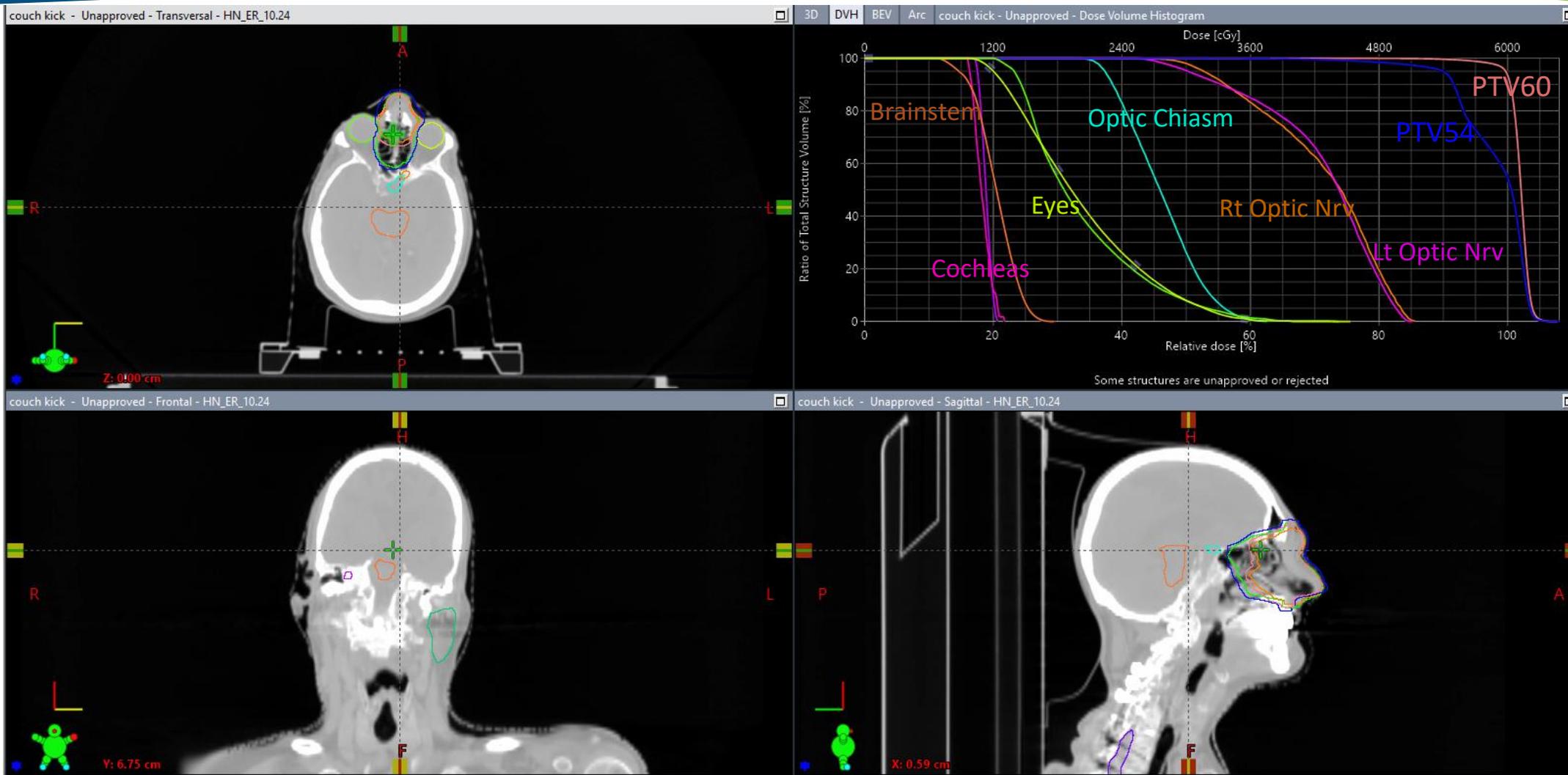


Standard Coplanar Plan

- 2 Arc VMAT
 - G179 – G181 CCW
 - G182 – G178 CW

Structure Plan	Type	Prescription	Constraint	Goal	coplanar	Pass/Fail
CTVHN6000_30	Target	H&N_PTV60: 6000cGy	V107% ≤	1%	0.001%	✓
CTVHN6000_30	Target	H&N_PTV60: 6000cGy	V95% ≥	97%	96.733%	✗
CTVHN6000_30	Target	H&N_PTV60: 6000cGy	Max ≤	110%	107.419%	✓
CTVHN6000_30	Target	H&N_PTV60: 6000cGy	V99% ≥	93%	95.072%	✓
CTVHN5400_30	Target	H&N_PTV54: 5400cGy	V95% ≥	97%	97.656%	✓
CTVHN5400_30	Target	H&N_PTV54: 5400cGy	V99% ≥	93%	97.106%	✓
Brainstem	OAR		Max ≤	5400cGy	1734cGy	✓
Mandible	OAR		Max ≤	6400cGy	3209.9cGy	✓
Mandible	OAR		V6000cGy ≤	1cc	0cc	✓
Parotid_L	OAR		Mean ≤	2400cGy	161.3cGy	✓
Parotid_L	OAR		V3000cGy ≤	50%	0%	✓
Parotid_R	OAR		Mean ≤	2400cGy	480.7cGy	✓
Parotid_R	OAR		V3000cGy ≤	50%	0%	✓
Cavity_Oral	OAR		Mean ≤	3000cGy	469.9cGy	✓
Cochlea_L	OAR		Mean ≤	1500cGy	1148.5cGy	✓
Cochlea_R	OAR		Mean ≤	1500cGy	1255.6cGy	✓
Eye_L	OAR		Max	cGy	4544.8cGy	
Eye_R	OAR		Max	cGy	4467.4cGy	
OpticChiasm	OAR		Max	cGy	3906.8cGy	
OpticNrv_L	OAR		Max	cGy	5370.9cGy	
OpticNrv_R	OAR		Max	cGy	5413.4cGy	

Non-Coplanar Plan

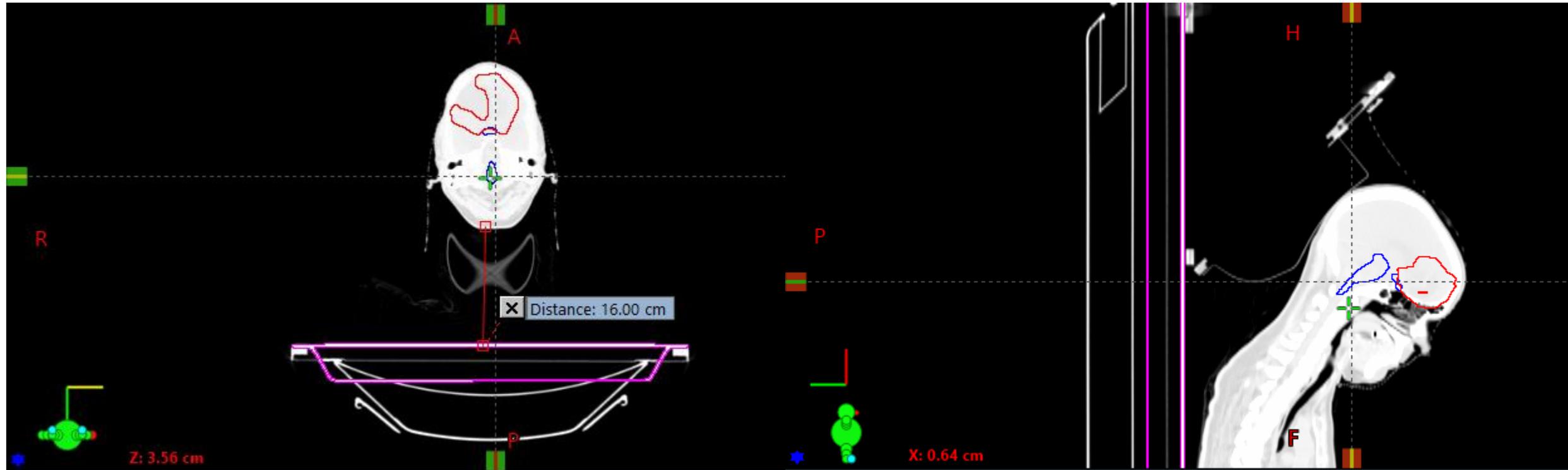


Non-Coplanar Plan

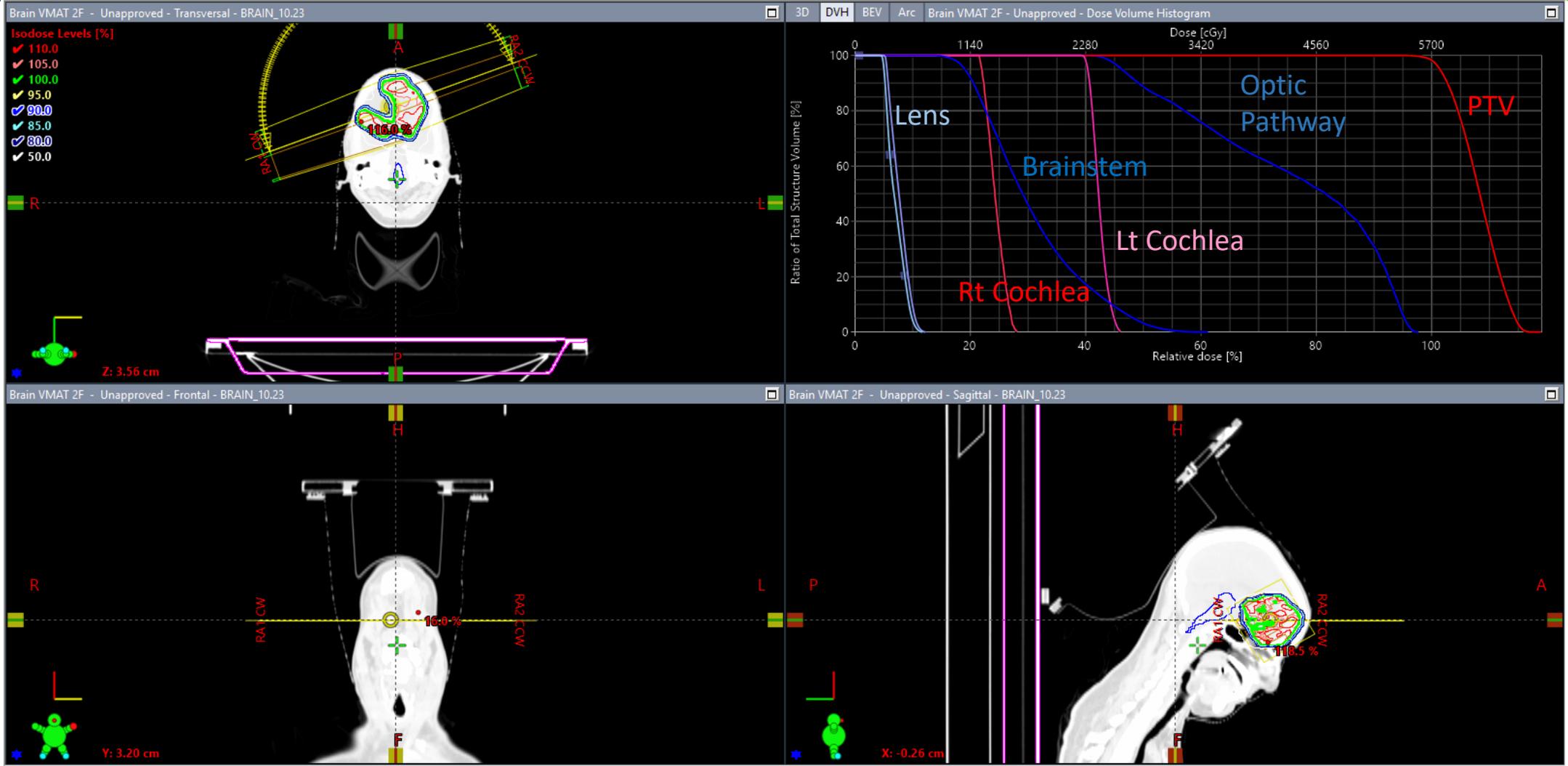
- 3 field VMAT plan
 - G179 – G181 CCW
 - G182 – G178 CW
 - G30 – G330 CCW T90

Structure Plan	Type	Prescription	Constraint	Goal	couch kick	Pass/Fail
CTVHN6000_30	Target	H&N_PTV60: 6000cGy	V107% ≤	1%	0.012%	✓
CTVHN6000_30	Target	H&N_PTV60: 6000cGy	V95% ≥	97%	97.063%	✓
CTVHN6000_30	Target	H&N_PTV60: 6000cGy	Max ≤	110%	107.768%	✓
CTVHN6000_30	Target	H&N_PTV60: 6000cGy	V99% ≥	93%	95.472%	✓
CTVHN5400_30	Target	H&N_PTV54: 5400cGy	V95% ≥	97%	97.815%	✓
CTVHN5400_30	Target	H&N_PTV54: 5400cGy	V99% ≥	93%	97.293%	✓
Brainstem	OAR		Max ≤	5400cGy	1776.5cGy	✓
Mandible	OAR		Max ≤	6400cGy	3003.7cGy	✓
Mandible	OAR		V6000cGy ≤	1cc	0cc	✓
Parotid_L	OAR		Mean ≤	2400cGy	260.1cGy	✓
Parotid_L	OAR		V3000cGy ≤	50%	0%	✓
Parotid_R	OAR		Mean ≤	2400cGy	515.3cGy	✓
Parotid_R	OAR		V3000cGy ≤	50%	0%	✓
Cavity_Oral	OAR		Mean ≤	3000cGy	664.6cGy	✓
Cochlea_L	OAR		Mean ≤	1500cGy	1097.9cGy	✓
Cochlea_R	OAR		Mean ≤	1500cGy	1132.2cGy	✓
Eye_L	OAR		Max	cGy	4536.1cGy	
Eye_R	OAR		Max	cGy	4422.6cGy	
OpticChiasm	OAR		Max	cGy	3765.2cGy	
OpticNrv_L	OAR		Max	cGy	5146.7cGy	
OpticNrv_R	OAR		Max	cGy	5120.4cGy	

Planning with a Clearance Map - Brain



Standard Plan – 2 Arc VMAT



Standard Plan – 2 Arc VMAT

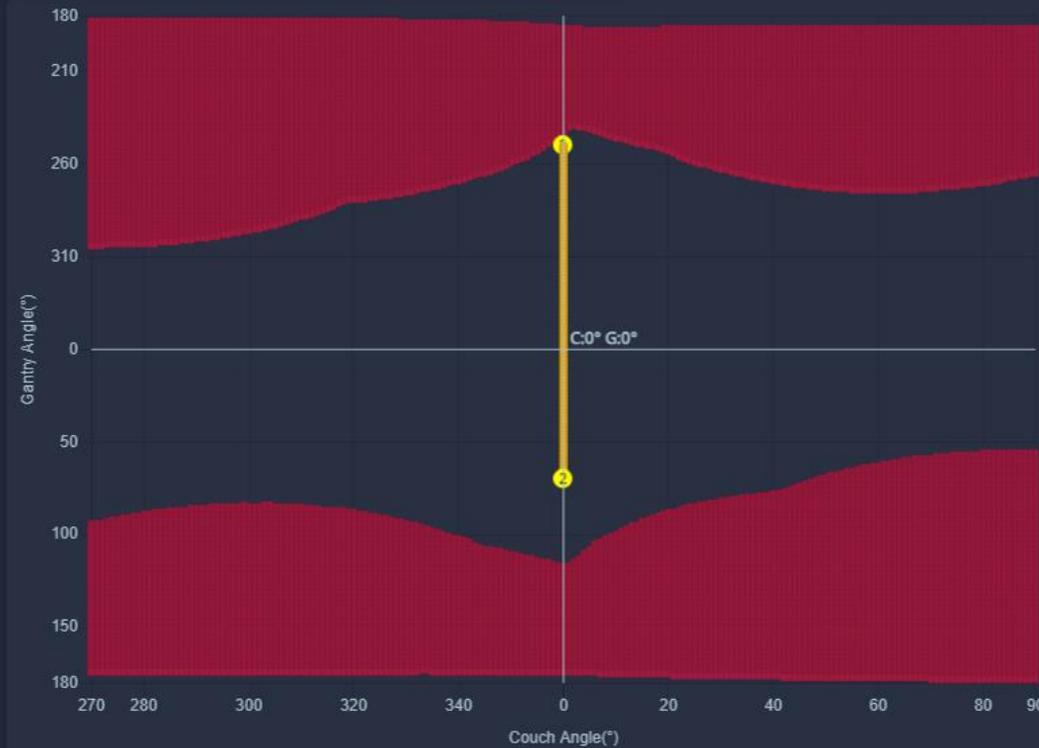
- 2 Field VMAT plan
 - CW G250-G70
 - CCW G70-G250

Priority	Structure Template	Structure Plan	Type	Prescription	Constraint	Goal	Brain VMAT 2F	Pass/Fail
1	PTV57	PTVFrontal_5700_30	Target	PTV57: 5700cGy	Max ≤	110%	119.081%	✗
2	PTV 57	PTVFrontal_5700_30	Target	PTV57: 5700cGy	V100% ≥	95%	98.257%	✓
3	Lens_R	Lens_R	OAR		Max ≤	700cGy	701.8cGy	✗
4	Lens_L	Lens_L	OAR		Max ≤	700cGy	666.7cGy	✓
7	Eye_L	Eye_L	OAR		Mean ≤	3000cGy	1139.7cGy	✓
8	Eye_R	Eye_R	OAR		Mean ≤	3000cGy	1151.6cGy	✓
12	Brainstem	Brainstem	OAR		Max ≤	5400cGy	3492.9cGy	✓
13	Cochlea_L	Cochlea_L	OAR		Max ≤	4500cGy	2634.8cGy	✓
14	Cochlea_L	Cochlea_L	OAR		Mean ≤	3500cGy	2414.1cGy	✓
15	Cochlea_R	Cochlea_R	OAR		Max ≤	4500cGy	1608.1cGy	✓
16	Cochlea_R	Cochlea_R	OAR		Mean ≤	3500cGy	1388.7cGy	✓

Standard Plan – 2 Arc VMAT

Brain VMAT 2F

Status	#	ID	Type	Gantry	Couch	Direction
✓	1	RA1 CW	Arc	250° to 70°	0°	CW
✓	2	RA2 CCW	Arc	70° to 250°	0°	CC



Couch Angle(°)

0

Gantry Angle(°)

0

1. TrueBeam - no H&N extension



Brain VMAT – 3 Arcs

- 3 Field VMAT plan
 - CW G250-G100
 - CCW G100-G250
 - CW G300-G50

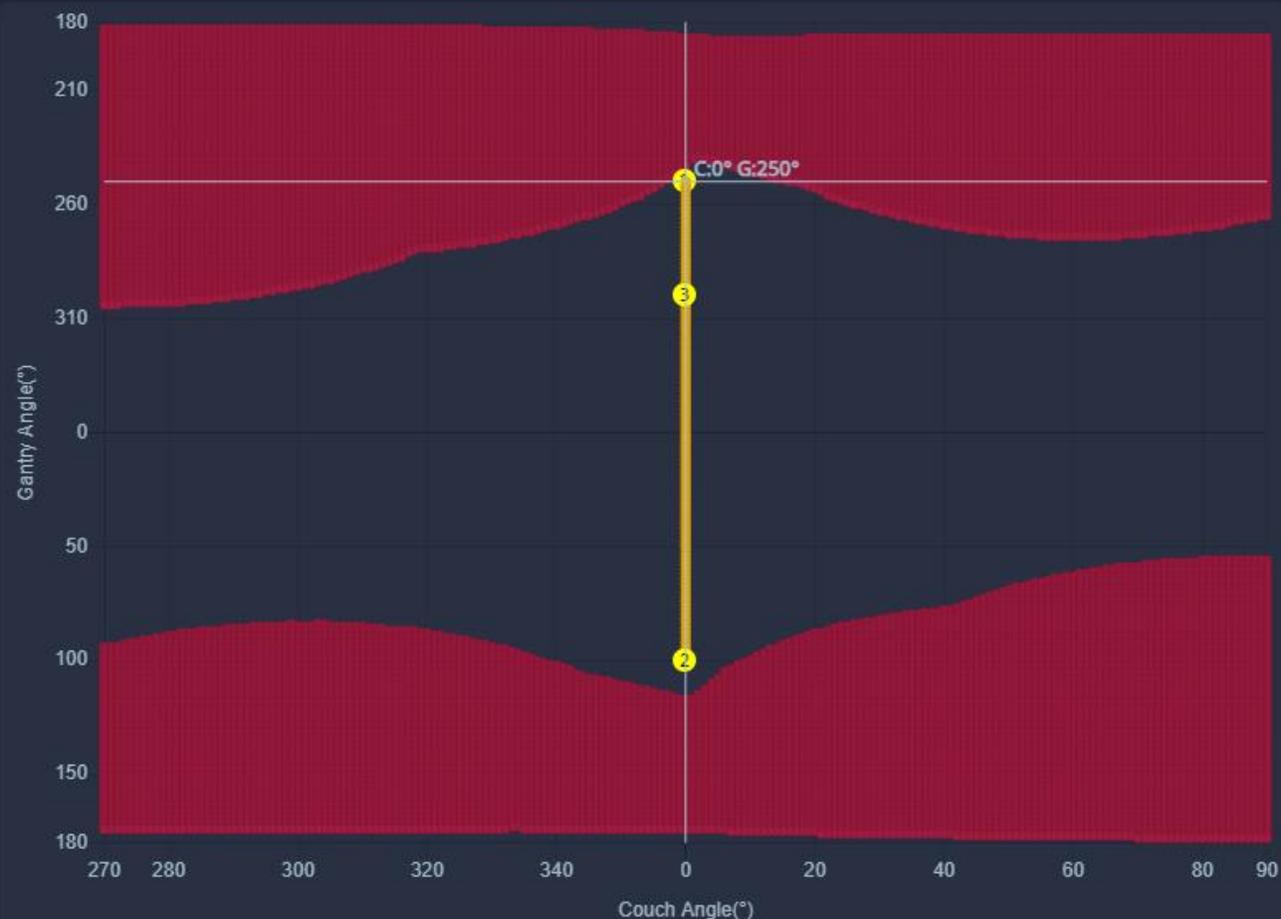
Priority	Structure Template	Structure Plan	Type	Prescription	Constraint	Goal	Brain VMAT 3F	Pass/Fail
1	PTV57	PTVFrontal_5700_30	Target	PTV57: 5700cGy	Max ≤	110%	118.796%	✗
2	PTV 57	PTVFrontal_5700_30	Target	PTV57: 5700cGy	V100% ≥	95%	98.337%	✓
3	Lens_R	Lens_R	OAR		Max ≤	700cGy	767.4cGy	✗
4	Lens_L	Lens_L	OAR		Max ≤	700cGy	574.1cGy	✓
7	Eye_L	Eye_L	OAR		Mean ≤	3000cGy	1086.2cGy	✓
8	Eye_R	Eye_R	OAR		Mean ≤	3000cGy	1152.3cGy	✓
12	Brainstem	Brainstem	OAR		Max ≤	5400cGy	3650.9cGy	✓
13	Cochlea_L	Cochlea_L	OAR		Max ≤	4500cGy	2294.3cGy	✓
14	Cochlea_L	Cochlea_L	OAR		Mean ≤	3500cGy	2085.8cGy	✓
15	Cochlea_R	Cochlea_R	OAR		Max ≤	4500cGy	1649.2cGy	✓
16	Cochlea_R	Cochlea_R	OAR		Mean ≤	3500cGy	1412.2cGy	✓

Brain VMAT – 3 Arcs

✓ Brain VMAT 3F

Status # ID Type Gantry Couch Direction

✓	1	RA1 CW	Arc	250° to 100°	0°	CW
✓	2	RA2 CCW	Arc	100° to 250°	0°	CC
✓	3	RA3 CW	Arc	300° to 50°	0°	CW

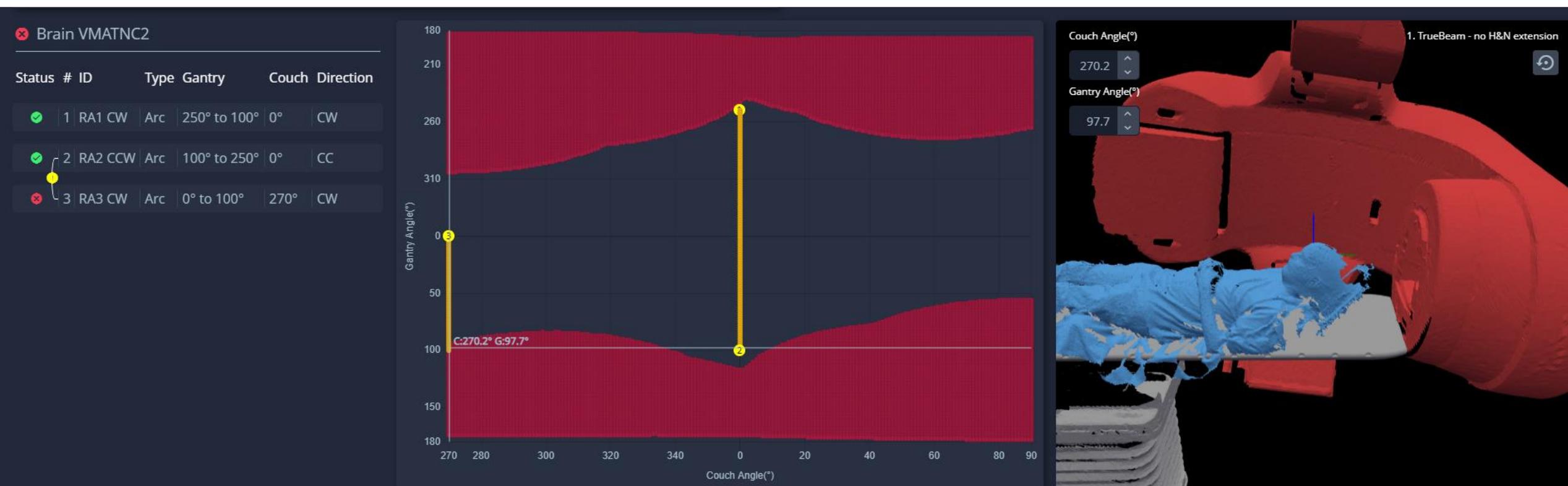


Brain VMAT – Non-Coplanar Arcs

- 3 Field VMAT non-coplanar plan
 - CW G250-G100
 - CCW G100-G250
 - **CW G0-G100, couch at 90**

Priority	Structure Template	Structure Plan	Type	Prescription	Constraint	Goal	Brain VMATNC2	Pass/Fail
1	PTV57	PTVFrontal_5700_30	Target	PTV57: 5700cGy	Max ≤	110%	115.253%	✗
2	PTV 57	PTVFrontal_5700_30	Target	PTV57: 5700cGy	V100% ≥	95%	98.46%	✓
3	Lens_R	Lens_R	OAR		Max ≤	700cGy	538.2cGy	✓
4	Lens_L	Lens_L	OAR		Max ≤	700cGy	525.2cGy	✓
7	Eye_L	Eye_L	OAR		Mean ≤	3000cGy	1285cGy	✓
8	Eye_R	Eye_R	OAR		Mean ≤	3000cGy	1179.7cGy	✓
12	Brainstem	Brainstem	OAR		Max ≤	5400cGy	2961.9cGy	✓
13	Cochlea_L	Cochlea_L	OAR		Max ≤	4500cGy	1553.8cGy	✓
14	Cochlea_L	Cochlea_L	OAR		Mean ≤	3500cGy	1395.3cGy	✓
15	Cochlea_R	Cochlea_R	OAR		Max ≤	4500cGy	1591.5cGy	✓
16	Cochlea_R	Cochlea_R	OAR		Mean ≤	3500cGy	1345.4cGy	✓

Brain VMAT – Non-Coplanar Arcs

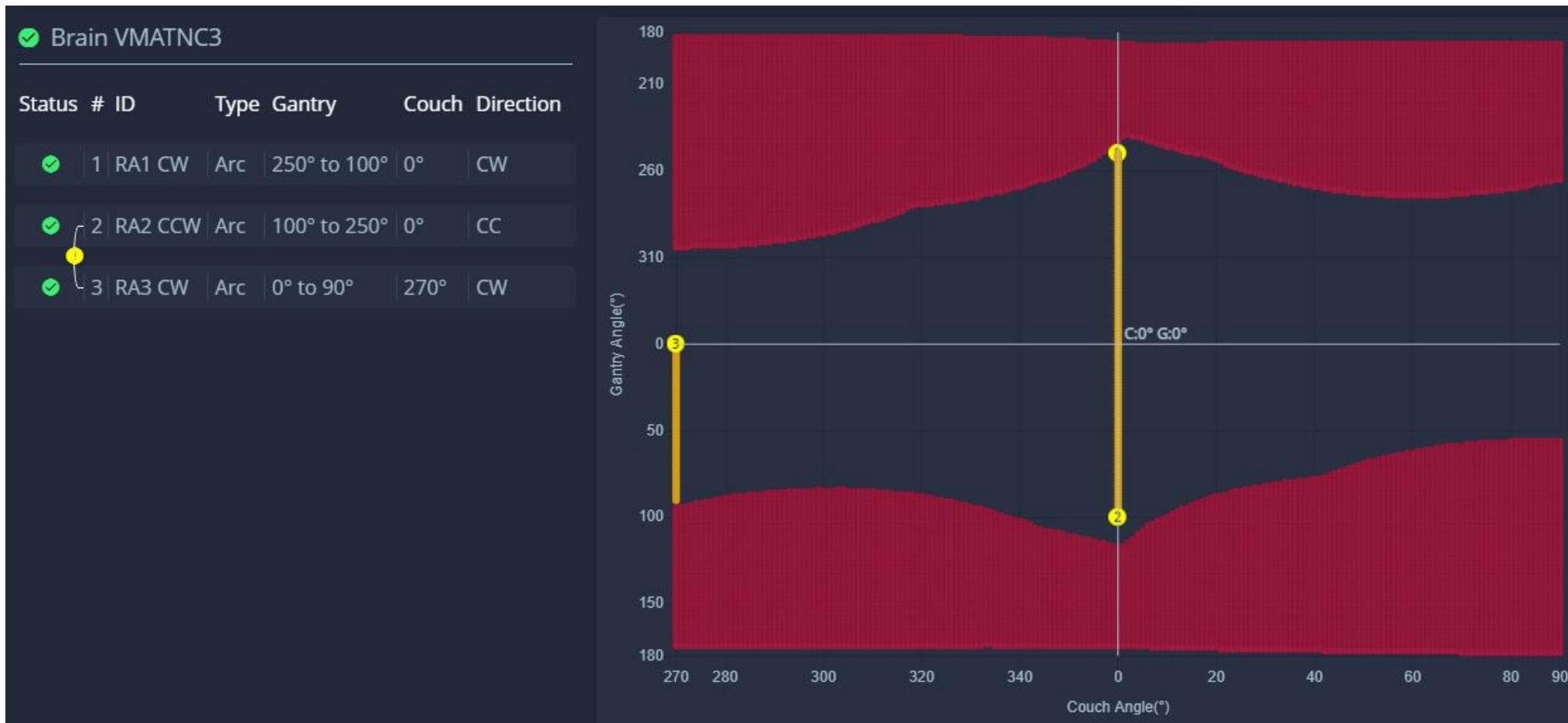


Brain VMAT – Non-Coplanar Arcs

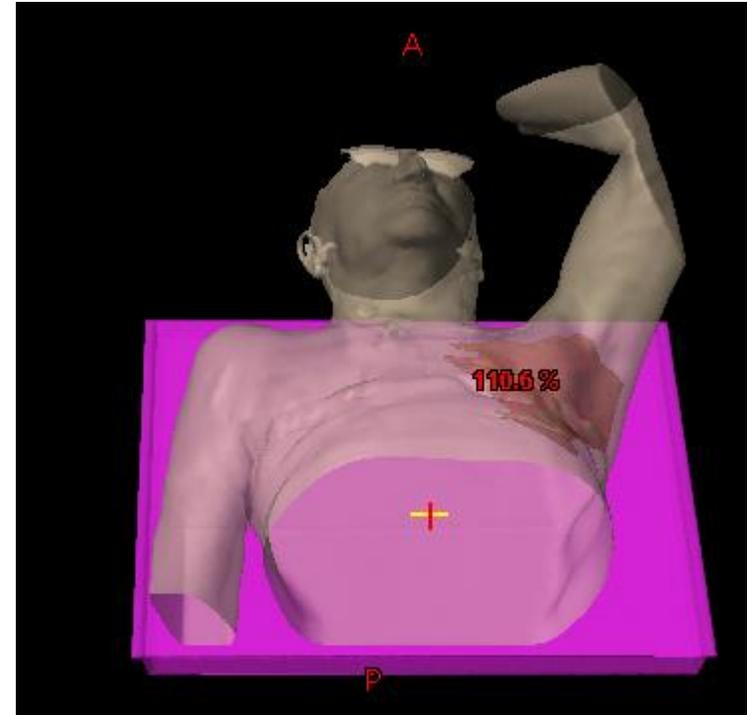
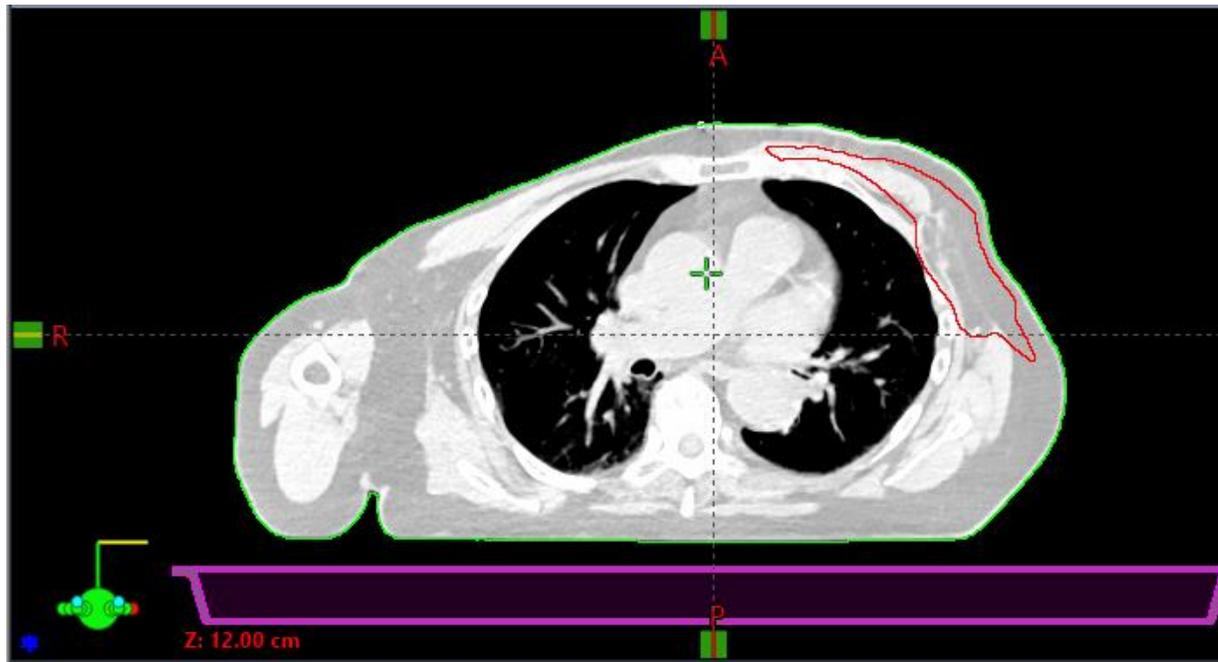
- 3 Field VMAT non-coplanar plan
 - CW G250-G100
 - CCW G100-G250
 - **CW G0-G90, couch at 90**

Priority	Structure Template	Structure Plan	Type	Prescription	Constraint	Goal	Brain VMATNC3	Brain VMAT 3F
1	PTV57	PTVFrontal_5700_30	Target	PTV57: 5700cGy	Max ≤	110%	115.149%	118.796%
2	PTV 57	PTVFrontal_5700_30	Target	PTV57: 5700cGy	V100% ≥	95%	98.763%	98.337%
3	Lens_R	Lens_R	OAR		Max ≤	700cGy	526.3cGy	767.4cGy
4	Lens_L	Lens_L	OAR		Max ≤	700cGy	521.6cGy	574.1cGy
7	Eye_L	Eye_L	OAR		Mean ≤	3000cGy	1193.8cGy	1086.2cGy
8	Eye_R	Eye_R	OAR		Mean ≤	3000cGy	1173cGy	1152.3cGy
12	Brainstem	Brainstem	OAR		Max ≤	5400cGy	3253.9cGy	3650.9cGy
13	Cochlea_L	Cochlea_L	OAR		Max ≤	4500cGy	1550.9cGy	2294.3cGy
14	Cochlea_L	Cochlea_L	OAR		Mean ≤	3500cGy	1398.8cGy	2085.8cGy
15	Cochlea_R	Cochlea_R	OAR		Max ≤	4500cGy	1384cGy	1649.2cGy
16	Cochlea_R	Cochlea_R	OAR		Mean ≤	3500cGy	1143.8cGy	1412.2cGy

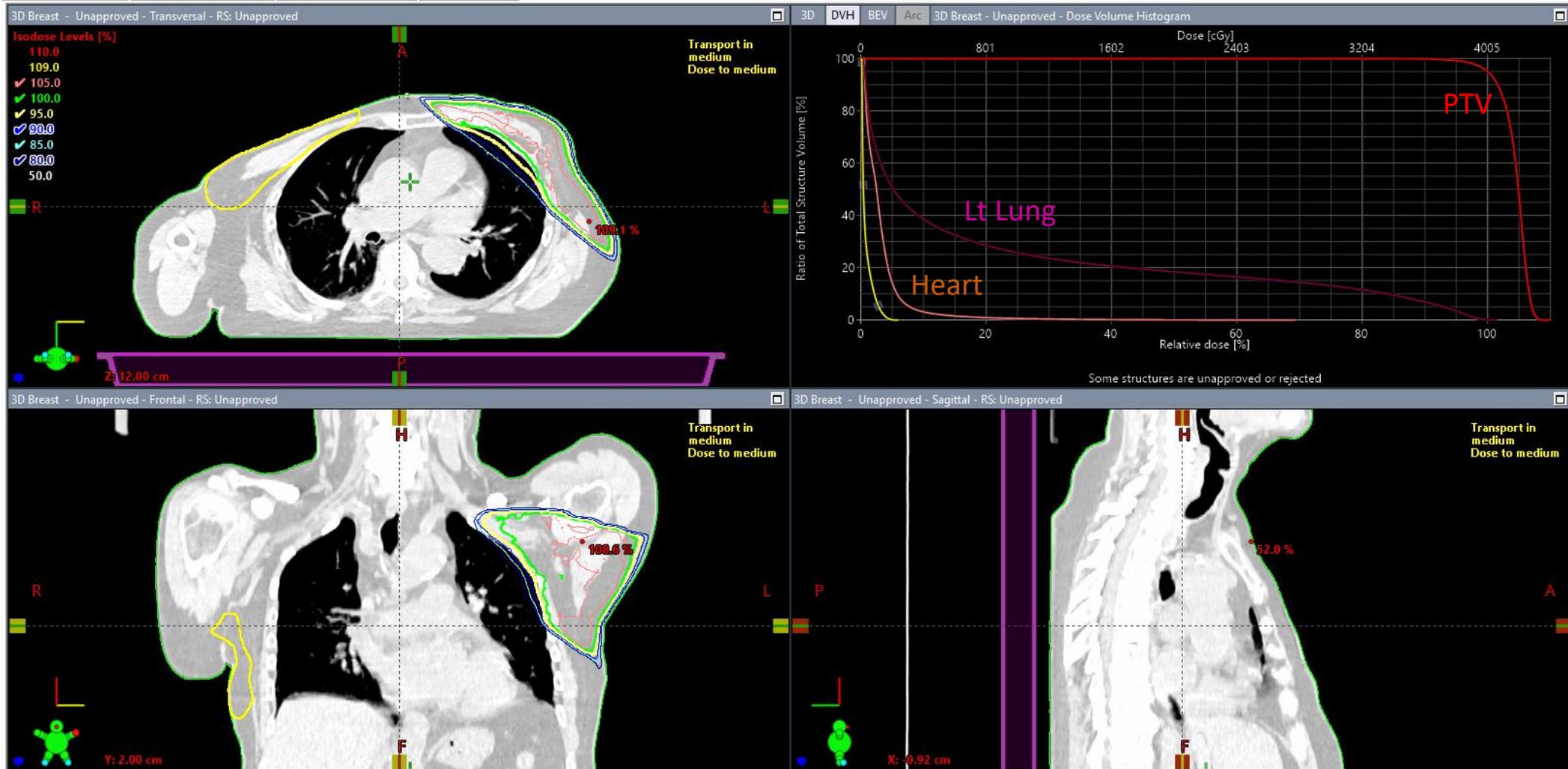
Brain VMAT – Non-Coplanar Arcs



Planning with a Clearance Map - Lt Breast



Standard Plan – 3D Breast Tangents

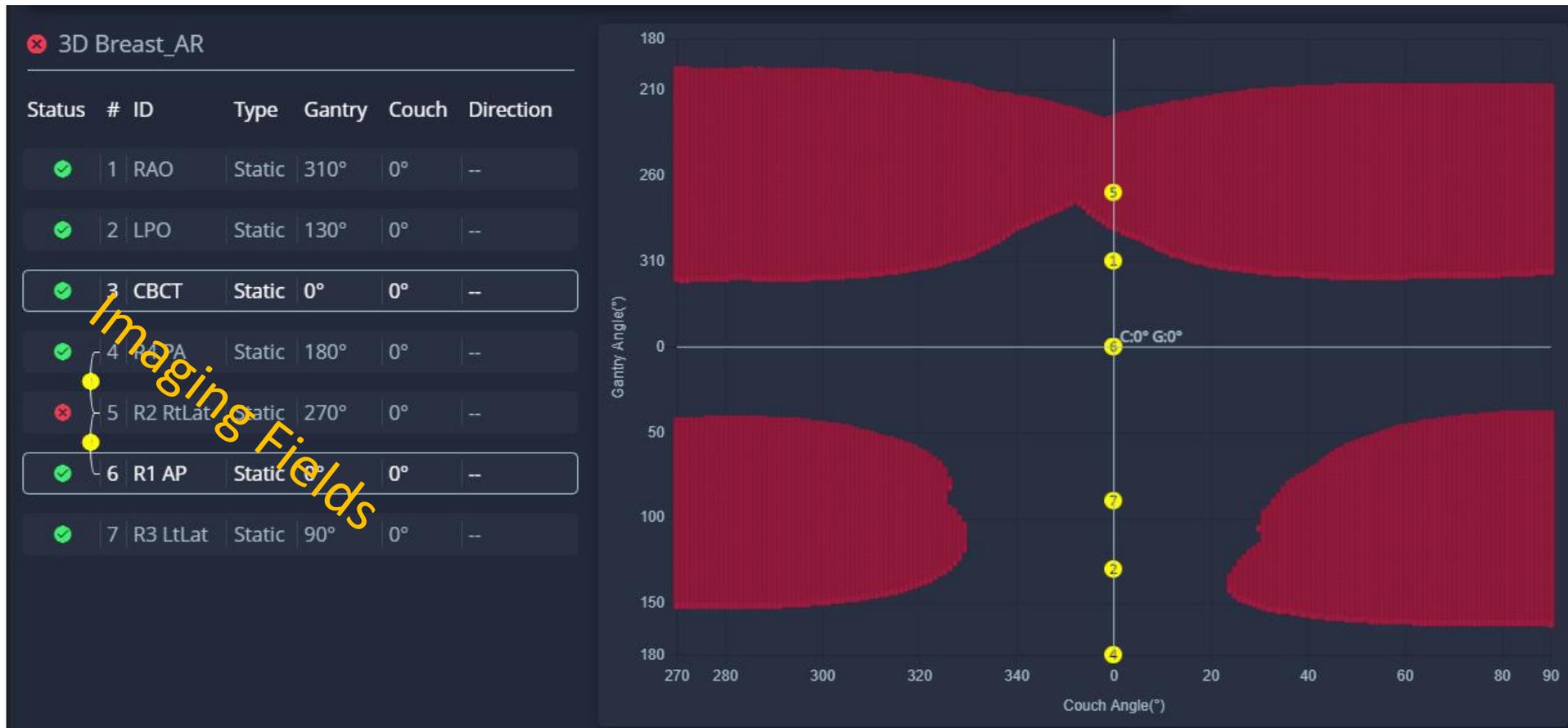


Standard Plan – 3D Breast Tangents

- 2 Field 3D Conformal plan
 - RAO G310
 - LPO G130

Priority	Structure Template	Structure Plan	Type	Prescription	Constraint	Goal	3D Breast	Pass/Fail
1	Lt Breast/CW eval	zptv_total	Target	Lt Breast/CW eval: 4005cGy	V95% ≥	95%	98.901%	✓
2	Lt Breast/CW eval	zptv_total	Target	Lt Breast/CW eval: 4005cGy	V107% ≤	10cc	31.327cc	✗
3	Lt Breast/CW eval	zptv_total	Target	Lt Breast/CW eval: 4005cGy	Max ≤	110%	110.034%	✗
4	Lt Breast/CW eval	zptv_total	Target	Lt Breast/CW eval: 4005cGy	D10% ≤	105%	106.655%	✗
5	Heart (Lt Breast)	Heart	OAR		V2250cGy ≤	10%	0.021%	✓
6	Heart	Heart	OAR		Mean ≤	300cGy	127cGy	✓
7	Lung_L	Lung L	OAR		V1800cGy ≤ (ipsilateral)	10%	19.497%	✗
8	Breast_R	Breast_R	OAR		V300cGy ≤ (contralateral)	1%	0%	✓
9	Lung_R	Lung_R	OAR		V480cGy ≤ (contralateral)	5%	0%	✓

Standard Plan – 3D Breast Tangents

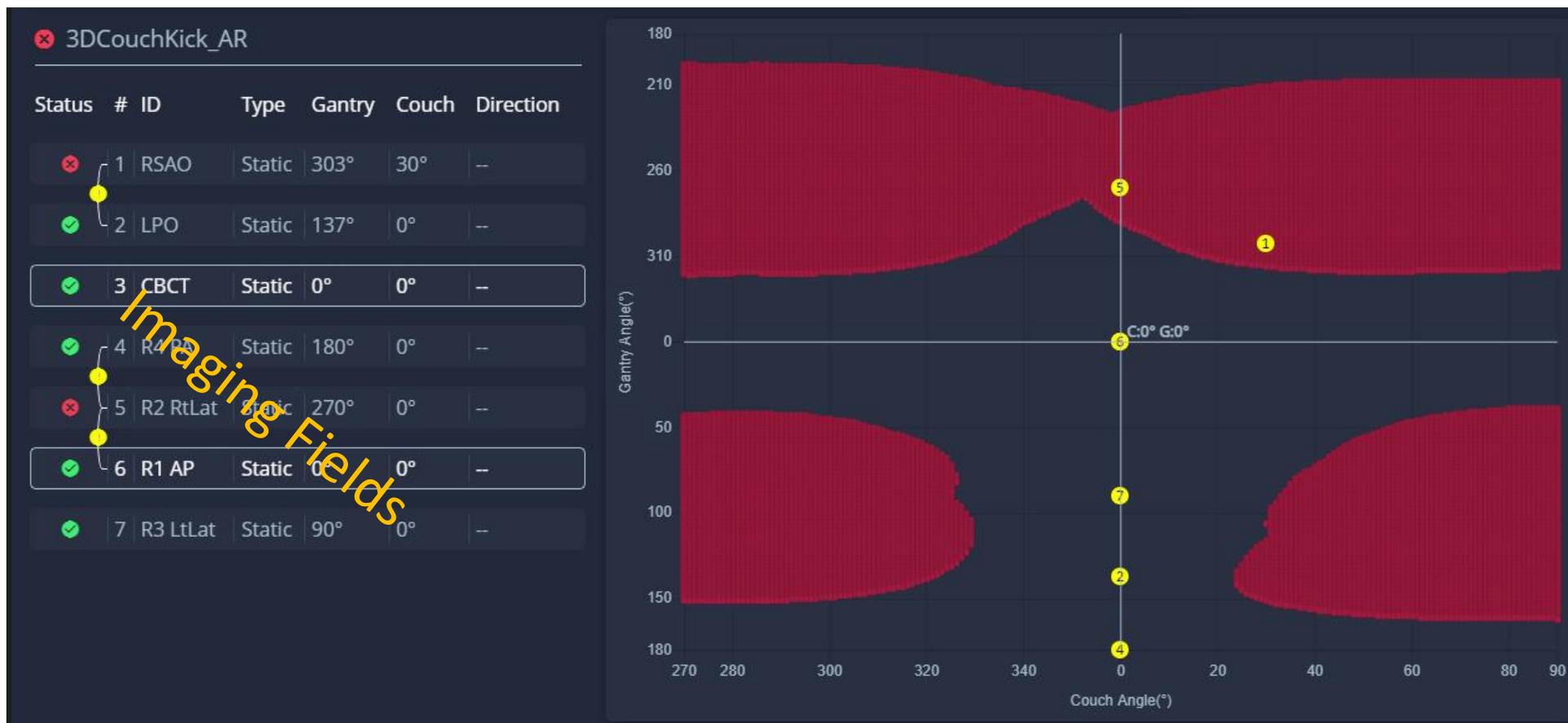


Lt Breast – Non-Coplanar Plan

- 2 Field 3D Conformal non-coplanar plan
 - RAO G303, C30, T330
 - LPO G137, C340, T0

Priority	Structure Template	Structure Plan	Type	Prescription	Constraint	Goal	3DCouchKick	3D Breast
1	Lt Breast/CW eval	zptv_total	Target	Lt Breast/CW eval: 4005cGy	V95% \geq	95%	95.991%	98.901%
2	Lt Breast/CW eval	zptv_total	Target	Lt Breast/CW eval: 4005cGy	V107% \leq	10cc	0cc	31.327cc
3	Lt Breast/CW eval	zptv_total	Target	Lt Breast/CW eval: 4005cGy	Max \leq	110%	106.654%	110.034%
4	Lt Breast/CW eval	zptv_total	Target	Lt Breast/CW eval: 4005cGy	D10% \leq	105%	102.553%	106.655%
5	Heart (Lt Breast)	Heart	OAR		V2250cGy \leq	10%	0.852%	0.021%
6	Heart	Heart	OAR		Mean \leq	300cGy	145.8cGy	127cGy
7	Lung_L	Lung L	OAR		V1800cGy \leq (ipsilateral)	10%	16.982%	19.497%
8	Breast_R	Breast_R	OAR		V300cGy \leq (contralateral)	1%	0%	0%
9	Lung_R	Lung_R	OAR		V480cGy \leq (contralateral)	5%	0%	0%

Lt Breast – Non-Coplanar Plan

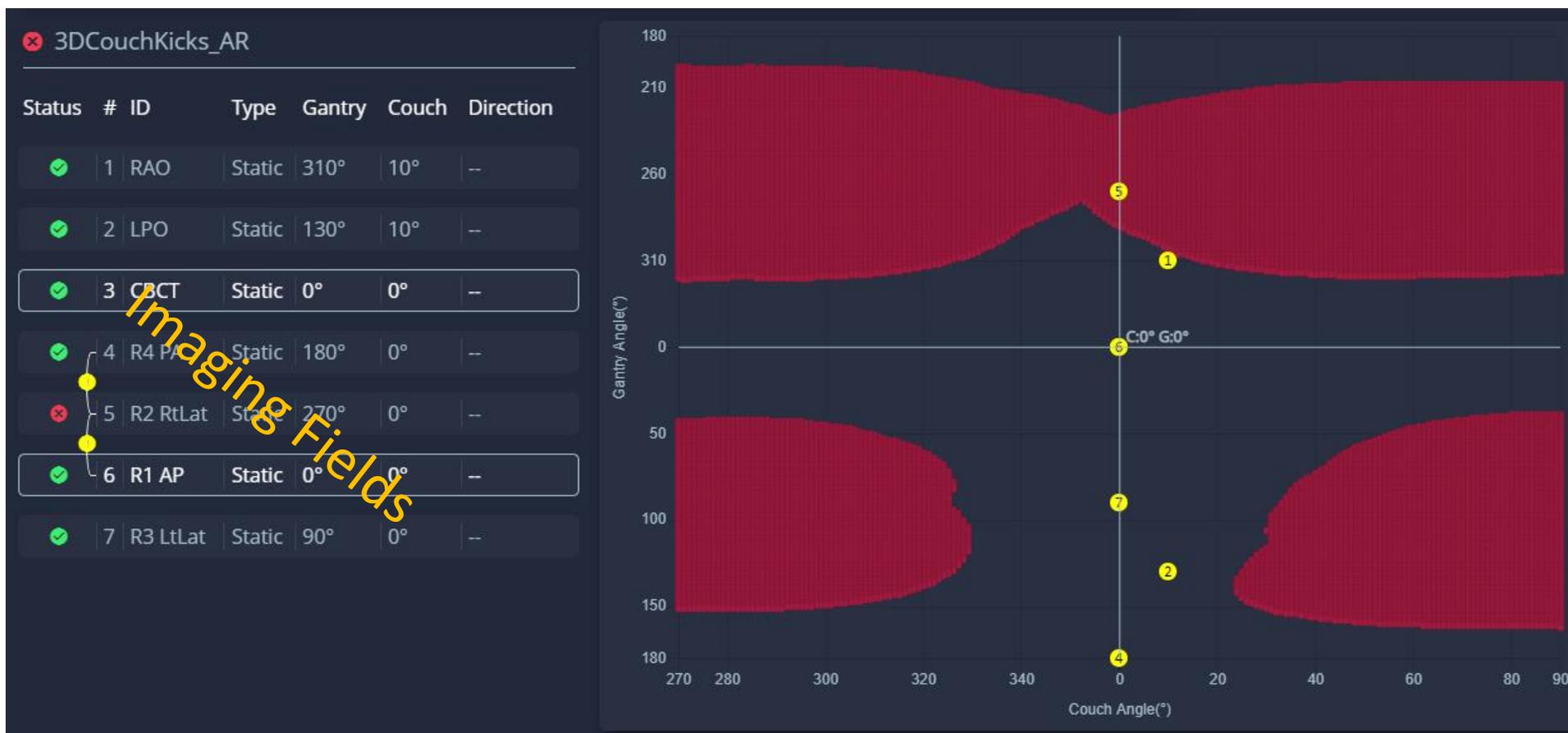


Lt Breast – Non-Coplanar Plan

- 2 Field 3D Conformal non-coplanar plan
 - RAO G310, C10, T350
 - LPO G130, C350, T350

Priority	Structure Template	Structure Plan	Type	Prescription	Constraint	Goal	3D breast CC	3D Breast
1	Lt Breast/CW eval	zptv_total	Target	Lt Breast/CW eval: 4005cGy	V95% ≥	95%	96.916%	98.901%
2	Lt Breast/CW eval	zptv_total	Target	Lt Breast/CW eval: 4005cGy	V107% ≤	10cc	0cc	31.327cc
3	Lt Breast/CW eval	zptv_total	Target	Lt Breast/CW eval: 4005cGy	Max ≤	110%	106.357%	110.034%
4	Lt Breast/CW eval	zptv_total	Target	Lt Breast/CW eval: 4005cGy	D10% ≤	105%	103.616%	106.655%
5	Heart (Lt Breast)	Heart	OAR		V2250cGy ≤	10%	0.002%	0.021%
6	Heart	Heart	OAR		Mean ≤	300cGy	105.7cGy	127cGy
7	Lung_L	Lung L	OAR		V1800cGy ≤ (ipsilateral)	10%	16.036%	19.497%
8	Breast_R	Breast_R	OAR		V300cGy ≤ (contralateral)	1%	0%	0%
9	Lung_R	Lung_R	OAR		V480cGy ≤ (contralateral)	5%	0%	0%

Lt Breast – Non-Coplanar Plan



Conclusion

- MapRT is an essential tool in treatment planning.
- Surface guided planning reduces planning time by preventing re-plans due to collisions
- The clearance map is a better more accurate alternative to a manual dry run.
- Planning with a clearance map can improve the quality of a treatment plan and its delivery

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