

Treatment Planning Skills That a Physicist Should Know

*Jonathan (Zhibin) Huang, PhD, DABR
Medical Physicist/Assistant Professor
East Carolina University*

Conflict of Interest

- Nothing to disclose

Learning Objective

- To familiarize with a variety of modern photon beam radiotherapy techniques
- To understand the workflow for treatment planning and factors affecting plan quality
- Conventional radiotherapy requires to achieve a uniform dose distribution inside the target volume and a dose as low as possible in the healthy tissues surrounding the target
- SBRT is becoming a standard for radiotherapy and RTOG protocols for SBRT treatment planning
- SRS/SRT planning and associated RTOG Guidelines

STRATEGIES FOR RADIATION THERAPY TREATMENT PLANNING

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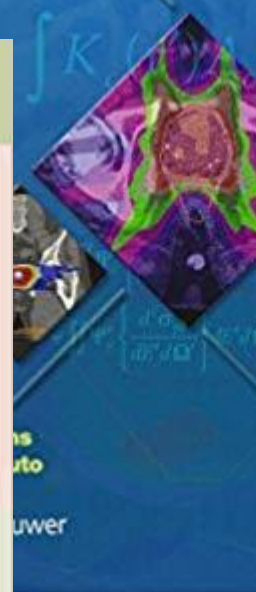
Treatment Planning in Radiation Oncology

THIRD EDITION

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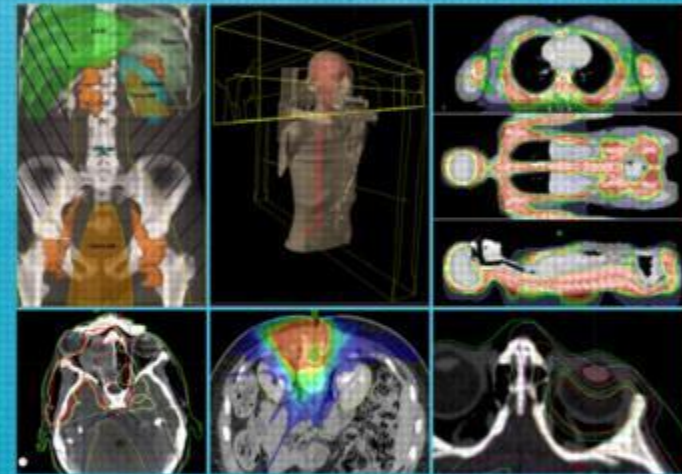
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KHAN'S Treatment Planning Radiation Oncology



SECOND EDITION

PEDIATRIC RADIOTHERAPY PLANNING AND TREATMENT



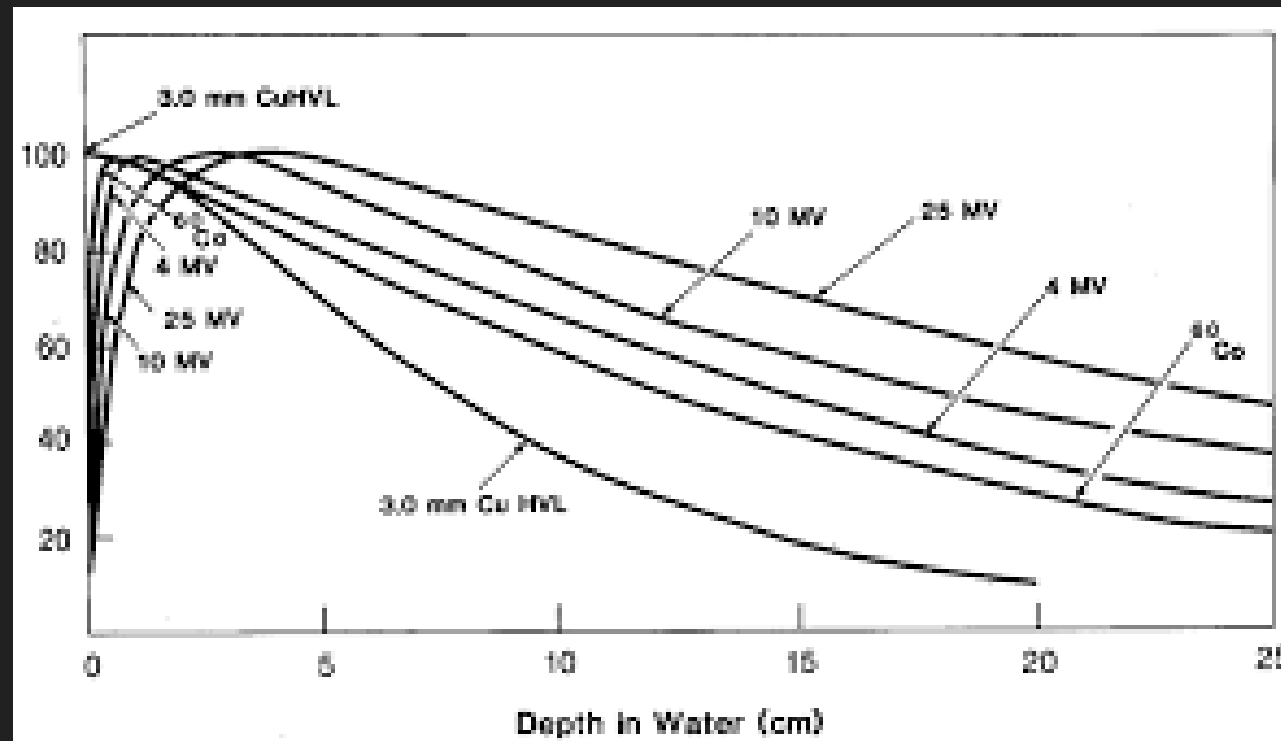
Arthur J. Olch, Ph.D., FAAPM

Treatment Planning Resource

- **Workshop**
- **Training Courses**
- **Colleagues/coworkers**
- **Some websites: econtour.com, prowork.com, etc.**

Photon Beam Characteristics

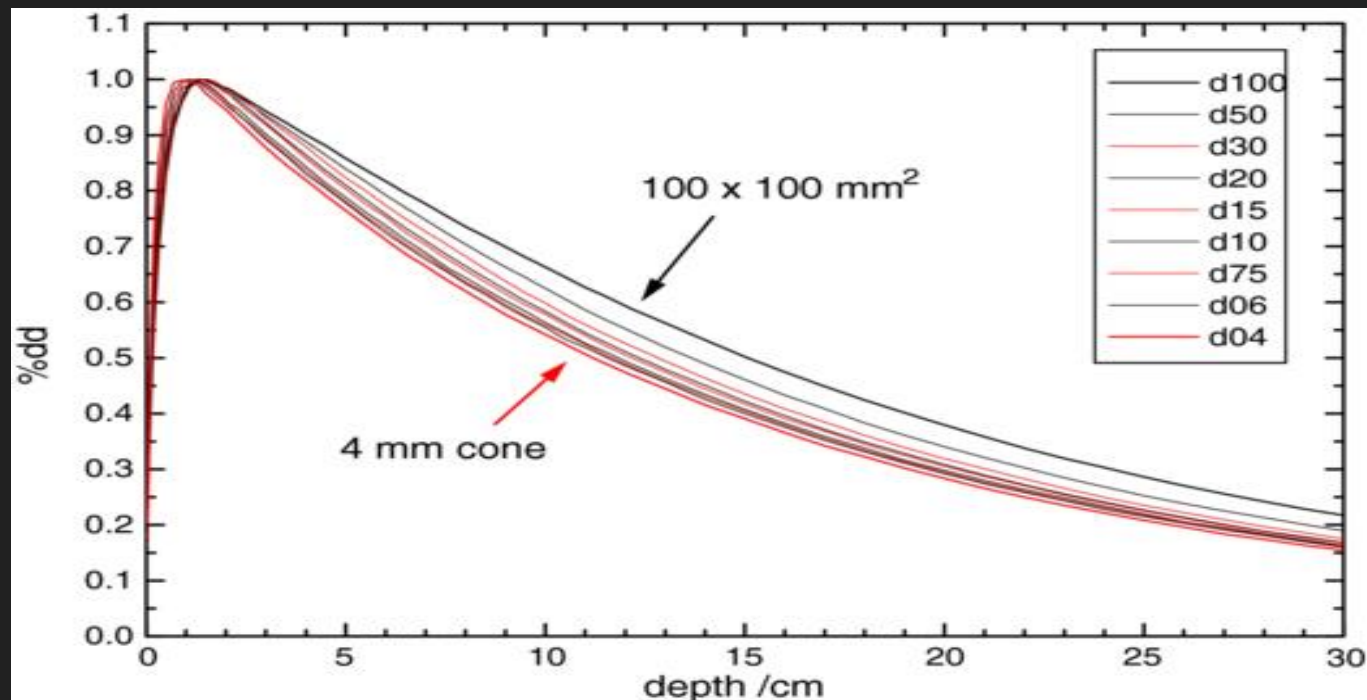
- PDD vs Energy



Photon Beam Characteristics

- PDD vs Field Size

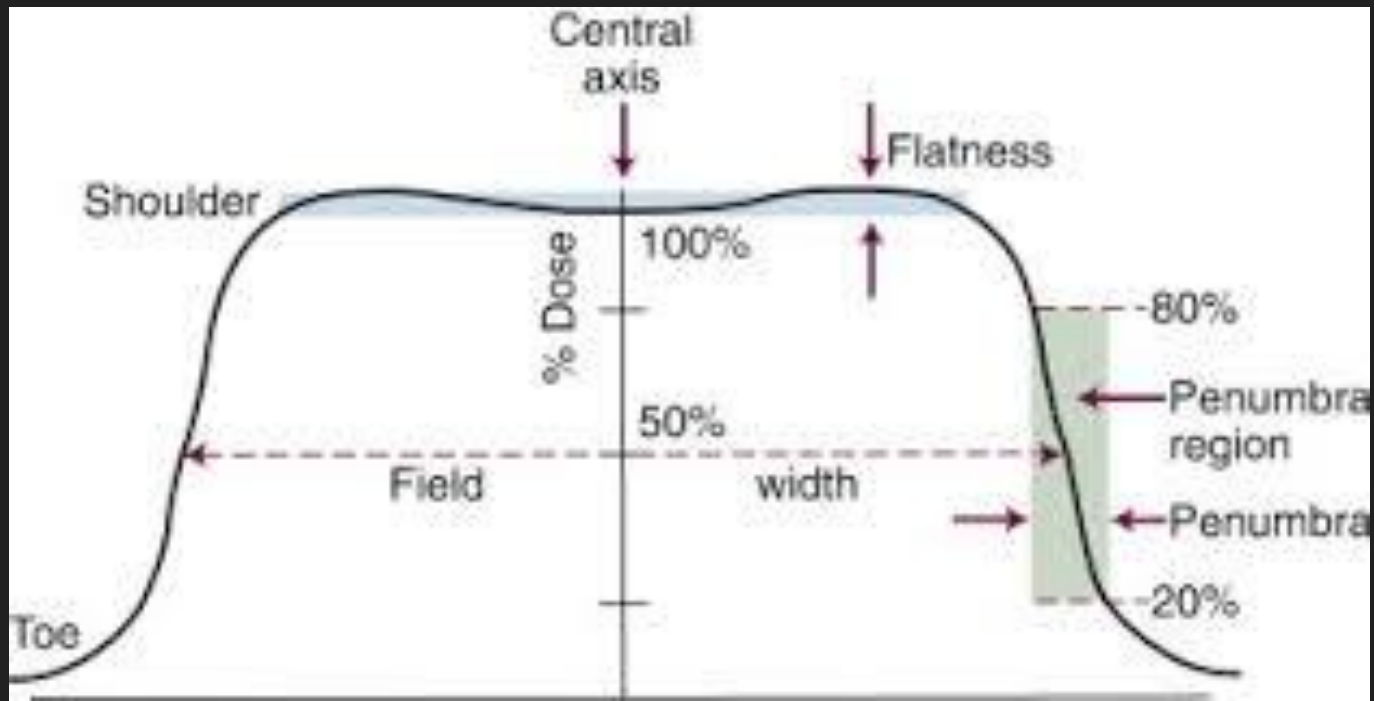
- George X Ding and Rob Krauss, Published 20 June 2013 • 2013 Institute of Physics and Engineering in Medicine Physics in Medicine & Biology, Volume 58, Number 14)



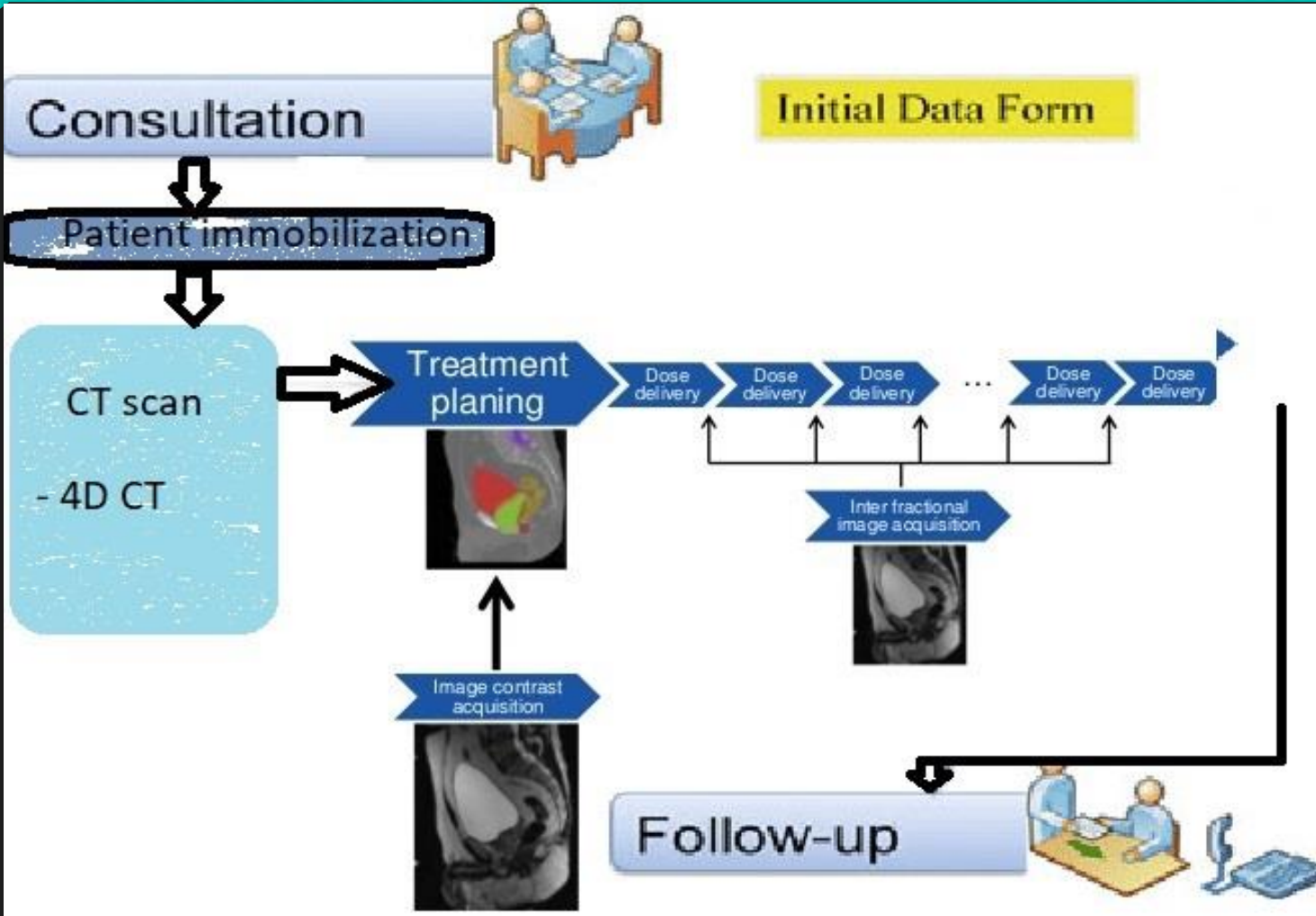
Photon Beam Characteristics

- Profile vs Field Size

- Single beam penumbra ~ 7-8 mm, from 80%- 20% → iso-dose lines ~ 10%/mm
- VMAT/IMRT isodose lines are subjected to this radiation physics
- Multiple beams make the beam penumbra shallower



Radiation Oncology Workflow



Treatment Planning

- **Prescription:**
 - **Convention vs SRS/SBRT**
 - **Patient specific planning requirements**
 - **What to compromise if you can not achieve planning requirements**
 - **Uniform dose in PTV important?**
 - **Surrounding structure sparing more important than PTV coverage?**
 - **What is Rx dose and daily fractional dose?**

What do we need in planning stage?

○ Target and critical structure delineation

1. Anatomy:

- Scout image
- Dynamic scanning
- Gated acquisition
 - i. Functional information, e.g. important brain areas, functional lung, bioimaging for tumor
 - ii. Registration methods; data communication; new image modalities
 - multimodality imaging; registration

2. RTOG target and OARs atlas for different sites

Breast Cancer

- **RTOG target and OARs atlas for breast cancer**
 - **Breast CTV**
 - **PTV=CTV+5mm**
 - **Lumpectomy GTV**
 - **Chestwall CTV**
 - **Regional nodal volumes**
 - **Ipsilateral lung, heart, and contralateral breast**

Breast Cancer

- Many studies show that toxicities were associated with dose inhomogeneity
 - Both acute and long term toxicities such as moist desquamation, pain, breast discomfort and breast hardness
- Randomized clinical trials:
 1. Donovan E, BleakleyN, DenholmE, et al. Randomised trial of standard 2D radiotherapy (RT) versus intensity modulated radiotherapy (IMRT) in patients prescribed breast radiotherapy. *RadiotherOncol.* 2007 Mar;82(3):254-64.
 - 306 patients were randomized to 2D or 3D IMRT
 - 2D-arm patients were 1.7 times higher than IMRT patients to have changes in breast appearance

Breast Cancer

- **Randomized clinical trials:**

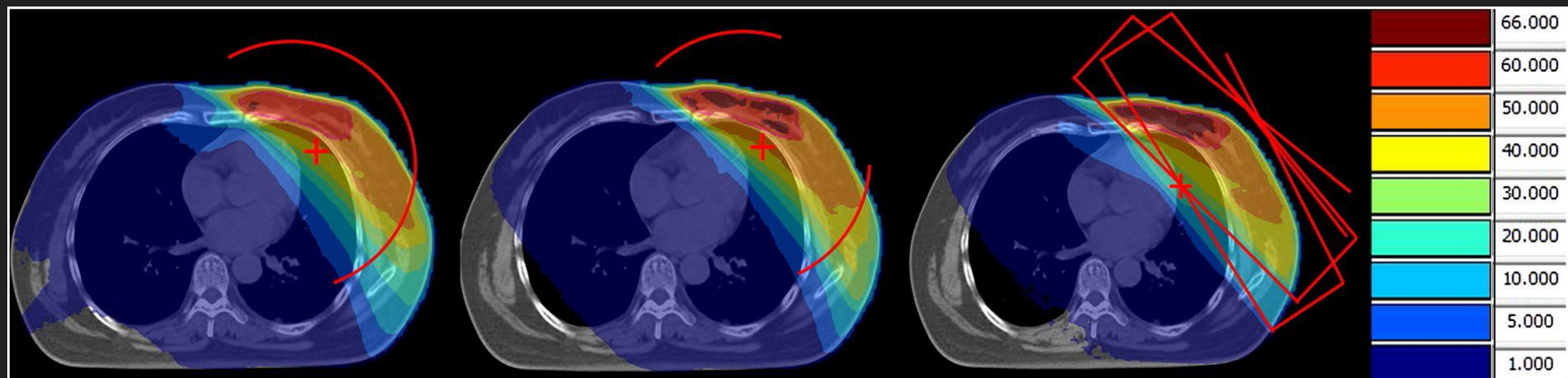
1. **PignolJP, Olivottol, RakovitchE, et al. A multicenter randomized trial of breast intensity-modulated radiation therapy to reduce acute radiation dermatitis. J Clin Oncol. 2008 May 1;26(13):2085-92.**
 - **358 patients were randomized in a multicenter double-blind clinical trial with either IMRT or 2D treatment planning**
 - **Moist desquamation in the IMRT group was 31.2% vs 47.8% (p=0.002)**

Breast Cancer – Dose Constraint to Target and OARs

Organ	Constraint
Chest Wall	V90 ≥ 90.0%
Breast	V100 ≥ 90.0% V95 ≥ 95.0% V105 ≤ 40.0% V110 ≤ 10.0%
IMN Nodes	V80 ≥ 100.0%
SCV	V90 ≥ 90.0%
Ax Nodes	V90 ≥ 90.0%
Contralateral Breast	V5Gy ≤ 15.0%
Ipsilateral Lung	V20Gy ≤ 45.0% V30Gy ≤ 35.0%
Whole Lung	V20Gy ≤ 25.0% V30Gy ≤ 20.0%
Heart	V5Gy ≤ 40.0% (≤ 50.0% for left-sided tumors) V20Gy ≤ 20.0%

Breat Cancer - VMAT, 2D, IMRT

- Dose distribution in a selected transversal plane and the beam arrangement in three techniques
 - [Scientific Reports | 7: 14748 | DOI:10.1038/s41598-017-15307-7](#)
- In conclusion, 2TARC was shown to be the optimal treatment technique amongst the studied techniques for patients with left-sided breast cancer after BCS, if they chose the photon therapy
- The doses to OARs were shown to increase significantly for the patients with inner quadrant tumor



Breast Cancer - Doses to OARs

www.nature.com/scientificreports/

			Plan A	PlanB	Plan C	P value		
						A Vs B	B Vs C	A Vs C
Lung_Right	Dmean(Gy)	mean ± SD	2.58 ± 0.54	1.39 ± 0.18	1.15 ± 0.14	0.000	0.000	0.000
		max/min	3.33/1.77	1.74/1.21	1.34/0.95			
Spinal cord	Dmax(Gy)	mean ± SD	3.60 ± 0.86	2.16 ± 1.13	1.25 ± 0.17	0.000	0.000	0.000
		max/min	4.80/2.15	5.07/1.24	1.57/1.01			
Breast_Right	Dmean(Gy)	mean ± SD	2.60 ± 0.69	1.74 ± 0.38	1.51 ± 0.54	0.000	0.028	0.000
		max/min	4.08/1.82	2.38/1.42	2.50/1.06			
	Dmax(Gy)	mean ± SD	5.73 ± 1.66	4.95 ± 1.32	5.38 ± 2.06	0.023	0.289	0.246
		max/min	9.51/4.61	8.39/3.31	9.67/3.15			
Lung_Left	V5(%)	mean ± SD	41.22 ± 8.86	38.18 ± 4.45	41.73 ± 6.12	0.206	0.092	0.852
		max/min	56.5/33.6	46.4/33.5	51.7/34.6			
	V10(%)	mean ± SD	23.53 ± 4.52	23.65 ± 3.68	28.10 ± 5.22	0.895	0.008	0.004
		max/min	31/18.1	30.5/19.3	36.2/22.9			
	V20(%)	mean ± SD	13.83 ± 2.93	15.28 ± 2.92	17.54 ± 4.16	0.047	0.035	0.008
		max/min	18.5/9.6	20.5/11.5	26.2/12.1			
	Dmean(Gy)	mean ± SD	9.23 ± 1.51	9.52 ± 1.63	10.20 ± 1.90	0.348	0.036	0.009
		max/min	11.67/7.21	12.92/7.47	13.81/7.68			
Heart	V5(%)	mean ± SD	28.97 ± 9.62	23.84 ± 8.33	24.35 ± 7.29	0.070	0.936	0.225
		max/min	49.5/17.4	35.5/10.6	35.1/12.3			
	V10(%)	mean ± SD	11.43 ± 4.49	10.72 ± 2.90	15.42 ± 5.34	0.702	0.012	0.055
		max/min	19.1/7	15.2/6.58	21.9/7.3			
	V20(%)	mean ± SD	4.71 ± 1.72	5.41 ± 2.02	8.30 ± 3.89	0.525	0.008	0.003
		max/min	8.4/2.9	8.1/2.7	12.9/4.3			
	Dmean(Gy)	mean ± SD	5.83 ± 0.86	5.38 ± 1.01	5.87 ± 1.27	0.047	0.035	0.917
		max/min	7.33/5.05	6.81/4.18	8.32/4.20			
Body	V5(%)	mean ± SD	22.80 ± 4.05	17.04 ± 3.12	17.21 ± 2.67	0.000	0.784	0.000
		max/min	29.19/17.72	21.87/13.43	20.35/13.93			

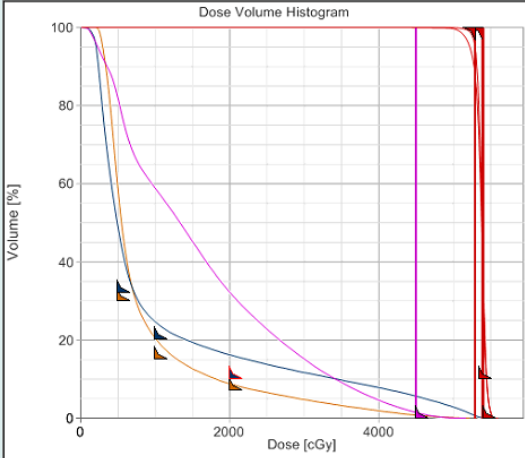
Table 2. Comparison of the doses to OARs (Plan A: 1ARC/Plan B: 2TARC/Plan C: 4IMRT, paired T test).

Breast Cancer – VMAT

Structures and Objectives

Use Normal Tissue Objective Priority: 75 Define NTO Settings...

Structure	Volume [cc]	Points	Resolution [mm]
<input type="checkbox"/> BBs	0	2316	1.00
<input type="checkbox"/> BODY	19647	476801	4.50
<input type="checkbox"/> Body_Ext	20978	424538	4.50
<input type="checkbox"/> Bone	1125	419954	3.00
<input type="checkbox"/> Cord	39	17889	2.59
<input type="checkbox"/> Dose 109[%]	4	10385	1.23
<input checked="" type="checkbox"/> Heart	638	63363	3.00
Upper	Volume [%]: 30.0	Dose [cGy]: 500.0	Priority: 120
Upper	Volume [%]: 15.0	Dose [cGy]: 1000.0	Priority: 90
Upper	Volume [%]: 7.0	Dose [cGy]: 2000.0	Priority: 70
<input checked="" type="checkbox"/> L_Lung	973	107227	3.00
Upper	Volume [%]: 32.0	Dose [cGy]: 500.0	Priority: 120
Upper	Volume [%]: 20.0	Dose [cGy]: 1000.0	Priority: 100
Upper	Volume [%]: 10.0	Dose [cGy]: 2000.0	Priority: 70
<input type="checkbox"/> Liver	1228	109670	3.00
<input type="checkbox"/> Lt Breast	1032	110753	3.00
<input type="checkbox"/> Lt Humeral Head	82	13232	3.00
<input checked="" type="checkbox"/> PTV_5400	1161	119221	3.00
Upper	Volume [%]: 0.0	Dose [cGy]: 5400.0	Priority: 120
Lower	Volume [%]: 100.0	Dose [cGy]: 5400.0	Priority: 120
<input type="checkbox"/> R_Lung	1133	113312	3.00
<input checked="" type="checkbox"/> Ring	3070	266829	3.00



Add Upper Objective Add Lower Objective Add Mean Objective Delete Objective

Avoidance Sectors (0 MU)

Define Settings...
None

MU Objective

Use Strength: 50

Min MU: 0 Max MU: 2000

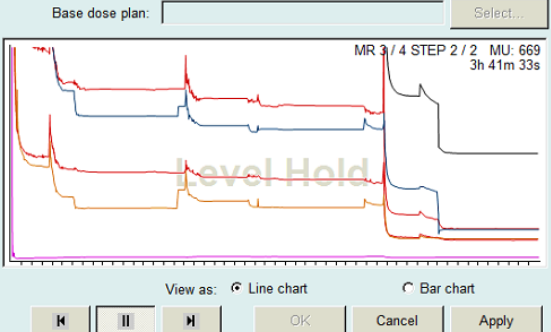
Automate Optimization

Continue automatically to final dose calculation

Save all after optimization and dose calculation

Automatic intermediate dose

Progress:



Order	Beam	Field	Target	Modality	Weight	IEC	Start X	Start Y	Start Z	End X	End Y	End Z	SSD	MU	Ref. D [cGy]								
01	CW RA	ARC-I	TB1 - 6X	VMAT	0.927	IEC61217	290.0	CW	160.0	345.0	0.0	None	15.0	-7.5	+7.5	22.7	-11.6	+11.1	9.04	-9.33	3.00	88.6	
02	CCW RA	ARC-I	TB1 - 6X	VMAT	0.997	IEC61217	160.0	CCW	290.0	15.0	0.0	None	15.0	-7.5	+7.5	22.0	-11.0	+11.0	9.04	-9.33	3.00	83.5	
03	CW RA	ARC-I	TB1 - 6X	VMAT	1.144	IEC61217	290.0	CW	160.0	330.0	0.0	None	15.0	-7.5	+7.5	23.9	-12.2	+11.7	9.04	-9.33	3.00	88.6	
04	CCW RA	ARC-I	TB1 - 6X	VMAT	0.932	IEC61217	160.0	CCW	290.0	30.0	0.0	None	15.0	-7.5	+7.5	22.7	-11.2	+11.5	9.04	-9.33	3.00	83.5	
93	CBCT	STATIC-I	TB1 - 6X		0.000	IEC61217				0.0	0.0	0.0	None	30.0	-15.0	+15.0	30.0	-15.0	+15.0	9.04	-9.33	3.00	92.9
91	AP KV	STATIC-I	TB1 - 6X		0.000	IEC61217				0.0	0.0	0.0	None	30.0	-15.0	+15.0	30.0	-15.0	+15.0	9.04	-9.33	3.00	92.9

Zhibin Huang Logout

Unapproved - Model View - Lt Chestwall_7_9

Standard Head First-Supine

Unapproved - Sagittal - Lt Chestwall_7_9

X: 9.04 cm

X1 [cm]	X2 [cm]	Field Y [cm]	Y1 [cm]	Y2 [cm]	X [cm]	Y [cm]	Z [cm]	SSD [cm]	MU	Ref. D [cGy]
-7.5	+7.5	22.7	-11.6	+11.1	9.04	-9.33	3.00	88.6		
-7.5	+7.5	22.0	-11.0	+11.0	9.04	-9.33	3.00	83.5		
-7.5	+7.5	23.9	-12.2	+11.7	9.04	-9.33	3.00	88.6		
-7.5	+7.5	22.7	-11.2	+11.5	9.04	-9.33	3.00	83.5		
-15.0	+15.0	30.0	-15.0	+15.0	9.04	-9.33	3.00	92.9		
-15.0	+15.0	30.0	-15.0	+15.0	9.04	-9.33	3.00	92.9		

User: zhuang Group: Physicist Site: Main CAP: NUM SCR: L

Breast Cancer - VMAT -Bolus for optimization

File Edit View Insert Planning Tools Window

Contouring Registration External Beam Planning Brachytherapy Planning Brachytherapy 2D Entry Plan Evaluation

1350
C1
Lt Breast

Bolus
 User Origin
 Reference Points
 PTV_4500
 Dose
 Fields
 01 CW RA
 01 CW RA-DRR (Live)
 MLC
 02 CCW RA
 02 CCW RA-DRR (Live)
 MLC
 03 CW RA
 03 CW RA-DRR (Live)
 MLC
 04 CCW RA
 04 CCW RA-DRR (Live)
 MLC
 93 CBCT
 93 CBCT-DRR (Live)
 91 AP kV
 91 AP kV-DRR (Live)
 92 RLat kV
 92 RLat kV-DRR (Live)
 94 PA kV
 94 PA kV-DRR (Live)
 95 LLat kV
 95 LLat kV-DRR (Live)

Lt Breast - Treatment Approved - Transversal - Lt Breast
 IsoDoses (cGy)
 4950
 4725
 4500
 4275
 4050
 25
 3600
 355.9 eGy
 Z: 0.50 cm
 Transport in medium
 Dose to medium

Lt Breast - Dose Volume Histogram
 Relative dose [%]
 22.222 44.444 66.666 88.888 111.11
 Ratio of Total Structure Volume [%]
 100
 80
 60
 40
 20
 0
 0 1000 2000 3000 4000 5000
 Dose [cGy]
 See Dose Coverage and Sampling Coverage in Dose Statistics!

Lt Breast - Treatment Approved - Frontal - Lt Breast
 34.1 cGy
 Y: -8.27 cm
 Transport in medium
 Dose to medium

Lt Breast - Treatment Approved - Sagittal - Lt Breast
 173.9 cGy
 X: 6.64 cm
 Transport in medium
 Dose to medium

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

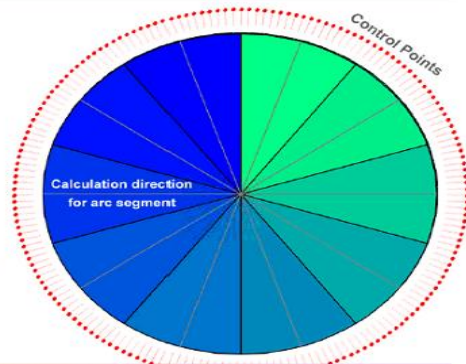
Fractionation Id	Dose / Fraction [cGy]	Number of Fractions	Total Dose [cGy]	Target Volume	Primary Reference Point [Volume]	Total Dose at Primary [cGy]	Relative Dose at Primary [%]	Prescribed Percentage [%]	Plan Normalization Mode	Plan Normalization Value [%]
F1	180.0	25	4500.0	PTV_4500	PTV_4500 [PTV_4500]	4500.0	100.0	100.0	100.00% covers 95.00% of Target Volume	96.3

Ready User: zbhuanq Group: Physicist Site: Main CAP NUM SCR

VMAT Planning Optimization

Progressive Resolution

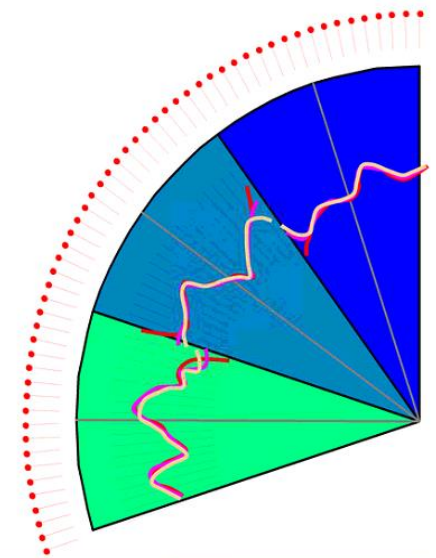
- Optimization performed in 4 resolution levels
 - The multi-resolution scheme applies to calculation directions only
 - The number of calculation directions doubles at each resolution level
 - Number of control points does not change
 - Algorithm flexibility preserved through optimization
 - Control points within single calculation direction merged into "fluence" for given calculation direction



- The optimization is performed in 4 resolution levels.
- The number of control points does not change during the optimization. It is set at the very beginning of optimization.
- The initial MLC shapes are conformed to the targets.
- The initial dose rates are equal for all dose calculation segments.
- Larger MLC changes are available during the earlier levels. The size of the MLC adjustments diminish as the optimization progresses through the levels.
- The DVH is equally accurate for OARs and targets from the very beginning of optimization.
- Only the calculation directions follow the multi-resolution scheme.
- The dosimetric accuracy increases with the resolution level.
- Control points which "belong" to a calculation direction are used to calculate fluence. This is used for a dose calculation from the calculation direction.

Steps

- Dose in calculation segment is calculated from combined fluence through MLCs at control points within sector
- Embedded leaf sequencing done at each optimization iteration
- All machine limits are enforced within calculation direction
- At the beginning calculation directions are independent
 - As if delivered separately not in continuous rotation
- Each resolution level divided into steps
- Each step increases dependence between calculation directions gradually enforcing machine limits at the calculation direction interface



Optimization - Calculation

VMAT Optimization - VMAT

Structures and Objectives

Use Normal Tissue Objective Priority: 75 Define NTO Settings...

Structure	Volume [cc]	Points	Resolution [mm]	Priority
heart	599	54541	3.00	50
Upper	14.5	1390.7		50
Mean		500.0		50
L Kidney	147	19262	3.00	100
Upper	55.2	1007.9		100
Upper	29.3	1813.4		100
Upper	16.7	2719.8		100
Mean		1500.0		100
L Lung	966	126313	3.00	50
Upper	15.6	2000.0		50
liver	1583	145058	3.00	50
PTV_4140	2902	169449	3.00	180
Upper	0.0	4150.0		180
Lower	99.0	4140.0		120
Lower	100.0	4130.0		180
R Kidney	187	23351	3.00	50
Upper	50.0	3000.0		50
Mean		1500.0		50
R Lung	1326	138742	3.00	50
Ring4140	7518	224614	4.50	75
Upper	0.0	3600.0		75
SHDA	5	12383	1.33	50

Avoidance Sectors (0 MU)

Define Settings...

None

MU Objective

Use Strength: 50

Min MU: 0 Max MU: 2000

Automate Optimization

Continue automatically to final dose calculation

Save all after optimization and dose calculation

Automatic intermediate dose

Progress:

Jaw Tracking

Base dose plan: Select

MR 3 / 4 STEP 2 / 2 MU: 826 4h 32m 10s

Level Hold

View as: Line chart Bar chart

Group	Field ID	Technique	Machine/Energy	MLC	Field Weight	Scale	Y1 [cm]	Y2 [cm]	Wedge	X1 [cm]	X2 [cm]	Field Y [cm]	Y1 [cm]	Y2 [cm]	X [cm]	Y [cm]			
<input type="checkbox"/>	Field 1	ARC-1	TB1 - 6X	Arc Dynamic	1.000	IEC61217	270.0 CW	150.0	345.0	0.0	None	15.0	-7.5	+7.5	21.4	-10.6	+10.8	4.66	-2.49
<input type="checkbox"/>	Field 2	ARC-1	TB1 - 6X	Arc Dynamic	1.000	IEC61217	150.0 CCW	270.0	15.0	0.0	None	15.0	-7.5	+7.5	20.6	-9.8	+10.8	4.66	-2.49
<input type="checkbox"/>	Field 3	ARC-1	TB1 - 6X	Arc Dynamic	1.000	IEC61217	270.0 CW	150.0	330.0	0.0	None	15.0	-7.5	+7.5	23.4	-11.8	+11.6	4.66	-2.49
<input type="checkbox"/>	Field 4	ARC-1	TB1 - 6X	Arc Dynamic	1.000	IEC61217	150.0 CCW	270.0	30.0	0.0	None	15.0	-7.5	+7.5	22.2	-10.6	+11.6	4.66	-2.49

Standard Head First-Supine

MR 3 / 4 STEP 2 / 2 MU: 826 4h 32m 10s

X: 4.95 cm

TeamViewer

Session list

Zhibin Huang (1 245 682 701)

User: zhuang

Comparison in optimization with and without levels hold

- 5 patients were included
- PTV (Min Dose, Max Dose, Mean Dose)
- Dose to critical structures (heart, ipsilateral lung, contralateral lung)

Dose to Target/OARs	PTV (Rx:4500cGy)			Heart			Ipsilateral Lung			Contralateral Lung		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Without levels hold	3663	5303	4888	144.9	2871	524	87.7	4731	1074	58.3	1897	334
With levels hold	3524	5010	4711	148.2	2807	490	82.8	4579	1008	52.8	1892	314

Sector Avoidance

- To reduce uncertainty including CT number, setup
 - Critical structures
 - e.g. hippocampus during whole-brain radiotherapy prevents cognitive side effects
 - Dental filling material (DFM)
 - The backscatter from the DFM for a single, parallel-opposed fields, and RapidArc treatment technique was found significant
 - The measured backscatter upstream dose from DFM for a single-field was 22% higher than without the DFM, whereas the downstream dose was lower by 14%

1. [Med Phys.](#) 2013 Aug;40(8):081714. doi: 10.1118/1.4816307.

Sector Avoidance

- To reduce uncertainty including CT number, setup
 - Hip Prothesis
 - Artifacts cause CT number uncertainty
 - Setup irreproducibility
 - e.g. daily pannus variability in set up, causing Dose differences between planned and re-calculated rectal wall mean dose and the $V_{24\text{Gy}}$ were numerically larger in the absence of the avoidance sector for all fractions and for both simulated pannus variations, with maximum changes of 2.6% and 1.3%.
 - I. Med Dosim. 2019 Summer;44(2):179-182. doi: 10.1016/j.meddos.2018.05.003. Epub 2018 Aug 16.

Sector Avoidance – example

-RT super clavicular mass

Index	Meterset Weight	Gantry Pin [deg]	Dose Rate [MU/min]	Gantry Speed [deg/s]	MU/deg
24	0.3767	226.0	307.049	4.800	1.066
25	0.3767	228.0	0.000	4.800	0.000
26	0.3767	230.0	0.000	4.800	0.000
27	0.3767	232.0	0.000	4.800	0.000
28	0.3767	234.0	0.000	4.800	0.000
29	0.3767	236.0	0.000	4.800	0.000
30	0.3767	238.0	0.000	4.800	0.000
31	0.3767	240.0	0.000	4.800	0.000
32	0.3767	242.0	0.000	4.800	0.000
33	0.3767	244.0	0.000	4.800	0.000
34	0.3767	246.0	0.000	4.800	0.000
35	0.3767	248.0	0.000	4.800	0.000
36	0.3767	250.0	0.000	4.800	0.000
37	0.3767	252.0	0.000	4.800	0.000
38	0.3767	254.0	0.000	4.800	0.000
39	0.3767	256.0	0.000	4.800	0.000
40	0.3767	258.0	0.000	4.800	0.000
41	0.3767	260.0	0.000	4.800	0.000
42	0.3767	262.0	0.000	4.800	0.000
43	0.3767	264.0	0.000	4.800	0.000
44	0.3767	266.0	0.000	4.800	0.000
45	0.3767	268.0	0.000	4.800	0.000
46	0.3767	270.0	0.000	4.800	0.000
47	0.3767	272.0	0.000	4.800	0.000
48	0.3767	274.0	0.000	4.800	0.000
49	0.3767	276.0	0.000	4.800	0.000
50	0.3767	278.0	0.000	4.800	0.000

View	DVH Line	Structure	Approval Status	Plan	Course	Volume [cm ³]	Dose Cover[%]	Sampling Cover[%]	Min Dose [%]	Max Dose [%]	Mean Dose [%]
<input type="checkbox"/>		BODY	Approved	Rt Supra_IMRT	C1	17185.8	100.0	100.0	0.0	113.7	8.3
<input type="checkbox"/>		SHD	Approved	Rt Supra_IMRT	C1						
<input type="checkbox"/>		Scar_wire	Approved	Rt Supra_IMRT	C1						
<input checked="" type="checkbox"/>		Left_Lung	Approved	Rt Supra_IMRT	C1	1335.1	100.0	100.0	0.1	43.5	3.6
<input checked="" type="checkbox"/>		Right_Lung	Approved	Rt Supra_IMRT	C1	445.5	100.0	100.0	0.6	108.6	18.2
<input checked="" type="checkbox"/>		cord	Approved	Rt Supra_IMRT	C1	154.4	100.0	99.9	0.0	94.0	8.3
<input checked="" type="checkbox"/>		Bone	Approved	Rt Supra_IMRT	C1						
<input checked="" type="checkbox"/>		heart	Approved	Rt Supra_IMRT	C1	497.2	100.0	100.0	0.2	1.3	0.5

Head&Neck

- PTV coverage:
 - 95% of PTV covered by 100% Rx
- More than 20 critical structures to contour
- Dose Constraints – RTOG
 - Spinal Cord: Max < 45 Gy, 1cc < 45Gy
 - Brainstem: Max < 55 Gy, 1% <54 Gy
 - Parotid glands: mean dose < 26 Gy
 - Optic structures: Max < 54 Gy
- Example: H&N treatment
 - I. Physician wants 72 Gy to target, 59.4Gy to lymph nodes
 - II. Meet dose constraints

Head&Neck

The screenshot displays the Arc Geometry Tool interface for a Head & Neck treatment plan. The main window shows a 3D model of a head and neck with dynamic arcs (01 CW RA, 02 CCW RA, 03 CW RA) and a yellow target volume. The interface includes a 'Worklist' at the top, a 'Quicklinks' menu, and a 'Logout' button. The main view is split into four quadrants showing different views: Frontal, Sagittal, and two other views. A 'Fields' panel on the left lists the treatment fields and their parameters. A 'Fields' table at the bottom provides detailed parameters for each field.

Arc Creation / Fine-tune Fields Panel:

- Approximated Minimum Distances: From treatment unit head to Body structure 17 cm in 01 CW RA, support or fixation structures 8 cm in 01 CW RA.
- Show VOI in 2D views: 01: 01 CW RA 02 CCW RA 03 CW RA 91
- Target Margin [cm]: 0.5
- Adjust isocenter while fitting in:
 - X direction
 - Y direction
 - Z direction
- Fit Collimator to Target

Fields Table:

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]
	01 CW RA	ARC-I	TB1 - 6X	Arc Dynamic	0.670	IEC61217	181.0 CW 179.0	15.0	0.0	None	13.1	-6.8	+6.3	11.0	-5.5	+5.5	-0.88	-0.82	-9.69	92.0		
	02 CCW RA	ARC-I	TB1 - 6X	Arc Dynamic	0.690	IEC61217	179.0 CCW 181.0	345.0	0.0	None	13.1	-6.3	+6.8	11.0	-5.5	+5.5	-0.88	-0.82	-9.69	92.0		
	03 CW RA	ARC-I	TB1 - 6X	Arc Dynamic	0.797	IEC61217	181.0 CW 179.0	90.0	0.0	None	9.7	-4.7	+4.9	12.5	-6.2	+6.2	-0.88	-0.82	-9.69	92.0		
	91 AP kV	STATIC-I	TB1 - 6X		0.000	IEC61217		0.0	0.0	None	15.0	-7.5	+7.5	15.0	-7.5	+7.5	-0.88	-0.82	-9.69	91.0		
	93 CBCT	STATIC-I	TB1 - 6X		0.000	IEC61217		0.0	0.0	None	15.0	-7.5	+7.5	15.0	-7.5	+7.5	-0.88	-0.82	-9.69	91.0		
	92 RLat kV	STATIC-I	TB1 - 6X		0.000	IEC61217		270.0	0.0	None	15.0	-7.5	+7.5	15.0	-7.5	+7.5	-0.88	-0.82	-9.69	93.7		

Head&Neck

File Edit View Insert Planning Tools Window

Contouring Registration External Beam Planning Brachytherapy Planning Brachytherapy 2D Entry Plan Evaluation

1319
C1
H&N 7200cGy

- Lt Parotid
- Lt Parotid - PTV
- Mandible
- Mandible-ptv
- MandibleInPTV
- nodes
- Nodes_Plan
- Post Neck
- pt5940_OPT
- PTV6570_OPT
- ptv7200_OPT
- PTV72_planning
- PTV_5940
- PTV_7200
- ptv_ISO
- ring5940
- ring7200
- Rt Parotid
- RT Parotid - PTV
- SHD
- Spinal Cord
- User Origin
- Reference Points
- ISO
- PTV_7200
- RadCalc
- Dose
- Fields

H&N 7200cGy - TreatmentApproved - Transversal - HN_5_9_19

H&N 7200cGy - TreatmentApproved - Frontal - HN_5_9_19

H&N 7200cGy - TreatmentApproved - Sagittal - HN_5_9_19

H&N 7200cGy - Dose Volume Histogram

Relative dose [%]
0 13.888 27.777 41.666 55.555 69.444 83.333 97.222 111.11

Ratio of Total Structure Volume [%]
0 20 40 60 80 100

Dose [cGy]
0 1000 2000 3000 4000 5000 6000 7000 8000

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

Fractionation Id	Dose / Fraction [cGy]	Number of Fractions	Total Dose [cGy]	Target Volume	Primary Reference Point [Volume]	Total Dose at Primary [cGy]	Relative Dose at Primary [%]	Prescribed Percentage [%]	Plan Normalization Mode	Plan Normalization Value [%]
F1	180.0	40	7200.0	PTV_7200	PTV_7200 [PTV_7200]	7200.0	100.0	100.0	100.00% covers 95.00% of Target Volume	93.1

Ready User: zhuang Group: Physicist Site: Main CAP NUM SCR 3:46 AM 5/14/2019

Pelvis/Prostate

○ Rectum

- $D_{40} \leq 65 \text{ Gy}$,
- $D_{30} \leq 70 \text{ Gy}$,
- $D_{10} \leq 75 \text{ Gy}$,
- $D_{\max}^* \leq 81 \text{ Gy}$ (* D_{\max} = dose to clinically significant volume)

○ Bladder

- $D_{30} \leq 70 \text{ Gy}$,
- $D_{\max}^* \leq 81 \text{ Gy}$

Brain Metastasis

○ Tolerance doses:

- Optic nerves: Max dose < 54Gy
- Lens: Max dose < 6 Gy
- Chiasm: Max dose < 54 Gy
- Brainstem: Max dose < 54 Gy
- Eyes: Max dose < 45 Gy
- Cochlea: Mean dose < 45 Gy

SRS/SBRT Lung Cancer

- RTOG 0813, RTOG 0915
- Prescription: 50Gy/5fx, 48Gy/4fx, 54Gy/3fx
- Dose to target/critical structures (NRG-BR001, Timmerman)
- R50, R100, D2cm
- Couch kick, collimator angle, gantry angle

SRS/SBRT RTOG Guidelines

- Multiple metastatic lesions: NRG-BR001
- SRS/SRT Brain: RTOG 90-05, RTOG 0933
- SRS Spine: RTOG 0631
- SBRT Prostate: RTOG 0938

Plan Evaluation

- PTV coverage is achieved?
 - Define endpoints such as 95% of PTV covered by 100% Rx
- Dose distributions on every CT slice
 - Rx, Max dose, Min dose
- Dose constraints meet the criteria?
 - Dose volume histogram (DVH)
- Refer to AAPM TG-100, TG-275, RTOG guidelines

How to improve the plan

- If the plan is not acceptable, what to do?
 - Image quality
 - Anatomy
 - Beam angle selection
 - Collimator angle selection
 - Sector avoidance
 - Bolus - buildup
 - Base dose plan
 - Single isocenter versus multiple isocenters

Imaging

- Image quality - Artifacts caused by
 - Hip prosthesis
 - Dental filling
 - BBs
 - Patient motions
- Image registration
 - PET/CT
 - MRI

Anatomy

- **Variation in target volume and location**
- **PTV too close to skin**
 - **a volume at least 3mm away from skin surface**
- **Geometry limitations**
 - **PTV and critical structure overlaying**

Beam angle selection

- **Avoid critical structures**
- **Maintain large beam separation if possible**
- **Use shortest pathway to irradiate the tumor**
 - **Beam angle selection is important if the tumor is not centrally located**

Collimator angle

Brachytherapy Planning | Brachytherapy 2D Entry | Plan Evaluation

Lt InguinalRA - Unapproved - Transversal - CT_left inguinal

Isodoses (%)

- 110.0
- 105.0
- 100.0
- 95.0
- 90.0
- 85.0
- 80.0
- 50.0

3D Dose MAX: 114.2 %
 3D MAX for PTV ParaAoringui: 114.2 %
 3D MIN for PTV ParaAoringui: 57.7 %
 3D MEAN for PTV ParaAoringui: 103.3 %

Transport in medium
Dose to medium

100.1 %

Standard
Head First-Supine
Z: 13.00 cm

Lt InguinalR1 - Treatment Approved - Transversal - CT_left inguinal

Isodoses (%)

- 110.0
- 105.0
- 100.0
- 95.0
- 90.0
- 85.0
- 80.0
- 50.0

3D Dose MAX: 112.1 %
 3D MAX for PTV ParaAoringui: 112.1 %
 3D MIN for PTV ParaAoringui: 65.4 %
 3D MEAN for PTV ParaAoringui: 103.3 %

Transport in medium
Dose to medium

107.3 %

Standard
Head First-Supine
Z: 13.00 cm

Lt InguinalRA - Unapproved - Frontal - CT_left inguinal

Transport in medium
Dose to medium

100.7 %

Standard
Head First-Supine
Y: -2.63 cm

Lt InguinalRA - Unapproved - Sagittal - CT_left inguinal

Transport in medium
Dose to medium

100.7 %

Standard
Head First-Supine
X: 2.93 cm

Lt InguinalR1 - Treatment Approved - Frontal - CT_left inguinal

Transport in medium
Dose to medium

100.7 %

Standard
Head First-Supine
Y: -2.63 cm

Lt InguinalR1 - Treatment Approved - Sagittal - CT_left inguinal

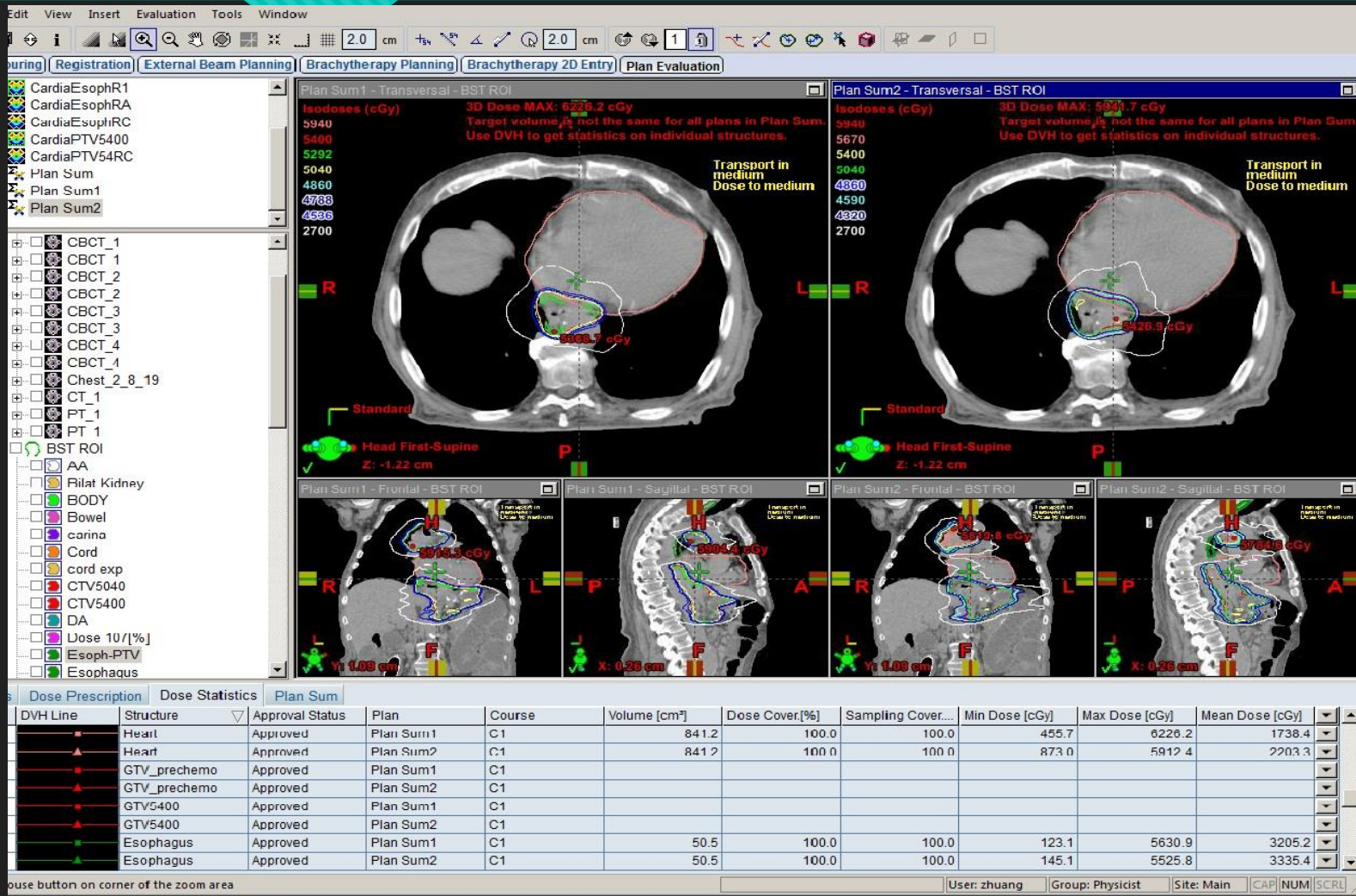
Transport in medium
Dose to medium

100.7 %

Standard
Head First-Supine
X: 2.93 cm

Number of Fractions	Total Dose [cGy]	Target Volume	Primary Reference Point [Volume]	Total Dose at Primary [cGy]	Relative Dose at Primary [%]	Prescribed Percentage [%]	Plan Normalization Mode	Plan Normalization Value [%]
20	3600.0	PTV ParaAoringui	PTV_3600 [PTV ParaAoringui]	3600.0	100.0	100.0	100.00% covers 95.00% of Target Volume	95.00

Single- vs Multiple-ISO



“Exposure of the heart to ionizing radiation during radiotherapy for breast cancer increases the subsequent rate of ischemic heart disease. The increase is proportional to the mean dose to the heart, begins within a few years after exposure, and continues for at least 20 years.”

N Engl J Med 2013; 368:987-998
DOI: 10.1056/NEJMoa1209825

Single- vs multiple-ISO radiosurgery
Poster Number: PO-GePV-T-336

Summary

- Review photon beam characteristics
- Present dosimetric skills for treatment planning
 - breast cancer
 - head&Neck cancer
 - SBRT lung cancer, etc.
- Evaluate treatment plans
- Improve treatment plan quality

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Thank you very much!

Comments to:
Zhibin.Huang@case.edu