



Radiotherapy Plan Competition 2016

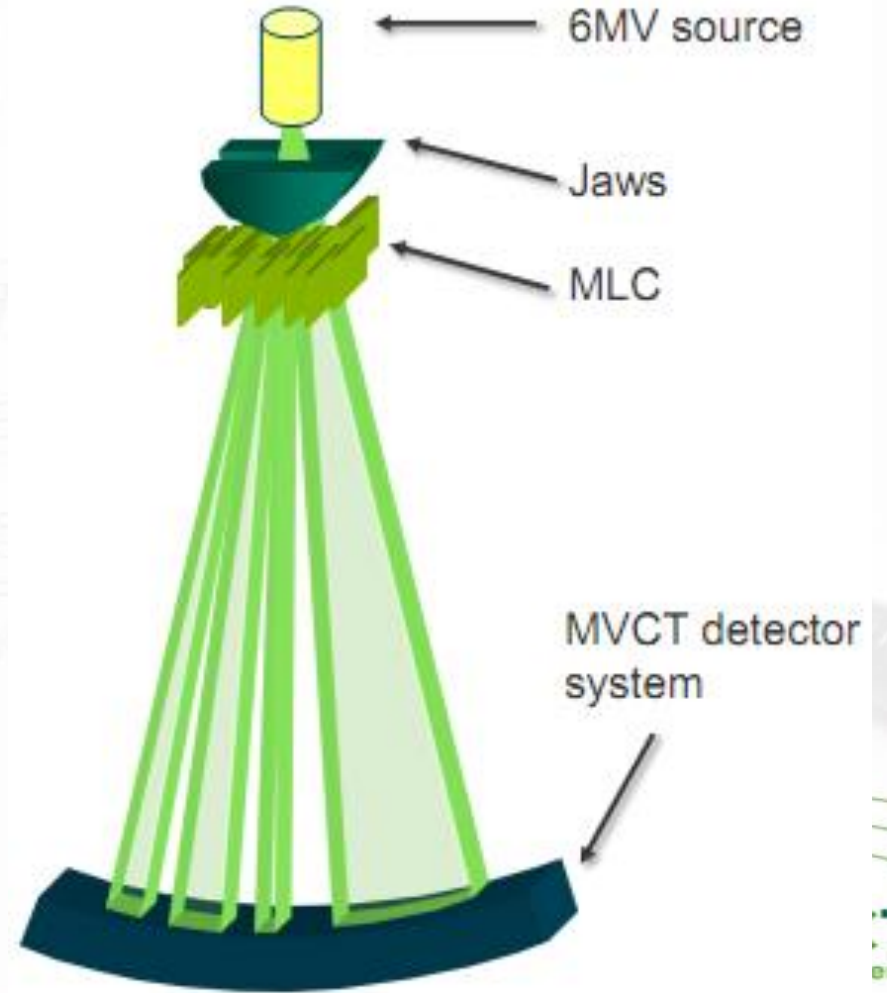
TomoTherapy Planning System

Dmytro Sychuk

Ukrainian Center of TomoTherapy,
Kirovograd, Ukraine

Beam Geometry

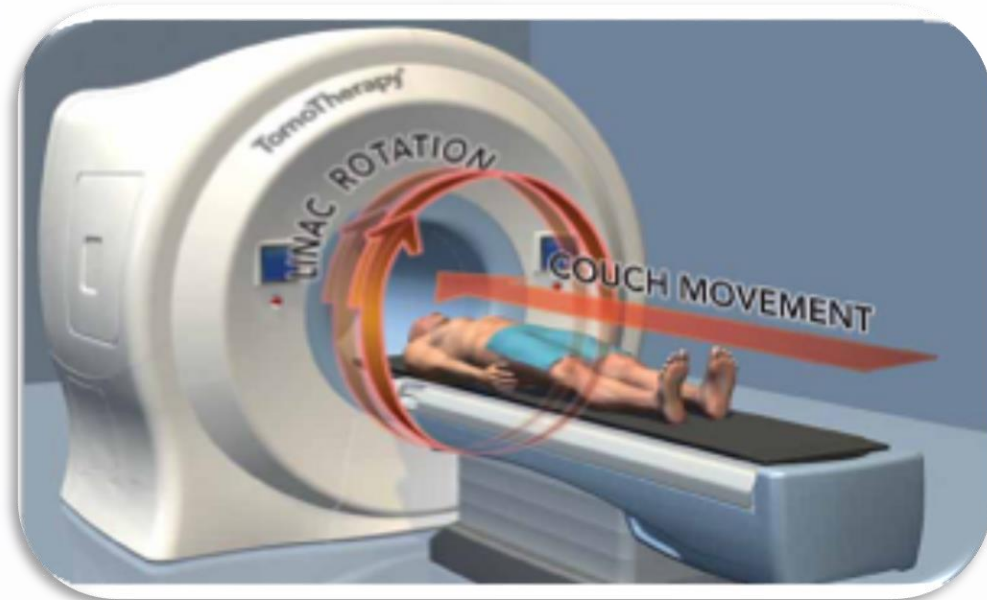
- 6MV fan beam
- 3 jaw options 1.0, 2.5 and 5 cm
- 64 leaves binary collimator
- Leaf measurement at isocenter 0.65cm



Delivery regimes

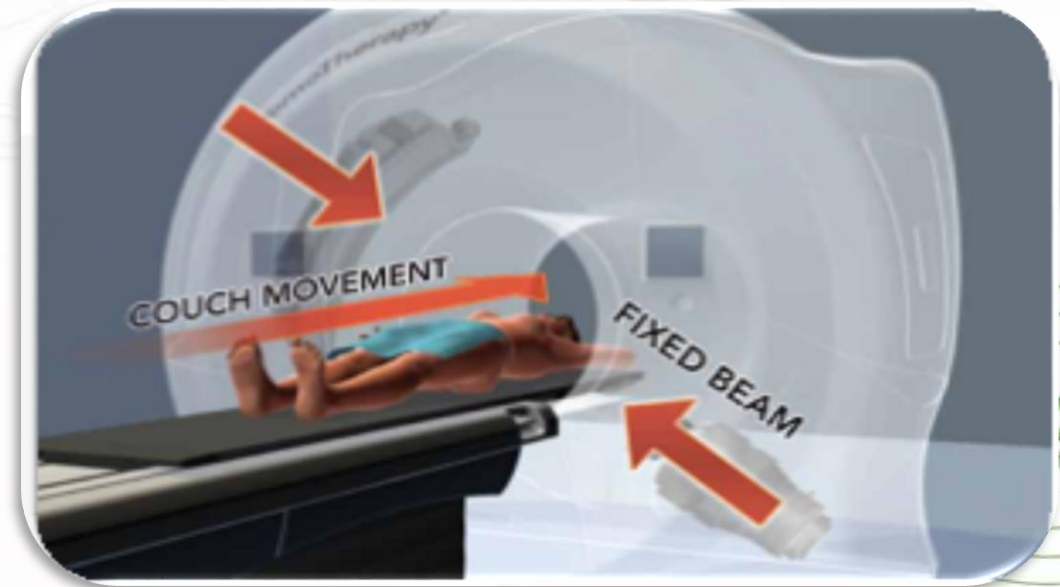
HELICAL

- Continuous gantry rotation at a constant rate
- Continuous couch movement in superior direction



DIRECT

- Discrete 2-12 static directions
- Continuous couch movement in superior direction for each direction separately



Objective function

$$F_{\text{Plan}} = F_{\text{Targets}} + F_{\text{OARs}}$$

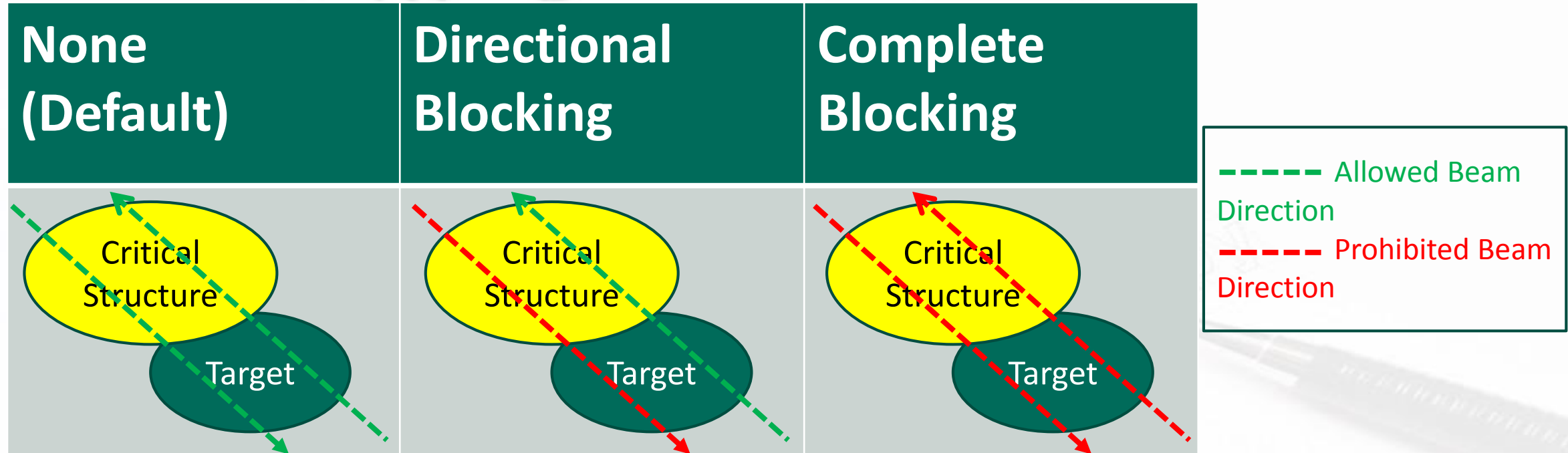
where

$$F_{\text{ROI}} = \sum_{\text{voxels}} (D_{\text{prescr}} - D_{\text{calc}})^2 \times \frac{\text{importance} \times \text{dose penalties} \times \text{DVH penalty}}{\text{ROI volume}}$$

The smaller volume we can control the better



Beam blocking



- Directional Blocking – only those beam directions that first go through the target are allowed
- Complete Blocking – all beam directions that go through the completely blocked structure are prohibited

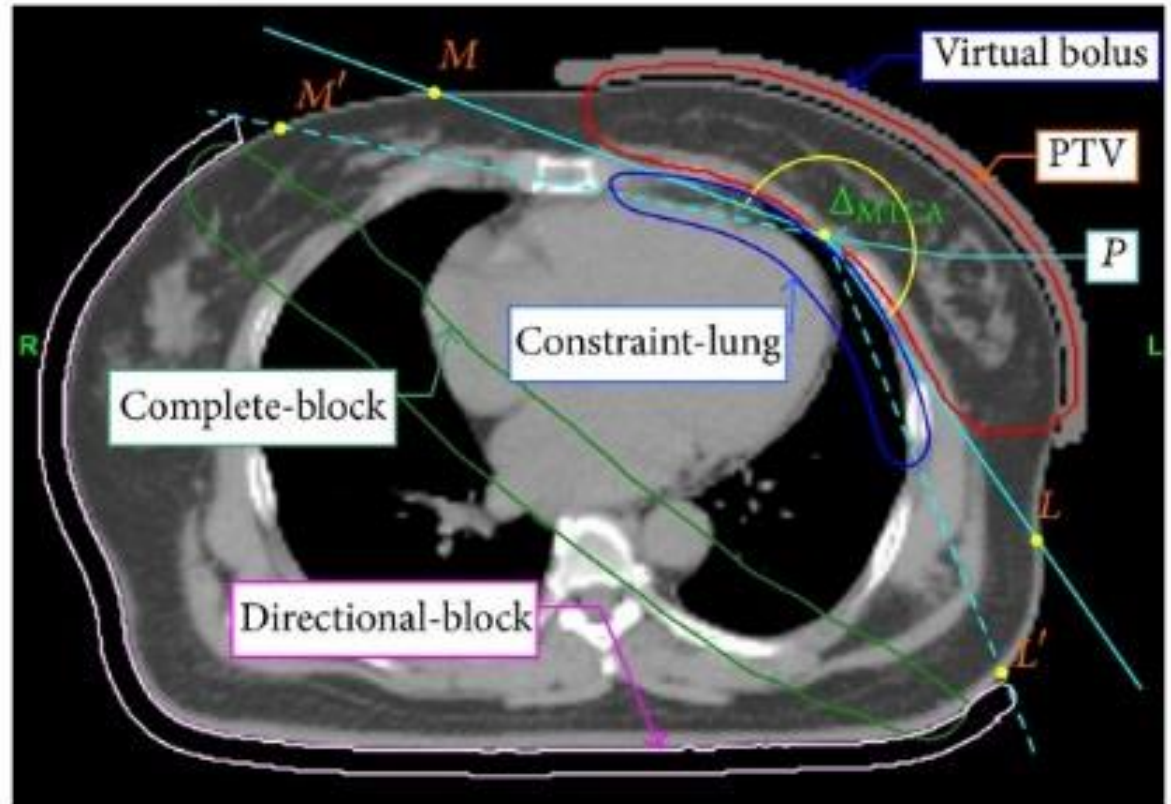
How I did my first Plan

Troubleshootings:

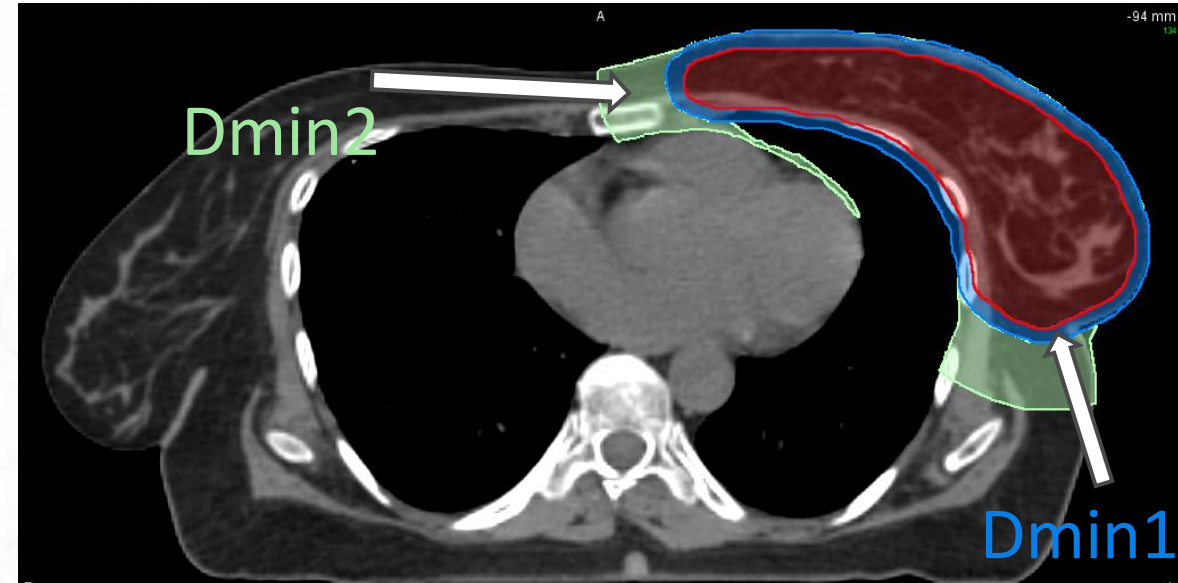
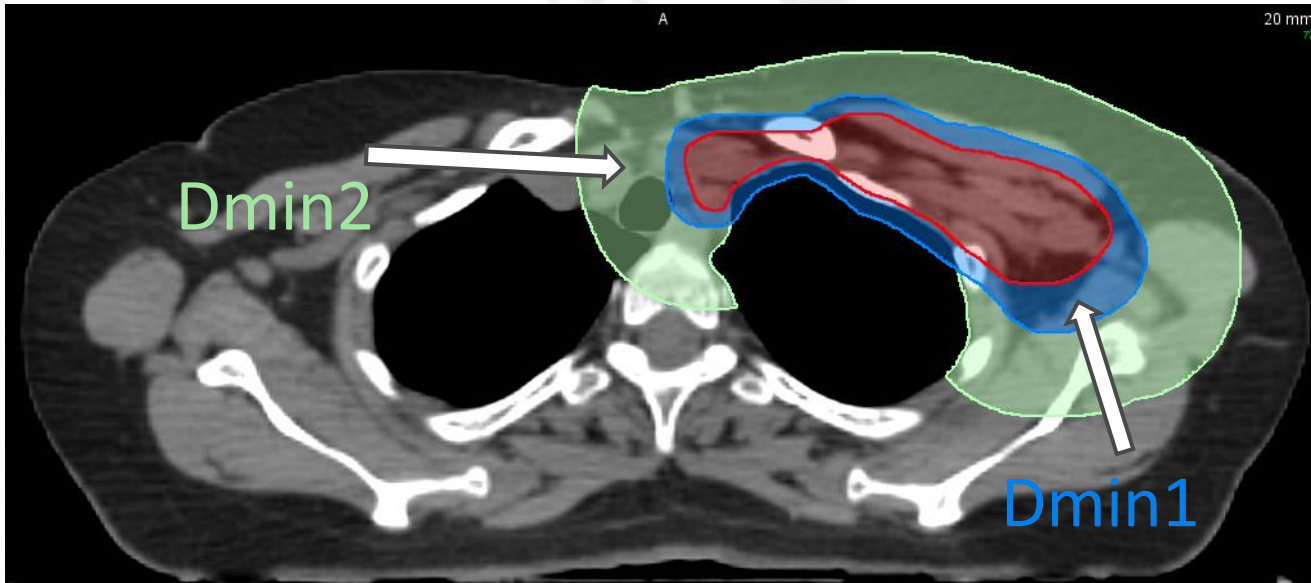
- Time cumbersome
- Works only for PTV_BREAST
- Steel needed additional structures

Left-Sided Whole Breast Irradiation with Hybrid-IMRT and Helical Tomotherapy Dosimetric Comparison

An-Cheng Shiau,^{1,2,3} Chen-Hsi Hsieh,¹ Hui-Ju Tien,¹ Hsin-Pei Yeh,¹ Chi-Ta Lin,¹ Pei-Wei Shueng,^{1,4,*} and Le-Jung Wu¹

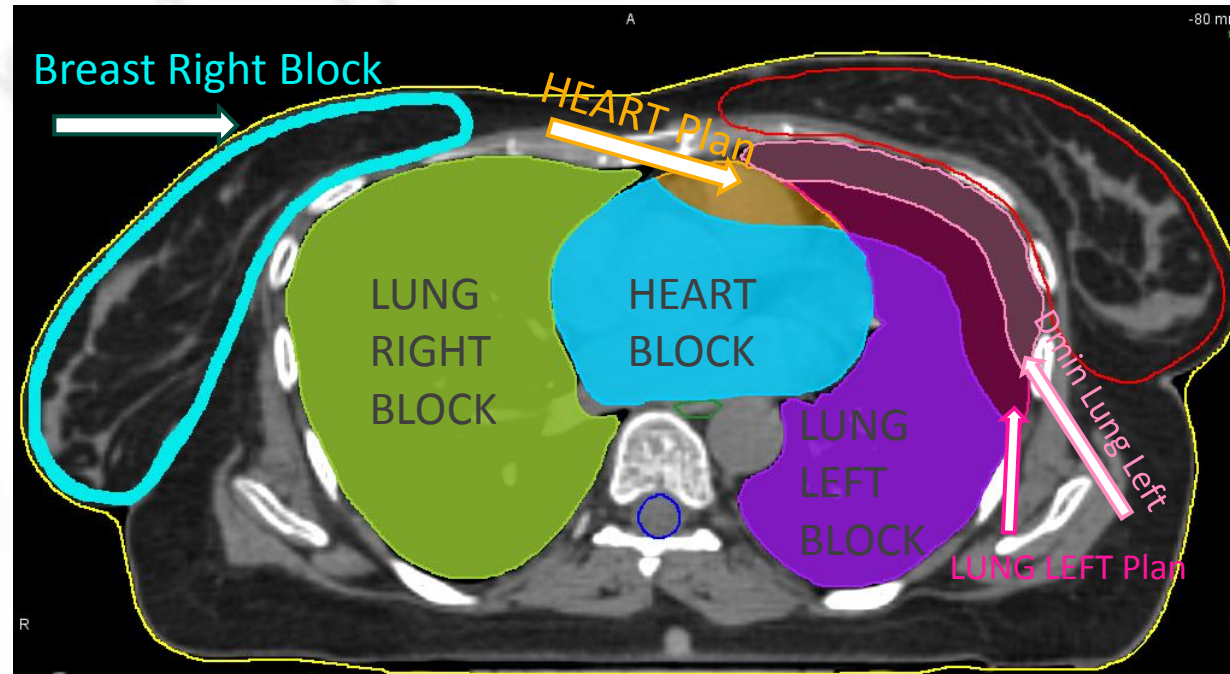


Additional Contours



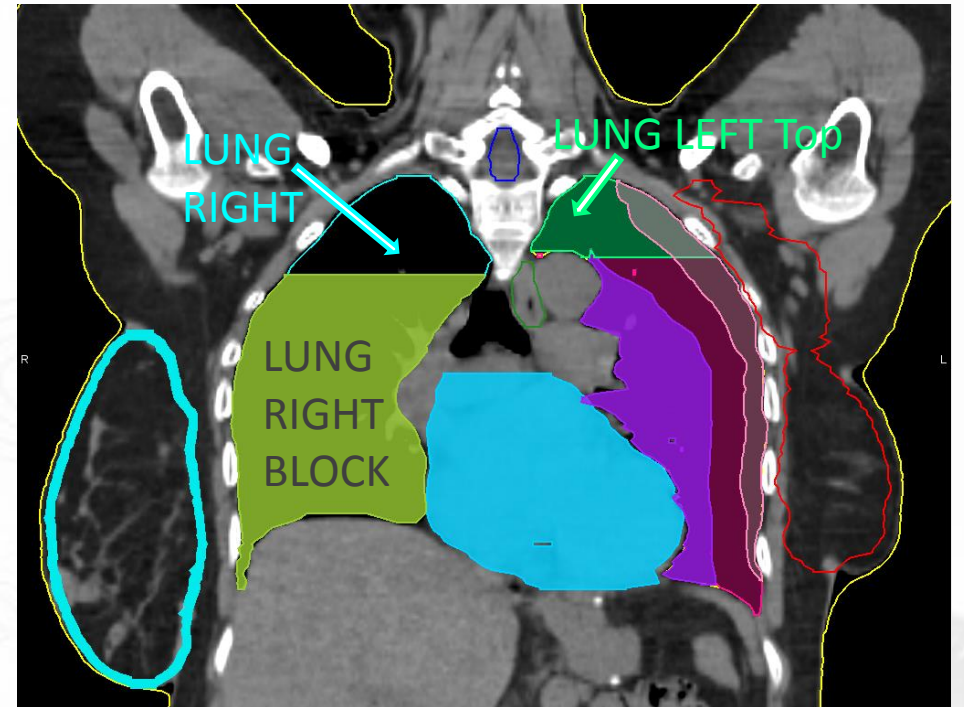
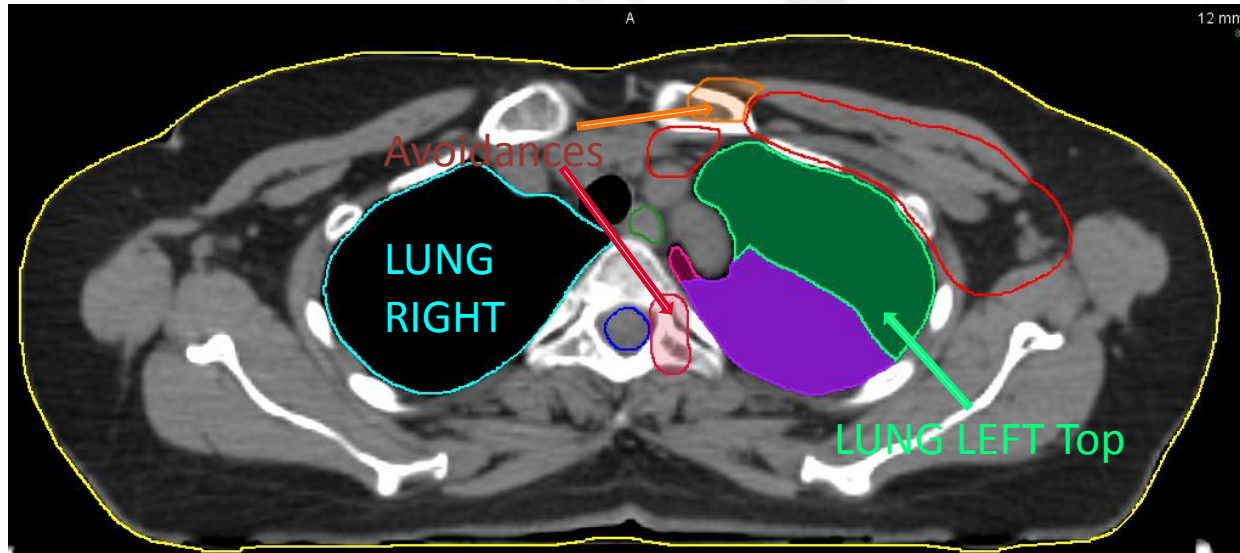
- Dmin1 – 0,5 cm margin around the PTV to create steep dose gradient around the target
- Dmin2 – 2,5-3 cm margin around the PTV to avoid high doses in body

Additional Contours



- Breast Right Block – 3 mm outer ring completely blocked to achieve no more than 2Gy dose inside right breast
- HEART BLOCK – part of the heart that is further than 3 cm from PTV (completely blocked)
- HEART Plan - part of the heart that is closer than 3 cm to PTV (here I optimize)
- LUNG LEFT BLOCK – part of the left lung that is further than 3 cm from PTV (completely blocked)
- Dmin Lung Left – part of the left lung that is closer than 1.5 cm to PTV
- LUNG LEFT Plan – part of the left lung that is closer than 3 cm to PTV excluding Dmin Lung Left

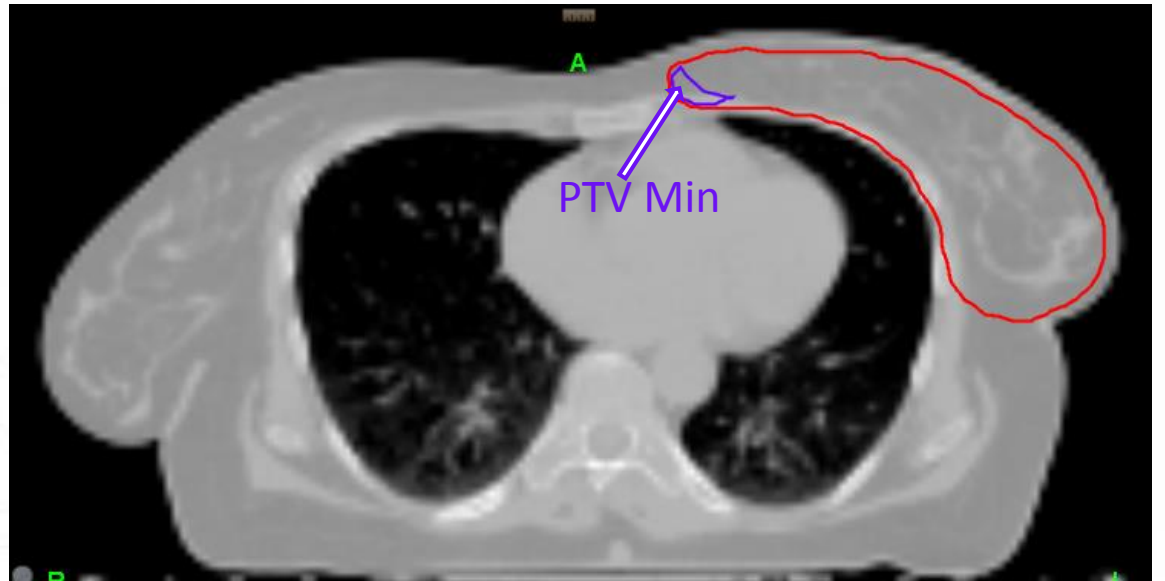
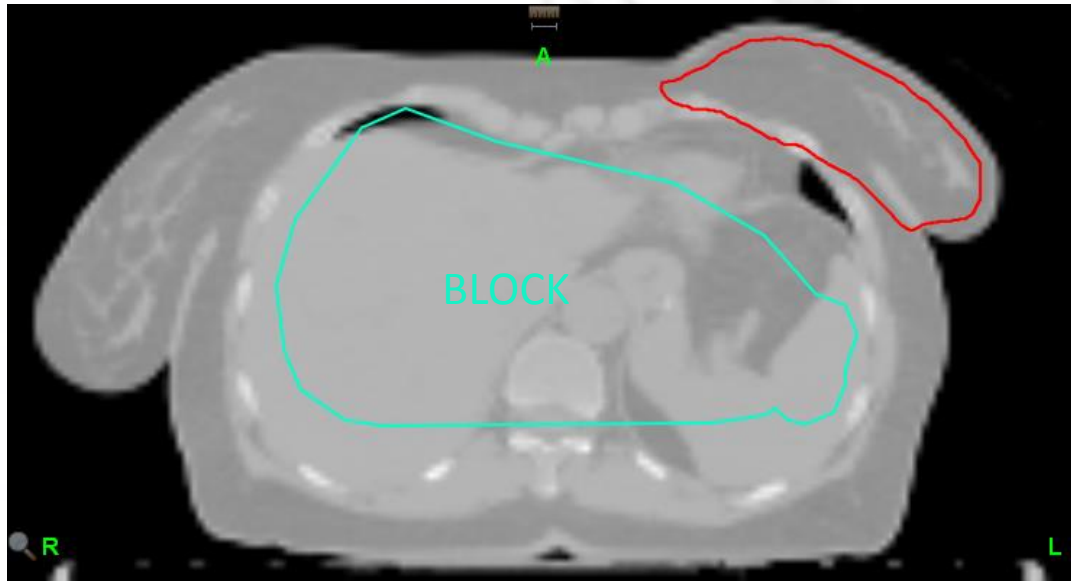
Additional contours



Emergence of PTV SC leads to:

- LUNG LEFT Top – part of the left lung that is closer than 3 cm to PTV on the slices where PTV SC is present
- LUNG RIGHT BLOCK – part of the right lung that is 1.5 cm lower than PTV SC
- Avoidances – some volumes where some “dose problems” are predicted or found

Additional contours



- **Block** – structure in the inferior part of the body made as the prolongation of the blocked regions
- **PTV Min** – small part of the PTV made to shrink the volume of minimum dose

General Parameters

Optimize

Dose Calc Grid

Field Width

Jaw Mode

Modulation Factor

Pitch

Mode

- Calculation Grid Fine resolution equal to imported planning images (256x256)
- Field width 2.5 cm was set according to the PTV length
- Beamlet Mode is a general mode in clinical practice - optimizer uses pre-computed dose volumes and simply re-weightings them

$$MF = \frac{\text{Max beamlet open time}}{\text{Average beamlet open time for used beamlets}}$$

$$\text{Pitch} = \frac{d_{\text{couch}}/\text{rotation}}{\text{field width}}$$



General Parameters

Theoretical analysis of the thread effect in helical TomoTherapy

Mingli Chen,¹ Yu Chen, and Quan Chen
Accuray Inc., 1240 Deming Way, Madison, Wisconsin 53717

Weiguo Lu
21st Century Oncology, Madison, Wisconsin 53719

(Received 17 May 2011; revised 17 August 2011; accepted for publication 7 September 2011; published 17 October 2011)

Pitch

Mode

$$MF = \frac{\text{Max beamlet open time}}{\text{Average beamlet open time for used beamlets}}$$

$$\text{Pitch} = \frac{d_{\text{couch}}/\text{rotation}}{\text{field width}}$$



Starting restrictions

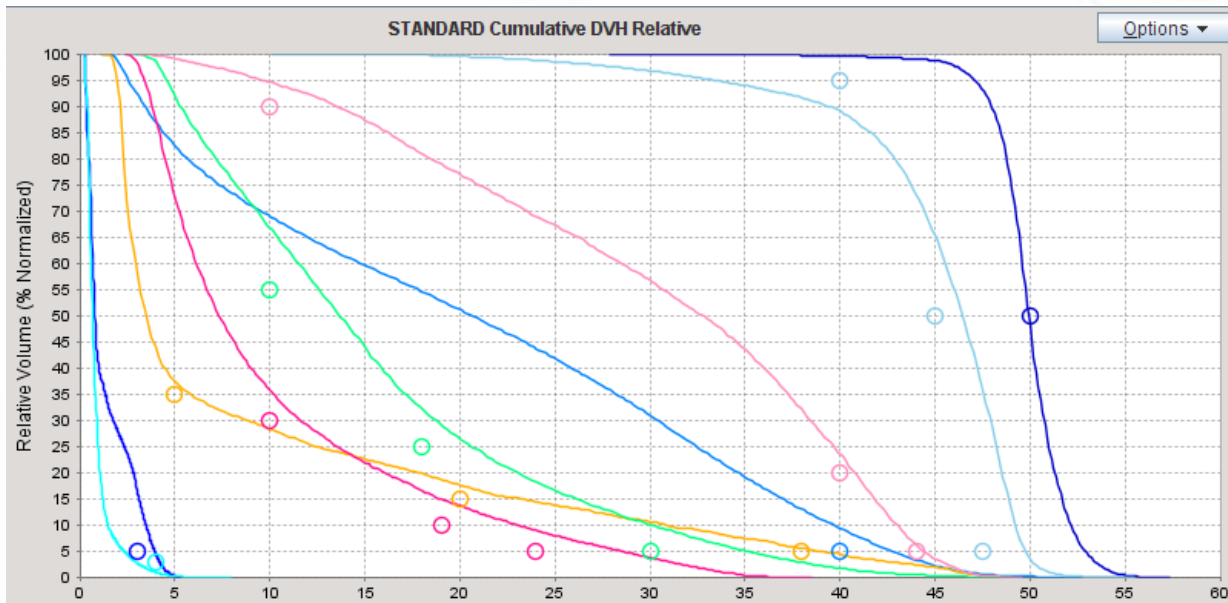
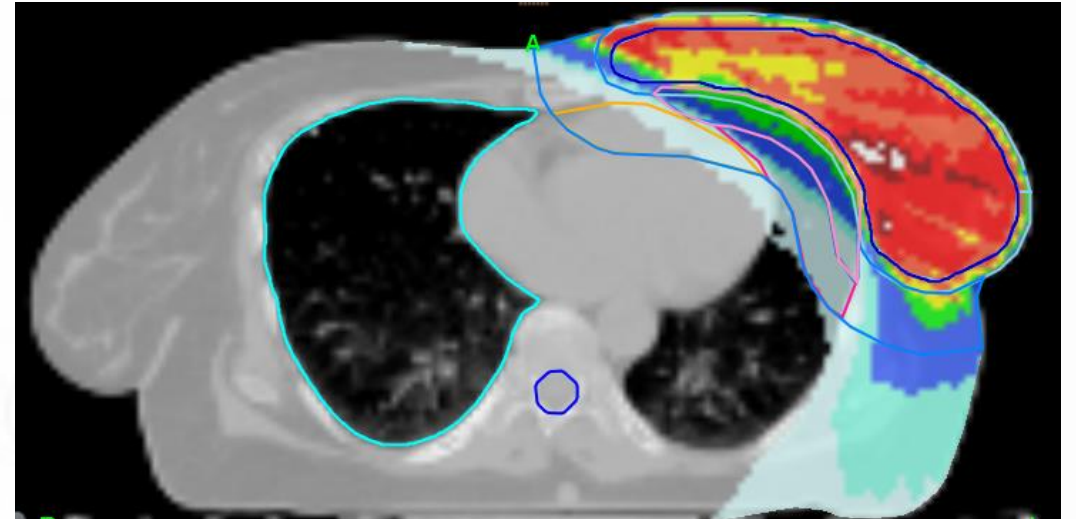
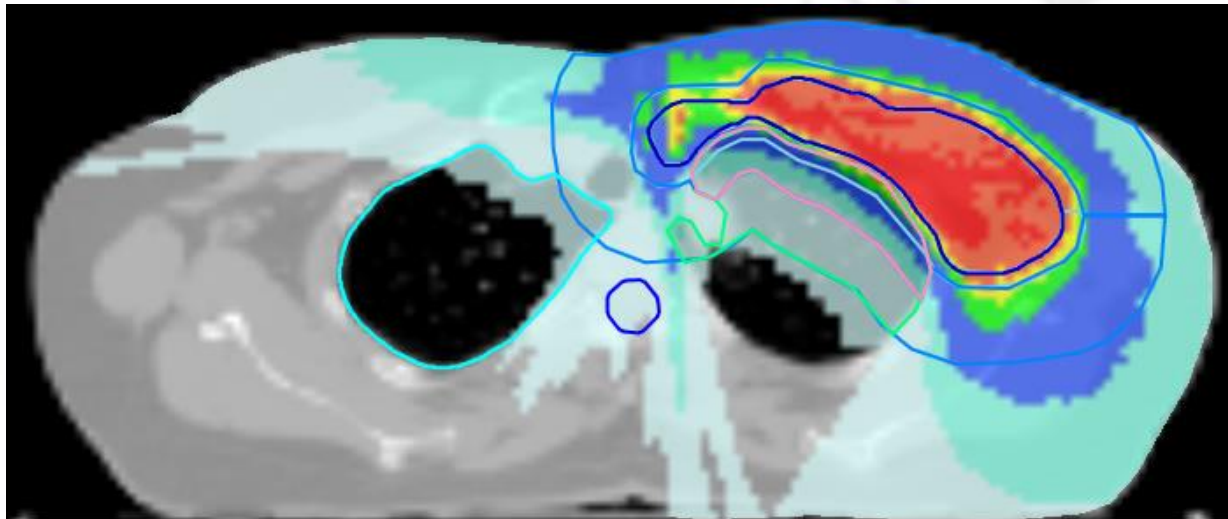
Name	Display	Color	Blocked	Use	Importance	Max Dose [Gy]	Max Dose Pen.	DVH Vol	DVH Dose [Gy]	Min Dose [Gy]	Min Dose Pen.
PTV Min	<input checked="" type="checkbox"/>	1	Unblocked	<input checked="" type="checkbox"/>	30	50.00	30	50.00 ▼	50.00 ▼	50.00	30
CTV-LUMPECTOMY	<input type="checkbox"/>	2	Unblocked	<input checked="" type="checkbox"/>	30	55.00	10	50.00 ▼	50.00 ▼	50.00	30
PTV_AXILL	<input type="checkbox"/>	3	Unblocked	<input checked="" type="checkbox"/>	30	50.00	30	50.00 ▼	50.00 ▼	50.00	30
PTV_SC	<input type="checkbox"/>	4	Unblocked	<input checked="" type="checkbox"/>	30	50.00	30	50.00 ▼	50.00 ▼	50.00	30
PTV_BREAST	<input type="checkbox"/>	5	Unblocked	<input checked="" type="checkbox"/>	30	50.00	30	50.00 ▼	50.00 ▼	50.00	30
PTV_TOT_EVAL	<input type="checkbox"/>	6	Unblocked	<input checked="" type="checkbox"/>	30	50.00	30	50.00 ▼	50.00 ▼	50.00	30

Name	Display	Color	Blocked	Use	Importance	Max Dose [Gy]	Max Dose Pen.	DVH Vol	DVH Dose [Gy]	DVH Pt. Pen.
LUNG_LEFT Block	<input type="checkbox"/>	1	Complete	<input checked="" type="checkbox"/>	1	7.00	1	5.00 ▼	4.50 ▼	1 ▼
LUNG_RIGHT Block	<input type="checkbox"/>	5	Complete	<input checked="" type="checkbox"/>	1	50.00	1	50.00 ▼	50.00 ▼	1 ▼
HEART Block	<input type="checkbox"/>	7	Complete	<input checked="" type="checkbox"/>	1	25.00	1	10.00 ▼	5.00 ▼	1 ▼
Breast Right Block	<input type="checkbox"/>	10	Complete	<input checked="" type="checkbox"/>	1	50.00	1	50.00 ▼	50.00 ▼	1 ▼
Block	<input checked="" type="checkbox"/>	15	Complete	<input checked="" type="checkbox"/>	1	50.00	1	5.00 ▼	50.00 ▼	1 ▼
LUNG_RIGHT	<input type="checkbox"/>	6	Directional	<input checked="" type="checkbox"/>	100	5.00	100	3.00 ▼	4.00 ▼	10 ▼
SPINAL CORD	<input type="checkbox"/>	9	Directional	<input checked="" type="checkbox"/>	50	5.00	750	5.00 ▼	3.00 ▼	1 ▼

Name	Display	Color	Blocked	Use	Importance	Max Dose [Gy]	Max Dose Pen.	DVH Vol	DVH Dose [Gy]	DVH Pt. Pen.
LUNG_LEFT Plan Top	<input type="checkbox"/>	2	Unblocked	<input checked="" type="checkbox"/>	18	47.50	18	5.00 ▼	30.00 ▼	20 ▼
Dmin Lung Left	<input type="checkbox"/>	3	Unblocked	<input checked="" type="checkbox"/>	15	47.50	15	5.00 ▼	44.00 ▼	15 ▼
LUNG_LEFT Plan	<input type="checkbox"/>	4	Unblocked	<input checked="" type="checkbox"/>	20	45.00	20	5.00 ▼	24.00 ▼	15 ▼
HEART Plan	<input type="checkbox"/>	8	Unblocked	<input checked="" type="checkbox"/>	15	47.50	15	5.00 ▼	38.00 ▼	15 ▼
Avoidance2	<input type="checkbox"/>	11	Unblocked	<input checked="" type="checkbox"/>	8	25.00	8	50.00 ▼	20.00 ▼	8 ▼
Avoidance	<input checked="" type="checkbox"/>	12	Unblocked	<input checked="" type="checkbox"/>	10	47.50	10	50.00 ▼	45.00 ▼	10 ▼
Dmin1	<input type="checkbox"/>	13	Unblocked	<input checked="" type="checkbox"/>	7	49.50	7	5.00 ▼	47.50 ▼	7 ▼
Dmin2	<input type="checkbox"/>	14	Unblocked	<input checked="" type="checkbox"/>	5	45.00	5	5.00 ▼	40.00 ▼	7 ▼



First Results



- First I protect OARs



Further optimization

Name	Display	Color	Blocked	Use	Importance	Max Dose [Gy]	Max Dose Pen.	DVH Vol	DVH Dose [Gy]	Min Dose [Gy]	Min Dose Pen.
PTV Min	<input type="checkbox"/>	1	Unblocked	<input checked="" type="checkbox"/>	300	50.00	300	50.00 ▼	50.00 ▼	50.00	450
CTV-LUMPECTOMY	<input type="checkbox"/>	2	Unblocked	<input checked="" type="checkbox"/>	300	55.00	10	50.00 ▼	50.00 ▼	50.00	300
PTV_AXILL	<input type="checkbox"/>	3	Unblocked	<input checked="" type="checkbox"/>	300	50.00	700	50.00 ▼	50.00 ▼	50.00	700
PTV_SC	<input type="checkbox"/>	4	Unblocked	<input checked="" type="checkbox"/>	300	50.00	1000	50.00 ▼	50.00 ▼	50.00	700
PTV_BREAST	<input checked="" type="checkbox"/>	5	Unblocked	<input checked="" type="checkbox"/>	300	50.00	750	75.00 ▼	50.00 ▼	50.00	1000
PTV_TOT_EVAL	<input checked="" type="checkbox"/>	6	Unblocked	<input checked="" type="checkbox"/>	300	50.00	300	50.00 ▼	50.00 ▼	50.00	300

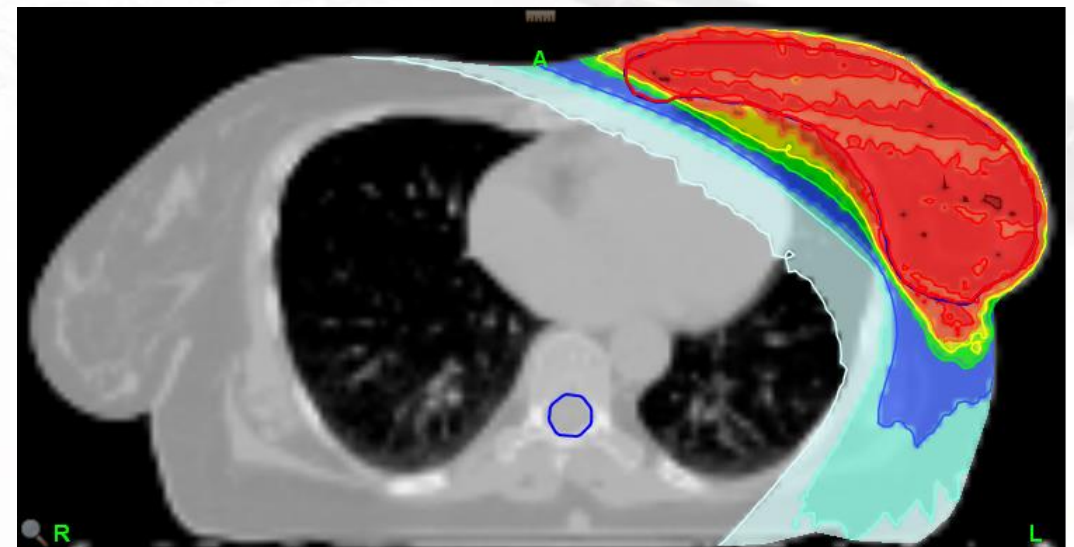
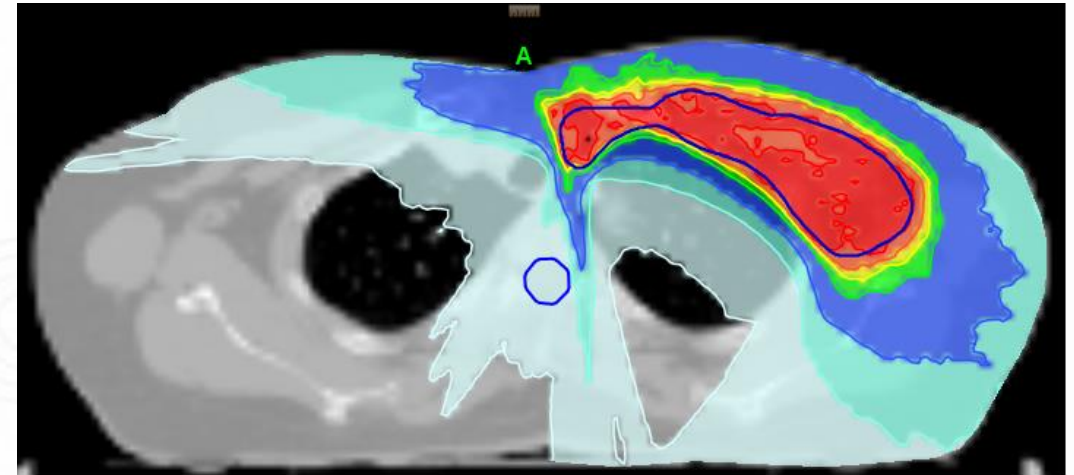
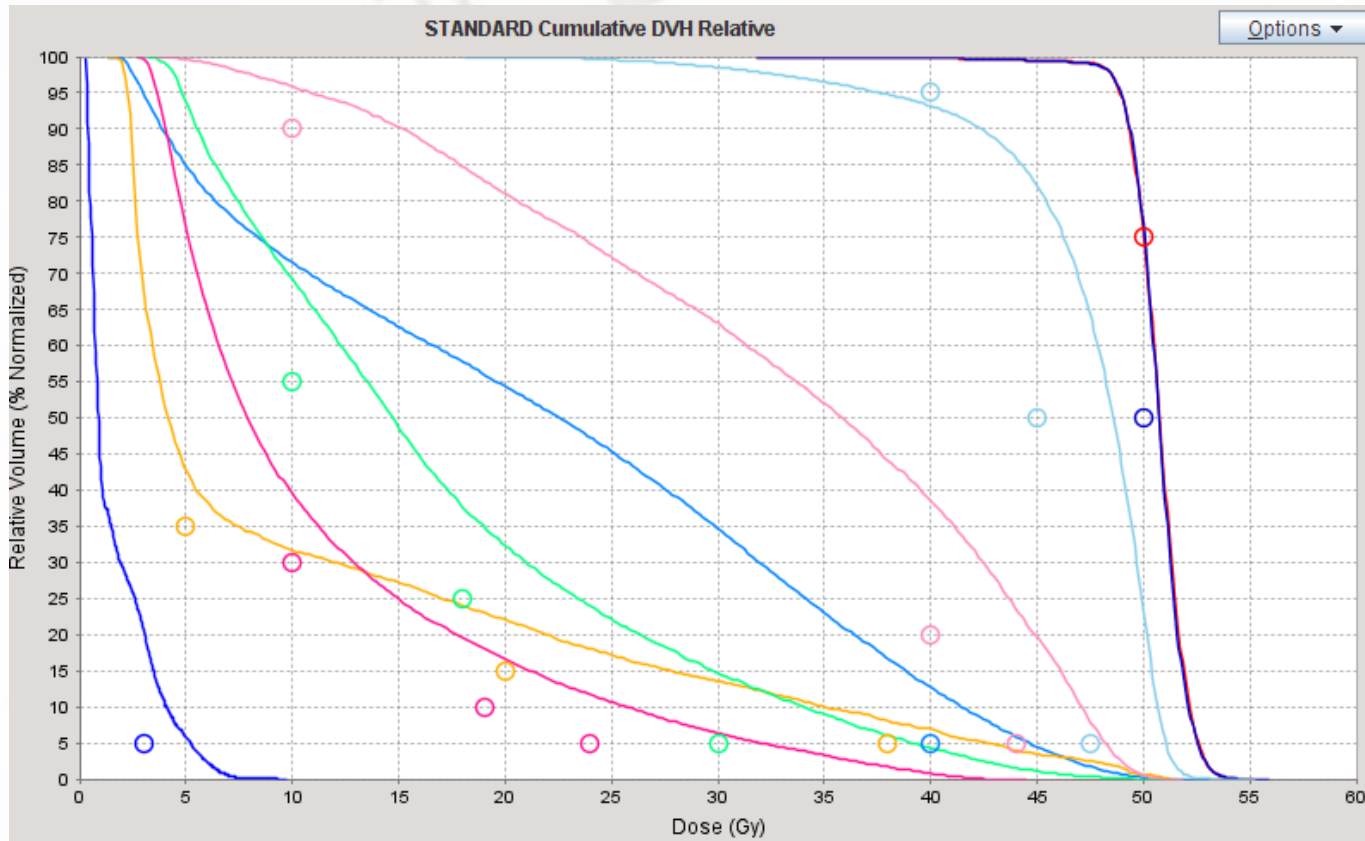
- Now I work with Targets

Name	Display	Color	Blocked	Use	Importance	Max Dose [Gy]	Max Dose Pen.	DVH Vol	DVH Dose [Gy]	DVH Pt. Pen.
LUNG_RIGHT	<input type="checkbox"/>	6	<i>Directional</i>	<input checked="" type="checkbox"/>	100	5.00	100	3.00 ▼	4.00 ▼	10 ▼
SPINAL CORD	<input checked="" type="checkbox"/>	9	<i>Directional</i>	<input checked="" type="checkbox"/>	100	5.00	1000	5.00 ▼	3.00 ▼	1 ▼
LUNG_LEFT Plan Top	<input checked="" type="checkbox"/>	2	Unblocked	<input checked="" type="checkbox"/>	18	47.50	18	5.00 ▼	30.00 ▼	20 ▼
Dmin Lung Left	<input checked="" type="checkbox"/>	3	Unblocked	<input checked="" type="checkbox"/>	15	47.50	15	5.00 ▼	44.00 ▼	15 ▼
LUNG_LEFT Plan	<input checked="" type="checkbox"/>	4	Unblocked	<input checked="" type="checkbox"/>	20	45.00	20	5.00 ▼	24.00 ▼	15 ▼
HEART Plan	<input checked="" type="checkbox"/>	8	Unblocked	<input checked="" type="checkbox"/>	15	47.50	15	5.00 ▼	38.00 ▼	15 ▼
Avoidance2	<input type="checkbox"/>	11	Unblocked	<input checked="" type="checkbox"/>	8	25.00	8	50.00 ▼	20.00 ▼	8 ▼
Avoidance	<input type="checkbox"/>	12	Unblocked	<input checked="" type="checkbox"/>	10	47.50	150	50.00 ▼	45.00 ▼	10 ▼
Dmin1	<input checked="" type="checkbox"/>	13	Unblocked	<input checked="" type="checkbox"/>	7	49.50	150	5.00 ▼	47.50 ▼	7 ▼
Dmin2	<input checked="" type="checkbox"/>	14	Unblocked	<input checked="" type="checkbox"/>	5	45.00	200	5.00 ▼	40.00 ▼	7 ▼

- Don't forget about OARs



Further optimization



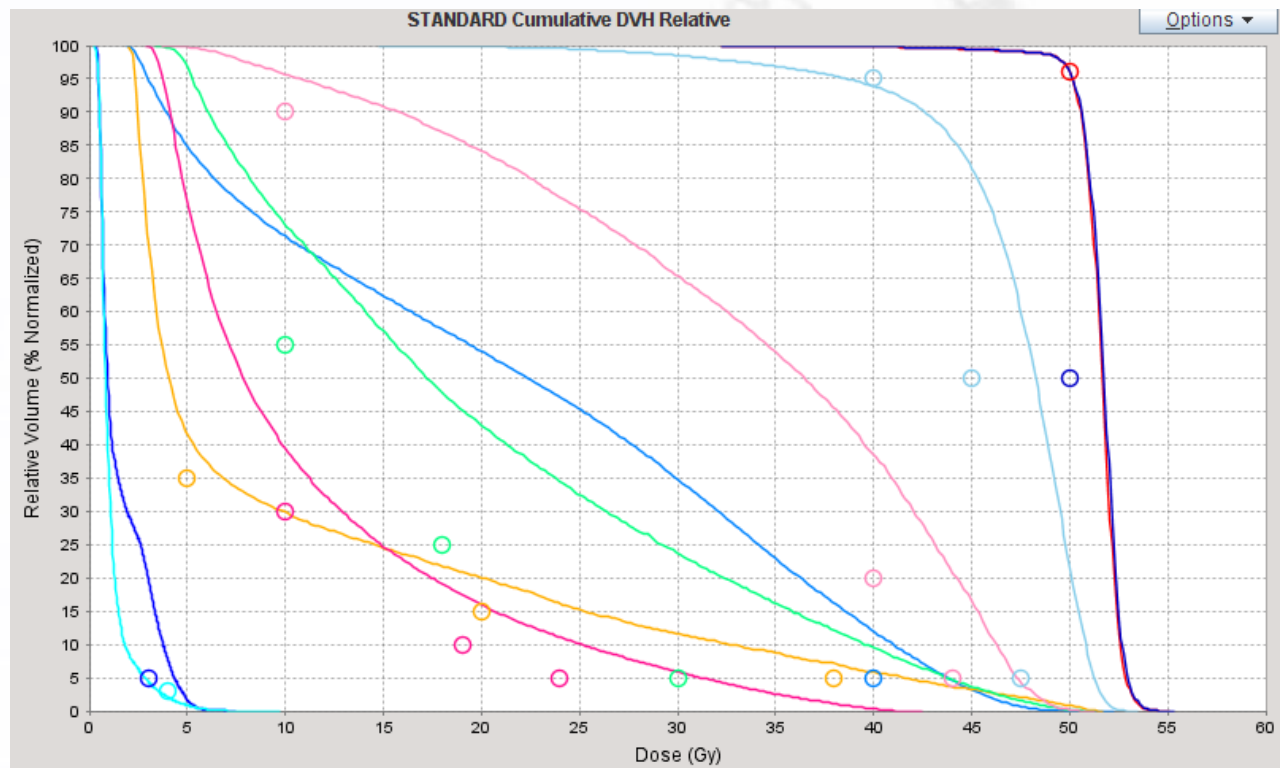
Final restrictions

Name	Display	Color	Blocked	Use	Importance	Max Dose [Gy]	Max Dose Pen.	DVH Vol	DVH Dose [Gy]	Min Dose [Gy]	Min Dose Pen.
PTV Min	<input type="checkbox"/>		1 Unblocked	<input checked="" type="checkbox"/>	300	50.00	300	50.00 ▼	50.00 ▼	50.00	450
CTV-LUMPECTOMY	<input type="checkbox"/>		2 Unblocked	<input checked="" type="checkbox"/>	300	55.00	10	50.00 ▼	50.00 ▼	50.00	300
PTV_AXILL	<input type="checkbox"/>		3 Unblocked	<input checked="" type="checkbox"/>	300	50.00	1800	50.00 ▼	50.00 ▼	50.00	700
PTV_SC	<input type="checkbox"/>		4 Unblocked	<input checked="" type="checkbox"/>	300	50.00	6600	50.00 ▼	50.00 ▼	50.00	700
PTV_BREAST	<input checked="" type="checkbox"/>		5 Unblocked	<input checked="" type="checkbox"/>	300	50.00	6000	96.00 ▼	50.00 ▼	50.00	1250
PTV_TOT_EVAL	<input checked="" type="checkbox"/>		6 Unblocked	<input checked="" type="checkbox"/>	300	50.00	600	50.00 ▼	50.00 ▼	50.00	450

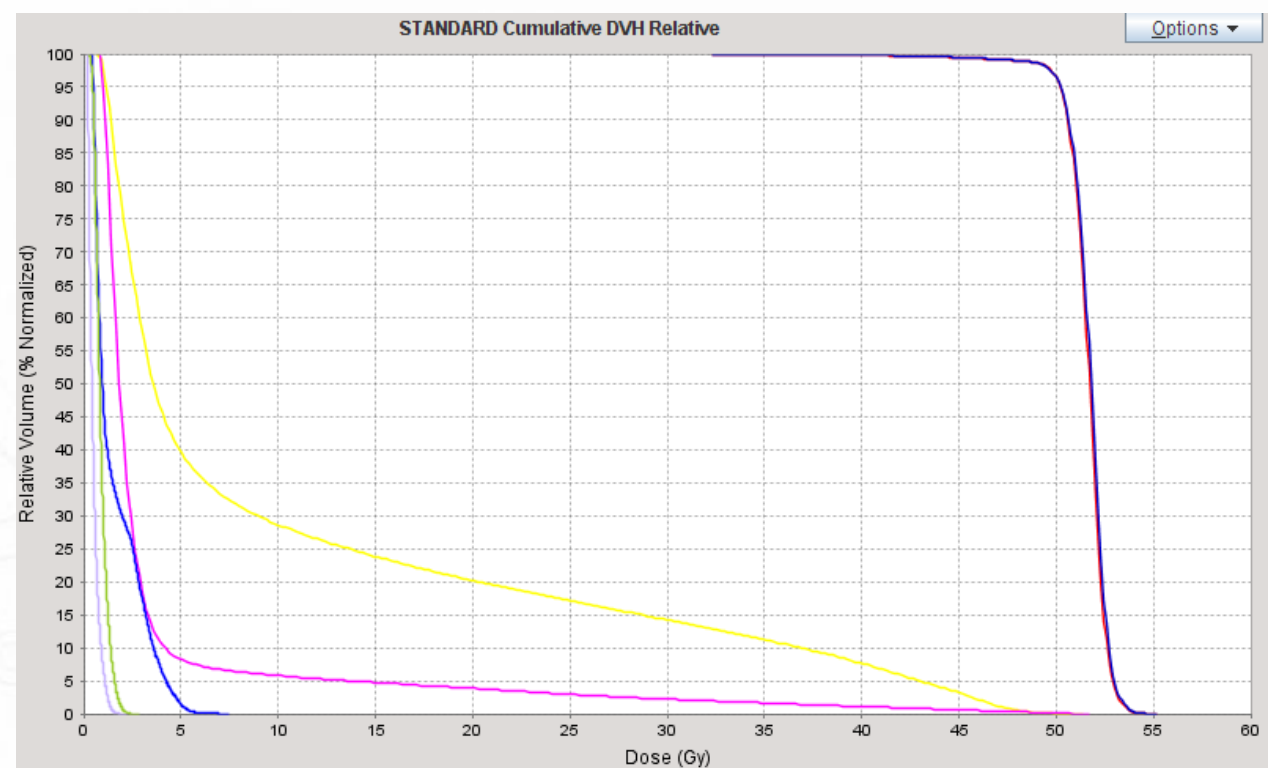
Name	Display	Color	Blocked	Use	Importance	Max Dose [Gy]	Max Dose Pen.	DVH Vol	DVH Dose [Gy]	DVH Pt. Pen.
LUNG_RIGHT	<input checked="" type="checkbox"/>		6 Directional	<input checked="" type="checkbox"/>	100	5.00	100	3.00 ▼	4.00 ▼	10 ▼
SPINAL CORD	<input checked="" type="checkbox"/>		9 Directional	<input checked="" type="checkbox"/>	200	5.00	4000	5.00 ▼	3.00 ▼	1 ▼
LUNG_LEFT Plan Top	<input checked="" type="checkbox"/>		2 Unblocked	<input checked="" type="checkbox"/>	18	47.50	18	5.00 ▼	30.00 ▼	20 ▼
Dmin Lung Left	<input checked="" type="checkbox"/>		3 Unblocked	<input checked="" type="checkbox"/>	150	47.50	300	5.00 ▼	44.00 ▼	150 ▼
LUNG_LEFT Plan	<input checked="" type="checkbox"/>		4 Unblocked	<input checked="" type="checkbox"/>	200	45.00	20	5.00 ▼	24.00 ▼	15 ▼
HEART Plan	<input checked="" type="checkbox"/>		8 Unblocked	<input checked="" type="checkbox"/>	150	47.50	15	5.00 ▼	38.00 ▼	150 ▼
Avoidance2	<input type="checkbox"/>		11 Unblocked	<input checked="" type="checkbox"/>	8	25.00	8	50.00 ▼	20.00 ▼	8 ▼
Avoidance	<input type="checkbox"/>		12 Unblocked	<input checked="" type="checkbox"/>	10	47.50	150	50.00 ▼	45.00 ▼	10 ▼
Dmin1	<input checked="" type="checkbox"/>		13 Unblocked	<input checked="" type="checkbox"/>	100	49.50	1500	5.00 ▼	47.50 ▼	7 ▼
Dmin2	<input checked="" type="checkbox"/>		14 Unblocked	<input checked="" type="checkbox"/>	100	45.00	1800	5.00 ▼	40.00 ▼	7 ▼



Final Histogram



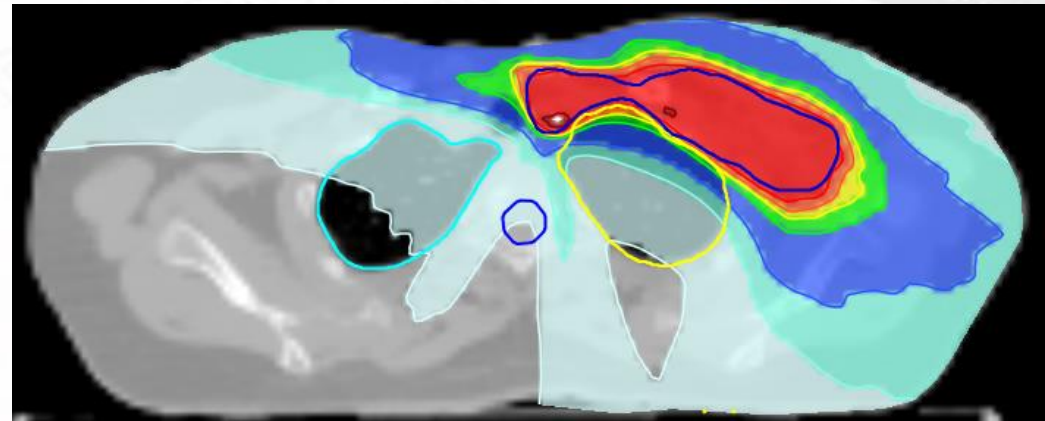
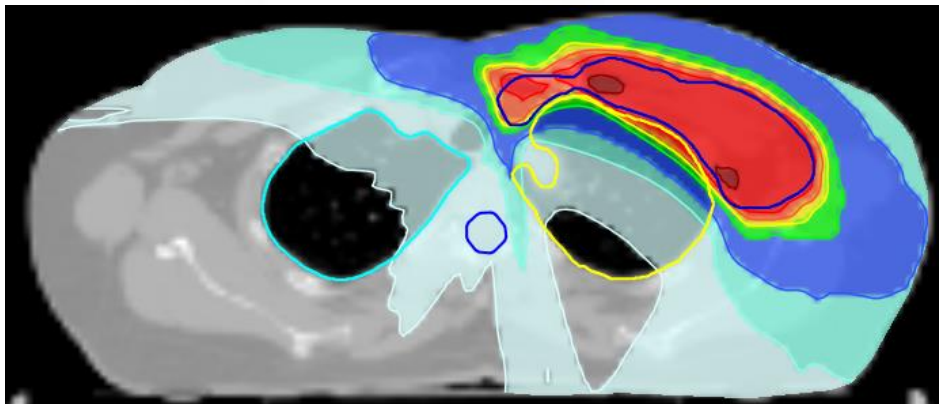
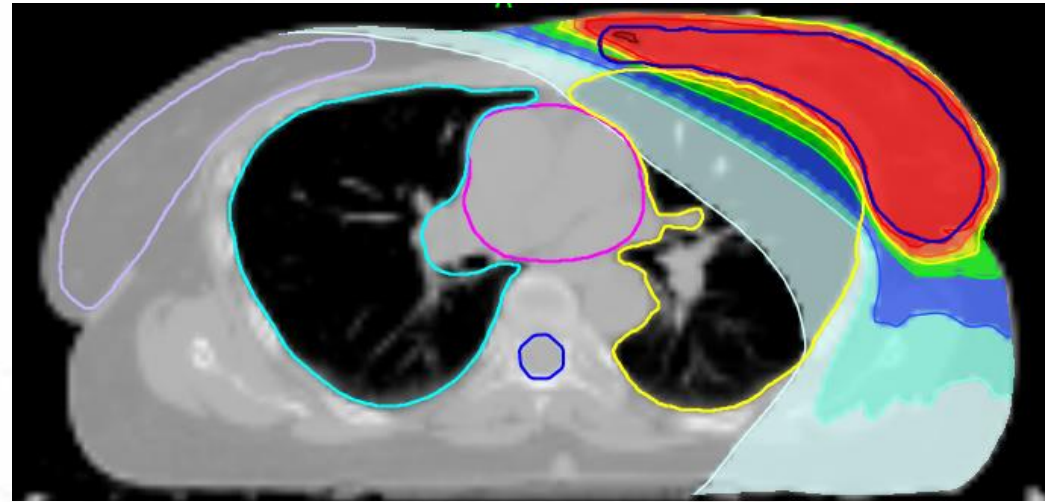
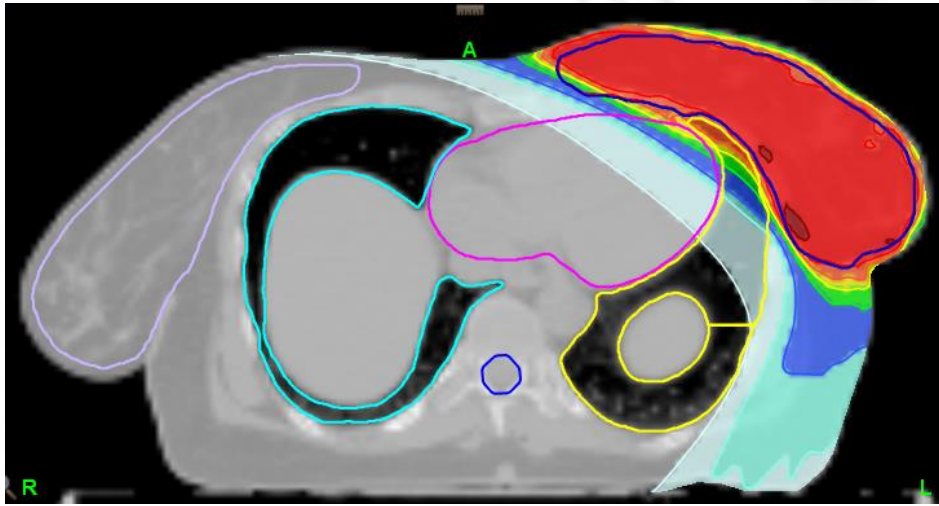
Full Dose



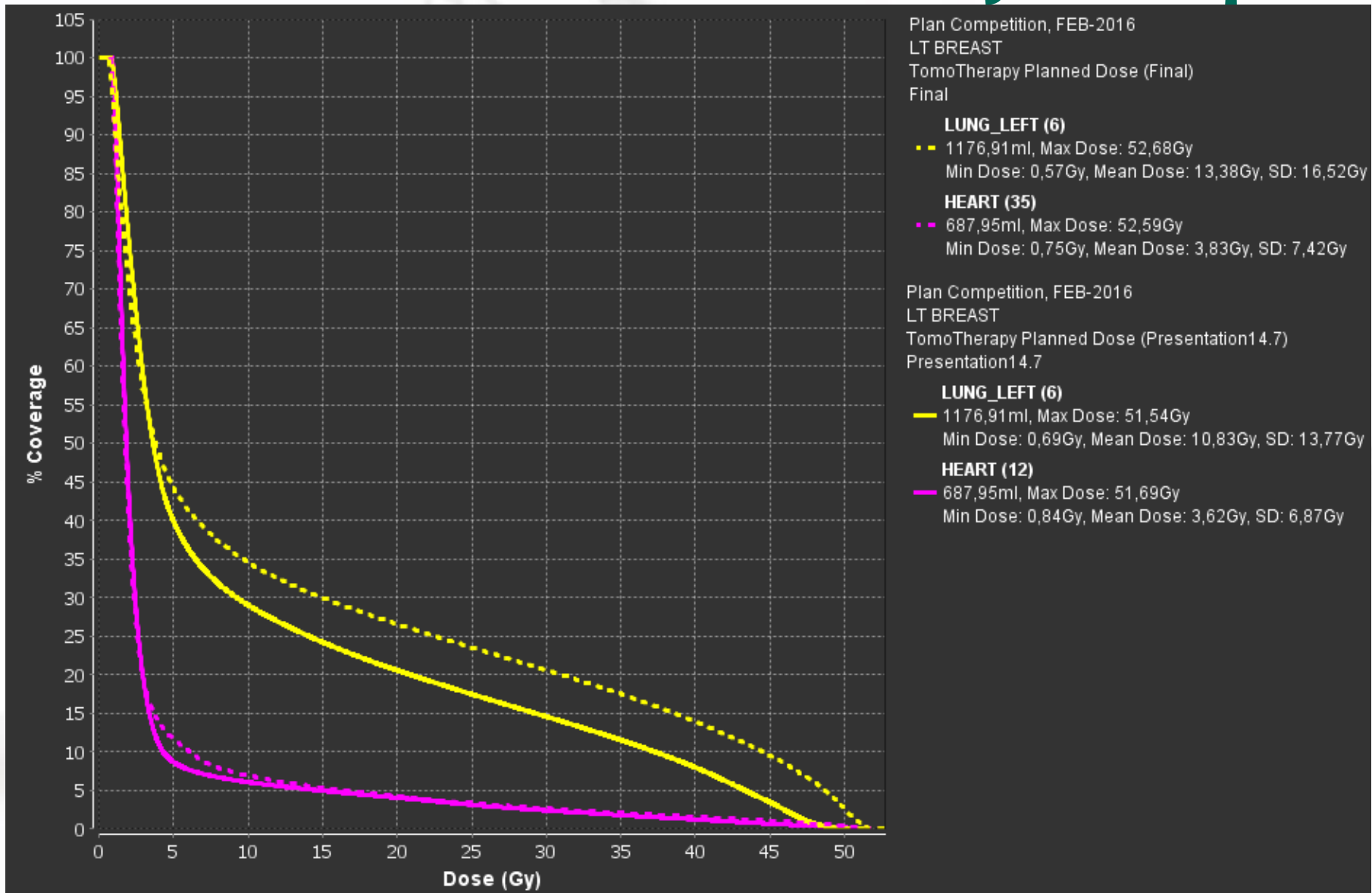
Final Dose



Final Dose Distribution



Main difference from my first plan



Evaluation

Old Results

New Results

Plan Quality Metric Component	Objective(s)	Result	Raw Score	Max Score	Performance	Result	Raw Score	Max Score	Performance
[PTV_TOT_EVAL] D[99.0%] (Gy)	> 45 [≥ 47.5]	48.6154	15.00	15.00	100.0%	47.6558	15.00	15.00	100.0%
[PTV_TOT_EVAL] D[95.0%] (Gy)	> 45 [≥ 50]	50.0419	5.00	5.00	100.0%	50.1664	5.00	5.00	100.0%
[PTV_TOT_EVAL] D[50.0%] (Gy)	< 54 [≤ 52]	51.3200	5.00	5.00	100.0%	51.7892	5.00	5.00	100.0%
[PTV_TOT_EVAL] D[0.3cc] (Gy)	< 57 [≤ 55]	54.0580	5.00	5.00	100.0%	54.7860	5.00	5.00	100.0%
[HEART] Mean dose (Gy)	< 5 [≤ 4]	3.8481	10.00	10.00	100.0%	3.6379	10.00	10.00	100.0%
[HEART] V[15.0Gy] (%)	< 20 [≤ 15]	5.3918	5.00	5.00	100.0%	4.9965	5.00	5.00	100.0%
[HEART] D[5.0%] (Gy)	< 25 [≤ 20]	16.6272	5.00	5.00	100.0%	14.9439	5.00	5.00	100.0%
[BREAST_RIGHT] D[0.3cc] (Gy)	< 3 [≤ 2]	2.0376	1.92	2.00	96.2%	1.9476	2.00	2.00	100.0%
[BREAST_RIGHT] D[5.0%] (Gy)	< 3 [≤ 2]	1.0421	4.00	4.00	100.0%	1.1059	4.00	4.00	100.0%
[SPINAL_CORD] D[0.03cc] (Gy)	< 20 [≤ 8]	5.5294	5.00	5.00	100.0%	5.3094	5.00	5.00	100.0%
[LUNG_RIGHT] V[5.0Gy] (%)	< 6 [≤ 3]	0.1461	5.00	5.00	100.0%	0.9710	5.00	5.00	100.0%
[LUNG_LEFT] Mean dose (Gy)	< 15 [≤ 9]	13.4265	1.31	5.00	26.2%	10.8542	3.45	5.00	69.1%
[LUNG_LEFT] V[20.0Gy] (%)	< 20 [≤ 15]	26.6111	0.00	5.00	0.0%	20.6368	0.00	5.00	0.0%
[LUNG_LEFT] V[10.0Gy] (%)	< 40 [≤ 30]	34.5564	2.72	5.00	54.4%	28.9586	5.00	5.00	100.0%
[LUNG_LEFT] V[5.0Gy] (%)	< 70 [≤ 50]	44.2398	4.00	4.00	100.0%	39.8888	4.00	4.00	100.0%
[PTV_TOT_EVAL] Homogeneity Index [50.0Gy]	< 0.2 [≤ 0.08]	0.0838	4.81	5.00	96.2%	0.1199	3.01	5.00	60.1%
[PTV_TOT_EVAL] Conformation Number [47.5Gy]	> 0.6 [≥ 0.9]	0.6641	0.64	5.00	12.8%	0.7427	2.28	5.00	45.6%
Global Max Location (ROI)	[BODY]	BODY	5.00	5.00	100.0%	BODY	5.00	5.00	100.0%
Total [18 Metrics]			84.41	100.00	84.4%		88.74	100.00	88.7%



Thank You!

